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Off-grid rural electrification experiences from South Asia: Status and best practices

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ABSTRACT

South Asia accounts for 42% of the global population without access to electricity. Such a situation continues to exist despite several initiatives and policies to support electrification efforts by the respective country governments. The challenges to enhance electricity access are manifold including technical, financial, institutional and governance barriers. This paper makes a modest attempt, based on extensive literature review, to highlight the rural electrification situation at the regional and country level in South Asia. The paper also does a comparative analysis to exploit cross learning potential and suggest specific boosters that could serve as input for policy evaluation, review and improvements to assist future electrification efforts in the region. We focussed on renewable energy based mini-grids and stand-alone systems and also covered conventional grid extension. The paper raised some pertinent issues and attempted to find solutions to these issues. The household connection needs to be improved considerably through a targeted approach and innovative micro-lending model. At the same time the electricity supply also needs to be enhanced, such as through distributed power projects utilizing locally available renewable resources, to ensure that connected households continue to receive electricity and that supply constraints do not inhibit extending electrification to new areas. Developing a regulatory mechanism to extend the tariff fixation for mini-grid projects and providing cross-subsidies to ensure long term sustainability of such projects are highlighted. Finally, economic linkages, access to credit and institutional arrangements also need to be organized appropriately, especially for off-grid RE to facilitate successful outcomes.

Introduction

The importance of rural electrification (RE) in bringing about both direct and indirect social and economic benefits for communities, ranging from incremental livelihood leading to reduced poverty to better facility for health and education has been well documented (Bastakoti, 2006; DFID, 2002; ESMAP, 2002; GNESD, 2007; NRECA, 2002; Zomers, 2003). The benefits of RE through grid extension are also realized in off-grid situations, even though the amount of power made available by such systems are smaller and the services provided more basic (World Bank, 2008).

While there is available literature (Bhattacharyya, 2006; Dubash, and Bradley, 2005; Khan, 2003; Krishnaswamy, 2010; Mainali and Silveira, 2011; Shrestha et al., 2004; TERI, 2009a), analyzing the RE at the individual country level, no recent comparative analyses exist at the South Asian regional level for cross learning by the countries. This paper seeks to do an extensive review of available literature on the status of RE in South Asian countries,[2] especially focussing on off-grid[3] electrification. It examines the current RE trends at the regional level and at the same time comprehensively captures the development in India, Bangladesh, Nepal and Sri Lanka, where RE has been relatively significant. Based on the review, we attempt a comparative analysis to exploit the cross learning potential, both at the country and region level, and suggest specific boosters that could serve as inputs for policy evaluation, review and improvements to assist future electrification efforts for improving the access. The categories studied include technology, delivery models, policy and regulatory architecture, local

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[2] South Asia Region consists of eight countries: Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka.

[3] The term "off-grid" is taken here to mean any power generation that does not depend on connection to the high-voltage transmission network. This may include mini-grids set up to serve isolated communities as well as stand alone systems to serve individual houses. A mini-grid is an electricity distribution network operating typically below 11 kV, providing electricity to a localized community and derives electricity from a diverse range of small local generators using both fossil fuels (diesel, gas) and renewable energy technologies with or without its own storage (batteries). Stand-alone power supply systems only cover the needs of one household (user) and include solar home systems, individual solar lanterns, etc. However, that one system serves one user does not mean that the system is necessarily owned by the user as lanterns recharged from solar charging stations and taken on rent or SHS on lease are also considered here as individual systems.

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Table 1
Rural electricity access in South Asia (as of 2009).

Country	Total population[a] (millions)	Population without electricity[b] (millions)	Rural electrification[b] (%)	Per capita GDP PPP[a] US $
Afghanistan	28.4	23.8	12.0	600
Bangladesh	156	95.7	28.0	1300
Bhutan	0.69	0.2	40.0	4100
India	1166	403.7	52.5	2500
Nepal	28.5	16.5	52.5	1000
Pakistan	176	68.0	46.0	2400
Sri Lanka	213	4.7	75.0	3900

[a] www.indexmundi.com.
[b] IEA (2010). http://www.worldenergyoutlook.org/database_electricity/electricity_access_database.htm>.

participation and financing. As data availability on off-grid electrification is often limited, the review is selective.

Current rural electrification trends in South Asia

The current level of household electrification in the rural areas of the region is around 50%, leaving some 612 million people without electricity (IEA, 2010) (Table 1). While the figure serves as a common denominator to the problem, there exists wide disparity in RE in South Asia. Sri Lanka has a RE rate of 75%,[4] higher than the global average (65.1%), while only 15% of the rural population in Afghanistan have access. Although the percentage of population with electricity access has increased during the last decade, there seems to be no significant decrease in the absolute number of people without electricity. This could be due to the fact that rural population has expanded at roughly the same pace as electrification in many countries. Another reason could be because of de-electrification[5] of villages, especially in India, due to poor or no supply of electricity to such areas, although officially such villages remain electrified.

Of the total population without electricity access in the region, many reside in isolated communities, such as islands, forests fringes and hilly settlements. These communities are generally small, consisting of low-income households — with characteristics that may be economically unattractive to electricity distribution companies or even government electrification program that usually prioritizes the allocation of the scarce resources. A substantial section of the un-served consumers are also found in mainstream rural and peri-urban areas, already connected to the grid, where the issue seems to be less of opportunity to get connected to grid, but more of inability of households to take electricity connection due to their financial constraints or the perception that electricity services (quantity and quality) will be inadequate.[6] For example, official figures indicate that India and Bangladesh has almost 93% and 57% of the villages covered through grid while it is observed that rural household connection levels are at 53% and 28% respectively.[7]

Review of rural electrification experiences in selected countries

India

With the largest rural population in the world, India continues to face a huge RE challenge. Though the government has been making conscious efforts since the beginning of planned economic development in the country in 1951 to make substantial improvements to the electricity infrastructure in terms of availability and accessibility, the household electrification level and power availability is still far below the world average. Low household electrification level may reflect the fact that historically the level of electrification has been measured as a percentage of electrified villages with extension of the grid to any point within the revenue boundary of a village, irrespective of whether any household is getting connected or not. In fact, some researchers argue that electrification as a part of the green revolution in agriculture was the main driver for RE (Bhattacharyya, 2006; Krishnaswamy, 2010). However, the Government of India adopted a new definition of village electrification[8] in 2004 and many villages that were previously considered electrified now fall by definition into the un-electrified category.

Currently, only seven states have achieved 100% village electrification, and five of these states are smaller ones. Though officially Andhra Pradesh and Tamil Nadu are considered to have achieved complete village electrification, reports from the TERI field study indicate that there are many hamlets and forest fringe villages in these states where any form of electricity, on-grid or off-grid, is yet to reach. The off-grid electrification, primarily undertaken under the Remote Village Electrification (RVE) Program, covers only about 1.5% of the total electrified villages in the country (refer to Off-grid RE in South Asia section for further details). Some of the larger states such as Assam, Bihar, Jharkhand, Orissa, Rajasthan and Uttar Pradesh and the north-eastern region lag behind in rural electricity access. Krishnaswamy (2010) argues that the main reason for poor electrification in these states is poor governance. Some have also noted that structural factors may explain disparities in the share of electrified villages between regions and states (Chaurey et al., 2004; Kemmler, 2007).

Over the years, a number of central government Programs (such as Kutir Jyoti, Minimum Needs Program, and Accelerated RE Program in grid extension mode and RVE program in off-grid mode) attempted to enhance electricity access either as part of overall rural development or specifically targeting RE. However, Bhattacharyya (2006) argues that multiplicity of programs made funding for each of them inadequate and implementation was also not properly coordinated or managed. Due to the financial burden that national programs have been imposing on state governments, the state government operated electricity utilities often have shown less interest in promoting these schemes actively and even the targets set by the utilities have not

[4] As per statistics of Government of Sri Lanka, the total electrification in the country is 90% for 2010 (source: Key Social Indicators, Annual Report 2010, The Central Bank of Sri Lanka).

[5] De-electrified village means a village which has been electrified earlier, however, it has become un-electrified at present as the distribution infrastructure has not been in working condition for a long time. However, in official records it continues to be shown as electrified. The de-electrified village category was accepted by the Government of India during the launch of RGGVY and included for repeat electrification of such villages.

[6] A TERI survey in Uttar Pradesh, the largest state in terms of population in India, indicates that the power shedding varies between 14 and 18 h and electricity in the villages is supplied only during night hours (11 pm to 5 am) and in some cases during daytime with frequent tripping. No electricity is supplied during the peak hours (6–10 pm) in any of the surveyed villages and the voltage dips to as low as 110 V making it difficult to use any appliances when there is electricity during day hours. However, as the tariff is based on flat rate and not metered, the consumers have to make the payment irrespective of whether they have actually consumed the electricity or not.

[7] Village electrification here is considered as percentage of villages where electricity grid or mini-grid exists. Household electrification on the other hand is defined as percentage households who have actually taken electricity connection.

[8] A village will be deemed to be electrified if: basic infrastructure such as distribution transformer and distribution lines are provided in the inhabited locality as well as the hamlet where it exists; electricity is provided to public places like schools, panchayat office, health centers, dispensaries, community centers etc. and the number of households electrified should be at least 10% of the total number of households in the village.

been met. To speed up the RE efforts as a 'political goal', the government declared the objective of 'Power for All by 2012' under the REST (Rural Electricity Supply Technology) Mission in 2001 and continued it with the launch of a large-scale electrification effort, the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) in 2005 to create access to electricity for all households and provide connections to 32 million BPL (below poverty line) households. To ensure revenue sustainability, RE distribution franchises[9] were also introduced, and made responsible for metering, billing and revenue collection for particular territories. In some cases, input based franchises (IBF) were also introduced who procure electricity in bulk from the distribution utility and distribute the same in their operational areas. These policies have improved the financial and institutional status of the state utilities and have widened the governments' scope of action in the sector.

However, the overall achievement of the RGGVY against the targets set to be attained by end of 2012 is not encouraging. While 61% of the targeted villages had been electrified as of April 2011, only about 20% of the un-electrified rural households have taken connection (MoP, 2011). Rejikumar (2005) argued that the timescale applied to the electrification targets seems to be highly infeasible. Dubash (2004) observed that electrifying all households by the end of 2012 would require connecting 10 million households a year, ten times the average historical pace of household electrification. Researchers argue that a more realistic date by which to achieve the government's targets is 2019/2020 (Dubash and Bradley, 2005; Purohit, 2009).

Bangladesh

According to IEA (2010), the overall electrification rate in Bangladesh was 41% in 2009, with only 28% of the rural population having access to electricity. The main mode of electrification has been the extension of the electricity grid through the rural electricity cooperatives called Palli Bidyuit Samity (PBS), modeled similar to the Rural Electricity Cooperatives in USA. The role of PBS is to construct rural electricity distribution backbone, manage and operate the facilities, and distribute power, all under the supervision of Rural Electrification Board (REB). The PBSs are connected to the grid and receive electricity in bulk from the Bangladesh Power Development Board, which is then distributed to their consumers. The tariff structure cross-subsidizes domestic and agricultural consumers by levying rates on them below the cost of service and levying rates above the cost of service on industrial and commercial consumers.

Currently, there are 70 operating PBS, bringing service to approximately 8.4 million consumers (REB, 2011). In addition, solar home systems (SHS) have also been disseminated in the remote areas of the country and have covered around 0.8 million consumers (refer Off-grid RE in South Asia section for further details). Despite the country's political, social, and economic instability, the REB model can be considered successful to the extent that it created the distribution backbone covering almost 90% of the effective rural area and has achieved a certain level of results in terms of proper system design, low system loss, and high collection efficiency. However, similar to Indian situation, households getting connected to the network continue to remain low as compared to the total number of rural households. Further, poor households have much lower electrification rate as compared to non-poor households (GNESD, 2004). One of the reasons for low level of electricity access by the poor could be high upfront cost of getting connected to the electricity network. At the same time, the focus on strictly enforced performance targets for PBS (such as revenue/km of line, collection efficiency, cost of service, system loss to name a few) may also have impeded the PBS to connect households in unviable areas. Shrestha et al. (2004) opines that inadequate electricity generation capacity commensurate with the increased demand due to expansion in the distribution network to cover new areas, lack of adequate financial resources to support RE as well as slow national economic growth could also have limited electricity access of rural households. Nevertheless, the Government of Bangladesh has targeted to provide access to all by the year 2020 (GoB, 2005).

Nepal

The RE rate in Nepal is around 52% with uneven distribution — being higher in the accessible lowland regions (the *terai*) and lowest in the mountain communities. Though the electrification rate is low, the country has made significant progress since the beginning of the last decade to extend electrification to the remote areas. Zahnd and Kimber (2009) observed that about 10 million people, out of Nepal's estimated 28.5 million (at the end of 2006), live in such remote locations where it will be difficult to extend the national electricity grid for decades to come. The Government recognized the fact early and formulated the hydro power policy 2001 (NDF, 2004) which allows domestic private sector to generate and distribute electricity by building micro-hydro power projects of up to 100 kW capacity. The Water Resources Strategy 2002 also emphasized active participation of rural communities and private entrepreneurs and envisaged electrifying 60% and 80% of the nation's households respectively by the end of years 2017 and 2027 respectively (NDF, 2004). A noteworthy feature of the RE situation in Nepal is that almost 30% coverage in rural areas and 10% of overall electrification is through the off-grid route (REP, 2008).

Since 2003, Nepal also started experimenting with community involvement as part of their Community RE Rules. This was done to bring in operational efficiency in the distribution sector, which was witnessing high system losses and poor revenue collection over the years. Consumer associations, typically in the form of cooperatives, take the responsibility of managing, maintaining, and expanding the rural distribution of electricity. Communities raise 20% of the investment cost for grid extension to their area and 80% of the cost is borne by the Government of Nepal through the Nepal Electricity Authority (NEA). The NEA sells power in bulk to rural electricity cooperatives that distributes and collects revenue from the villagers. Ghimire (2011) reports more than 230 cooperatives across Nepal have entered into agreements with NEA. Ghimire also shares that currently 135,000 rural households have been electrified through community based RE and the number will increase to about 230,000 households as pipeline projects are completed by end of 2011 and the communities have till now contributed a total of US$ 6.89 million towards their share.

Sri Lanka

Sri Lanka stands out among the South Asian countries for its high rate of household electrification. During the period 1986 to 2005, the

[9] Under the Electricity Act 2003, a franchisee means a person authorized by a distribution licensee to distribute electricity on its behalf in a particular area within his area of supply. Broadly there are two types of franchisees operating in India viz. revenue franchises (RF) and input based franchises (IBF). The role of a RF is limited to billing, revenue collection, complaint redressal, facilitating release of new service connection and keeping vigil on the status of distribution network in the franchised area for providing appropriate feedback to the utility. The franchisees are paid a fixed percentage of collections on achievement of the target. There is also levy of penalty for not achieving the targets and incentive for exceeding the target. However, the drawback in the RF model is that the franchisee is not a partner in loss reduction since the remuneration is linked to the collections made and not on the energy input to the area. On the other hand, the IBF, buys electricity from the utility at a pre-determined rate and distributes the electricity within the prescribed territory. It also handles all commercial activities related to issue of new service connections, metering, meter reading, billing, collection, realizing bad debts, disconnection, reconnections, customer complaint handing etc. The energy is supplied by the utility to the IBF and is recorded through a meter at a point (say at the distribution transformer level or 11 kV feeder level). The IBF collects revenues from the consumers based on the regulated tariff and keeps the surplus after paying the utility for the energy received at a bulk supply tariff. The more efficient the franchisee is in reducing distribution losses and improving billing and collection efficiencies the more profits it earns. The utility on the other hand is insulated from any distribution losses arising from the working of the franchisee in the area.

national electrification rate improved significantly from 10.9% to 76.7% due to aggressive electrification efforts (ADB, 2007). Almost 75% of the rural households are connected to electricity grid while another 2% are connected through off-grid option. Sri Lanka's high electrification rate compared to other South Asian countries reflects an early move by the Government to create grid electricity infrastructure through donor support as well as utilize the country's significant hydro resources for meeting the demand. Another significant feature is setting up of annual targets for household connection rate as part of the Energy Policy 2006 and the road map for achieving the targets. ADB has been mainly supporting the Sri Lankan Government to achieve its electrification goals. Similar to other developing countries, connection prices were a barrier to electrification of households. ADB designed and created a revolving fund to support grid connections for poor households through micro-lending (ADB, 2009). The power fund targeted poor households who are within range of a grid but lack finance to take connection, costing US$130 to US$170. Building on the initial success of the scheme from 2004 to 2009, ADB approved a new credit program, which aims to connect at least 75,000 households into the grid by 2016 to support the government's goal to substantially raise rural electricity coverage to more than 90% through grid by 2016.

Grid-connected vis-à-vis off-grid mode

It is observed from the Current rural electrification trends in South Asia section that grid extension has been the most favored approach to rural electrification. A TERI study in India indicates that off-grid connections act more as a pre-electrification option, with the community continuing to aspire for grid connection because of fixed duration[10] and limited supply of power[11] from off-grid projects (TERI, 2009a). While the above may be true, off-grid technologies have a role to play in the context of RE. However, it is important to analyze the factors that should influence our choice of technology so that both can complement each other without competing for the same scarce financial resources in enhancing access in the region.

Reddy and Srinivas (2009) opine that the choice of energy technology in the context of RE is influenced by various actors and factors — prevailing policy and implementing agencies at the macro level, distributors, service companies and financing institutions at meso level and finally the household socio-economics at micro level. Even though both grid-connected and off-grid have their own advantages and disadvantages, the underlying principle for choice of a particular mode is adopting the least cost technology options and with minimum maintenance requirements as far as possible. Kumar et al. (2009) made an attempt to develop a decision making tool which involves approaches that are to be followed for entire planning and formulation of off-grid electrification projects vis-à-vis grid connected projects. The technical feasibility may depend on several factors such as terrain of that location (whether within forest, hilly region, island, plains), distance to existing grid, size of loads, and local availability of resources (both fuel and human resources). While comparing the cost of investments for mini-grids based on local generation versus the cost of grid extension gives a rough estimate of what could be a best solution, the number of prospective connections per km of line (grid extension is favorable if number of connections per km of distribution line are high say more than 25) also is considered to arrive at the best solution.

Off-grid solutions (mini-grid or stand alone) are usually preferred when accessibility is the central issue and cost of extension and servicing of central grid is high. A mini-grid based on locally available renewable energy sources is an attractive option if the village has the threshold number of households (for e.g. under the Village Energy Security Program in India, the threshold number of households is 100 and the required length of the distribution network is within 2 km for system capacity of 10 kWe), optimal load (for e.g. the minimum threshold load for biomass gasifier power projects is 10 kWe as this is the commercially available minimum capacity) and lies in a geographically flat terrain. The main advantage of mini-grid is that it provides a better exploitation of the energy resources and utilization of the power generating equipment is higher (provided capacity is matched with the load while designing) than if stand alone systems are used.

If it is difficult to reach consumers that live dispersed within the distribution lines (the rule of thumb is that if number of consumers is less than 50 in a village or number of connections per km of distribution line is less than 4) or in rough terrains, individual systems such as SHS or solar lanterns are better options. Such individual systems do not necessarily require a community organization; it only requires that there is sufficient willingness and ability to pay and a robust product and spares supply chain exists. However, they suffer disadvantages such as low capacity factor, excess battery costs and finite capacity to store electricity forcing to throw away the extra energy generated.

Further, in areas with adequate availability of renewable energy resources to generate and ensure availability of quality power, distributed generation with local mini-grid, which could work off-the-grid, but, also have the compatibility of being connected with the central grid, could also be an appropriate option. In this case, the priority is to cater to the local needs and any surplus generation is fed into the central grid, and when there is deficit, electricity is drawn from the grid. Also for mini-grids based on infirm resources such as solar and wind power, hybrid systems may be preferred. However, we would like to stress that choosing electrification method and generating equipment can never be done without careful regard to local conditions, with regard to resource availability, technical skills, socio economics and governance setting.

Off-grid RE in South Asia

Choice of technology

The most common technologies used for off-grid electrification in the region are solar photovoltaic (PV) and mini/micro hydro systems. Solar PV applications in the region include both SHS as well as mini-grids. While a typical SHS includes a 20 to 100 Wp (peak watt) PV array, a rechargeable battery for energy storage, one or more high efficiency lamps (either compact fluorescent or LED) and an outlet for a portable black and white television or other very low power consuming appliances,[12] the mini-grids are typically in the range of 2 kWp to 150 kWp and provide AC electricity (Shukla, 2010; Ulsrud et al., 2011). Almost all the countries reviewed have used SHS as a means for extending lighting to areas that could not be reached with grid electricity. An interesting feature in Nepal is that smaller capacity SHS (locally called *solar tuki*) with capacity between 2.5 Wp and 10 Wp have also been widely disseminated. India, on the other hand, has also implemented solar mini-grids especially in Sunderban region and Chhattisgarh to cover un-electrified areas. A key factor of the success of the solar PV program in different countries is due to quality standards ensured for PV panels, batteries, and other components as approved by the technical standards committees in respective

[10] Based on field studies, it has been observed that usually solar PV and biomass gasifier based mini-grids operate for 4–8 h in a day. A SHS or solar lantern is also designed to provide lighting for 4–5 h with 1–2 days battery autonomy.

[11] Since the systems work off the grid and have a fixed capacity, they are designed to serve the base load (usually lighting) and any critical load. Any peaking loads such as irrigation pumpsets or milling applications could not be served as in such case the system sizing has to be enhanced. Though it is technically possible to have higher capacity systems, however, this may lead to higher capital cost and lower the overall load factor.

[12] Usually SHS with less than 40 Wp is used for lighting purpose whereas SHS above 40 Wp can be used for operating other electrical appliances such as TV, motor, fan, etc.

countries. However, effective after sales maintenance in remote rural areas continue to pose challenges, especially in India and Nepal, for functionality of solar devices.

The mini/micro hydro systems (usually capacity in the range of 50 kW to 3 MW) have been used to create mini-grids to supply AC electricity locally. While Sri Lanka and Nepal have extensively used this technology to extend electrification to off-grid areas, such plants have also been installed in the hilly regions of India such as Arunachal Pradesh, Sikkim, and Uttarakhand. Many mini/micro hydro projects in the region have been driven by 'technology push', with micro-hydro now being a mature technology greatly improved by electronic load controllers, low-cost turbine designs, and the use of plastics in pipe work and penstocks. However, one of the key challenges faced by mini/micro hydro systems especially in India is low utilization factor due to unavailability of sufficient water discharge during dry season and very high discharges during monsoon in the Himalayan streams (when the plant has to be shut down to avoid damage to the penstock or turbine due to possibility of high quantity of silt coming with the water). The low load factors also results in high O&M costs resulting in uneconomical operation in isolated mode in the hilly areas.

Biomass gasifiers have found use in India and to a limited extent in Sri Lanka for off-grid electrification (Abeygunawardana, 2011; Ghosh et al., 2006). Biomass gasifier based mini-grids are typically in the range of 10 kW to 500 kW. The technology however has found limited success in India for off-grid electrification. One of the key reasons for this is absence of standardized performance oriented technical specifications of the systems to ensure quality of the products and also due to non creation of proper after sales maintenance network to service the systems in the remote rural areas[13] (TERI, 2009b). Ghosh et al. (2006) opine that technical barriers remain in the development of engines running only on producer gas for small capacity biomass gasifiers[14] — these engines are not designed for producer gas and are mostly developed through modification of existing diesel engines that leads to substantial capacity derating. Producer gas quality concerns also remain for handling of the gas by both producer gas only and turbo-charged engines. The technology is also significantly hindered by limited manufacturing capabilities with most gasifier manufacturers having small workshops or small fabricators.

Business models

Most off-grid electrification programs in the region have been grant-based and donor-driven, and continue to be so in countries such as India, Nepal and Pakistan. Yet markets have also developed in some countries, such as the SHS and solar lantern market in Bangladesh, Sri Lanka, and India. The rise of these markets reflects innovations in system design as well as in financial and institutional mechanisms. While the grid has been extended mainly through the utility based model (in India, Sri Lanka and Nepal) or rural electricity cooperative (in Bangladesh), a review of literature indicates community based models were often adopted for mini-grid based electrification, albeit with different names such as VEC (village energy committee), VDC (village development committee), and REC (rural electricity cooperative). The VEC or the REC plays the role of stand-alone power producer, distributor and supplier of electricity, manages the revenue through collection of payments for the electricity used from users and dispute resolution in case of power supply disruption. Though previously private Rural Energy Service Companies have not attempted to in any of the countries, it is observed since last few years that private developers in some Indian states have started providing electricity services on flat rate basis (e.g. Rs 150/per light point per month) in rural areas, through installation of biomass gasifier based power generation systems[15] or diesel generators.[16]

In case of individual SHS, used primarily for providing lighting and entertainment (radio and TV) to some extent, fee-for service, leasing and consumer financing have been attempted. Sri Lanka and Bangladesh followed the consumer financing model involving banks and MFIs (micro financing institutions) for large scale dissemination of SHS. In both, development of effective after-sales maintenance networks was inherent to the business model. Also a key feature of the Sri Lankan model is the provision of buyback and identification of the clear cut consumer service responsibilities between the participating credit institutions (PCIs) and the suppliers of the solar equipment. The RVE program and VESP in India followed the VEC approach. On the other hand, private agencies like SELCO and rural banks (such as Aryabrat Grameen Bank and Prathama Grameen Bank in Uttar Pradesh, Gurgaon Grammen Bank in Haryana, SEWA Bank in Gujarat and Syndicate Bank in Karnataka) and NGOs such as TERI (The Energy and Resources Institute) have been successful in extending lighting through SHS and solar lanterns using the leasing, consumer financing and fee-for-service model respectively.

The major off-grid technologies and the business models in the four selected South Asian countries are shown in Table 2.

Table 2
Technologies for off-grid electrification and business models adopted in four South Asian countries.

Country	Major off-grid technologies implemented	Business models adopted
Bangladesh	SHS	Consumer financing, leasing
India	SHS, solar lanterns, biomass gasifier, micro/mini hydro power	Consumer financing, leasing, fee for service, village energy committee
Nepal	SHS, micro/mini hydro power	Consumer financing, village energy committee
Sri Lanka	SHS, micro/mini hydro power	Consumer financing, village development committee

Coverage and management

In India, the off-grid electrification has been carried out under RVE Program, the VESP and the Technology Demonstration Program, all administered by the Ministry of New and Renewable Energy (MNRE) and implemented primarily through designated state renewable energy development agencies. In addition, various NGOs have also been attempting to create electricity access through off-grid options with funding support from MNRE, bilateral and multilateral aid agencies. The RVE program, initiated in 2001, covers un-electrified census villages and hamlets that are not likely to receive grid connectivity. RVE electrified 8033 villages and hamlets as of

[13] The performance of the biomass gasifier projects implemented under VESP or RVE program in remote rural areas is found to be unsatisfactory especially due to technology management and product quality issues On the other hand, biomass gasifiers implemented by private companies in some parts of India for electricity supply to 'not so remote' areas are reported to be working satisfactorily (refer also footnote 8).

[14] Usually, for small capacity gasifier systems running on only producer gas such as 10 kWe or 20 kWe, diesel engines are modified (CI engine converted to SI engine) and coupled with the gasifier, as gas engines are not commercially available for smaller capacity range. Gas engines are used for 25 kWe capacity systems and above.

[15] Husk Power Systems, DESI Power and Sharan Renewables are some privately owned companies that have set up biomass gasifier-based power plants with capacity ranging from 30 to 100 kWe covering around 300 villages and hamlets across Bihar and Uttar Pradesh. These gasifiers run on a variety of crop residues, such as rice husk, sugar cane toppings, corn cob, etc. and provide electricity services to villages on flat rate or metered basis.

[16] In many villages across India, especially in Bihar, Madhya Pradesh and Uttar Pradesh, use of diesel gensets (called *choti bijli*) is common. These are usually owned by individuals and used to supply power to their own homes or for powering irrigation water pumps. Often an enterprising villager works out an arrangement to provide power either to a cluster of houses or for some economic activity. The electricity is priced as flat rate (ranging between Rs 10 and Rs 15 per kWh if converted to kWh basis) and so it is availed of only by those who can afford it or who cannot afford to do without it.

December 2010 (MNRE, 2011). The VESP, conceptualized as a step forward to the RVE program, attempted to address the total energy need for cooking, electricity, and motive power in remote villages through use of the locally available biomass. In the test phase, 79 projects, covering as many villages, were sanctioned of which 56 have been commissioned till date. MNRE statistics also indicate that about 5.8 MWe of solar PV, 6.98 MWe micro hydro power and 669,400 SHS have been deployed till 30 March 2011.

Bangladesh has an impressive SHS program for off-grid areas, implemented by IDCOL (Infrastructure Development Company Limited), a state-owned financial institution. IDCOL implements SHS through its 30 partner organizations (POs) whose main role is to select the project areas and potential customers, offer micro-lending, install the systems, provide after sales maintenance support, and provide training to the users and local technician in order to create local expertise and ownership on the system. Of the targeted 1 million SHS installations by the end of year 2012, around 872,070 systems have already been installed as of March 30, 2011 (IDCOL, 2011).

The Energy Service Delivery project, under the aegis of Sri Lanka Sustainable Energy Authority, was primarily responsible for steering the off-grid program in Sri Lanka. This project provided the basis for a market-based approach, coupled with a credit line, to the introduction of renewable energy development in Sri Lanka. It was designed to promote private sector and community based initiatives for the provision of electricity services through grid-connected mini hydro projects, off-grid village hydro schemes and solar PV electrification of rural homes. While the village hydro schemes were built, owned and operated by rural communities through electric cooperative societies, the private sector was instrumental in promoting SHS (Gunaratne, 1994). The Energy Service Delivery project catalyzed the solar market, involving financial intermediaries, called participatory credit institutions, by installing 20,953 SHS, with a total capacity of 985 kW, against a target of 15,000 systems; 31 MW of mini hydro capacity against a target of 21 MW; and 350 kW capacity through 35 village hydro schemes serving 1732 beneficiary households against a target of 250 kW (REREDP, 2010). The REREDP (Renewable Energy for Rural Economic Development Project), which followed the Energy Service Delivery project, has over the past decade, electrified more than 130,000 rural households through SHS and isolated mini-grids.

Off-grid electrification in Nepal started to develop after the establishment of the AEPC (Alternate Energy Promotion Centre) in 1999. Under AEPC, donor supported programs namely Energy Sector Assistance Program (ESAP) and Rural Energy Development Program (REDP) assisted in a substantial way to promote off-grid energy supply. From 2000 to 2005, Nepal achieved, on a per capita basis, the fastest penetration of renewable energy systems in support of rural electrification. For example, it is reported that two-thirds of the increase in the RE rate during the period from 2001 to 2004/05 came from off-grid solutions (REP, 2008). Bhandari and Stadler (2009) note that about 115,000 SHSs had been installed under various government programs and private sales with a total installed capacity of around 3.5 MW. The current phase of ESAP aims to provide energy solutions to more than 1 million households through its various program (ESAP, 2010). It is supporting creation of mini-grids, to be fed by hydro power with capacity 5 kW to 1 MW, as pre-grid electrification option. In addition to mini-grids, it is also targeting to cover 150,000 households with SHS and about 250,000 households by solar tuki systems (ESAP, 2010).

Enabling policies

Most of the countries in the region have established RE bodies or formulated schemes with supportive legislation to extend RE. However, there has been no separate policy framework for the off-grid based RE. In India, the Electricity Act (EA) 2003 made the government (both state and central) obligated to supply electricity to rural areas.[17] It also opened the door to off-grid generation to a much greater extent than it existed before. The EA specifies distributed generation (DG) through stand-alone energy systems under Section 2 (63) in addition to grid extension as a mode for RE. Further, provision of electricity to "notified" rural areas, from generation through to distribution, is allowed with no prior need for a license, opening the door to dedicated rural electricity businesses. The National Electricity Policy and Rural Electrification Policy state that wherever grid based electrification is not feasible, DG together with local distribution network would be provided. This made inclusion of DG as part of the RGGVY, which was a great step for mainstreaming off-grid technologies within the ambit of the national RE strategy. Though the Jawaharlal Nehru National Solar Mission has not been established to foster RE per se, it does mention the use of solar energy as a means for RE and envisages that by the end of phase 1 in 2013, the mission should have led to the setting up of cumulative capacity of 200 MW of off-grid power (MNRE, 2010).

The Energy Policy 2006 in Sri Lanka clearly emphasized provisioning of electricity to all feasible areas, by extending the national grid and focused rural energy initiatives using off-grid technologies, and set up specific annual targets, milestones and institutional arrangements to achieve the same (GoSL, 2006). The Policy also attempted to address the issue of energy supply under Small Power Purchase Agreement and also made provision for viability gap funding to ensure renewable projects become financially viable for the project developers for augmenting the electricity supply. The Hydro Power Policy 2001 in Nepal is by far the most relevant policy in existence for RE (NDF, 2004). It emphasized the tying up of electrification with economic activities and encouraged establishing small and mini hydropower projects at local levels. At the same time, the Water Resources Strategy 2002 also recognized the fact that providing electricity to rural populations is a major challenge in Nepal due to the scattered nature of the population in remote mountainous areas and thus envisaged a combination of grid extension, isolated generation and reliance on alternative approaches.

The establishment of the Rural Electrification Board in Bangladesh, through the issuance of Ordinance Number LI of 1977 was the first major institutional reform in the power sector that emphasized RE and aimed at increasing electricity access in rural areas. This institutional reform helped to increase the number of electrified households from around 25,972 during the pre-reform period (i.e. 1982) to more than 8 million households now. On the other hand, the promotion of SHS in Bangladesh was successful mainly because of a market based model and a suitably designed financing model by IDCOL. The Renewable Energy Policy Bangladesh, published in 2008, has recognized renewable energy as having strong potential for delivery of electricity services to the entire country by 2020.

Local participation

Community participation is widely accepted as a pre-requisite to ensuring equity and sustainability of RE efforts. It is observed from the RE efforts in all the study countries, that local participation, whether in the form of RE distribution franchises in India, the electricity cooperatives in Nepal and Palli Bidyut Samities in Bangladesh, have helped in reducing theft and distribution losses, improved billing and revenue collection efficiency and more importantly ensured stable delivery of electricity (TERI, 2007a,b, 2010; Yadoo and Cruickshank,

[17] The EA 2003 made the government (both state and central) obligated to supply electricity to rural areas including villages and hamlets. Section 6 of the act mandates the hitherto implied Universal Service Obligation by stating that the government shall endeavor to supply electricity to all areas including villages and hamlets. Section 5 further mandates the formulation of national policy on RE focusing, especially, on management of local distribution networks through local institutions. The EA 2003 in Section 4 also frees stand-alone generation and distribution networks from licensing requirements.

2010). With local participation in the case of PBS, the system has remained transparent in the crucial areas of management and operations and the transparency has also motivated the stakeholders to adhere to strict financial discipline. Further, it is also observed that there has been more success where intermediary organizations, such as NACEUN (National Association of Community Electricity Users — Nepal) and PBS, have helped the local planning process. In off-grid programs the involvement of rural communities, particularly their participation in decision-making committees, has added value to the planning process and given communities a sense of ownership. While community participation in off-grid projects has been relatively successful, there has also been negative fallout from community-centered projects. One of the key reasons is because of the fact that almost all off-grid projects are located at remote locations, thereby making it more challenging for sustainability. Shrank (2008) observes, based on a case study in the Sunderbans, that the community management system did not create incentives for maximizing profit at each power plant, thus creating problems for the coverage of costs of the power supply.

Financing

In case of off-grid electrification, it is observed that leasing of energy generating products, consumer financing models, and direct subsidy under state program has been instrumental for promotion of decentralized systems. Micro-hydro system costs per kW vary from \$1850 to \$5010 including the cost of power evacuation and distribution system (Mainali and Silveira, 2011; Nouni et al., 2006). The wide variation of costs can be attributed to highly site-specific nature of hydro projects. Costs also are impacted by management practices, proper sizing and appropriate standards. The typical SHS cost in the region varies from \$8 to \$20 per Wp, while biomass gasifier costs in India ranges between \$ 1000 and \$1400 per kW for small capacity systems.

Among the successful SHS programs, IDCOL and Energy Service Delivery/REREDP offer refinancing through soft loans (6% interest with 10 years maturity and 2 years grace period) to their intermediaries (such as POs and PCIs) and also channel grants to reduce the cost of SHS. The intermediary provides credit to customers, who pay 10–20% of the total cost as down payment and the outstanding in monthly installments, which also covers the maintenance cost. The center piece of these schemes were long term loan packages from donors to the government which made it possible for government to 'on lend' funds to local banks for proving credit to customers.

Mainali and Silveira (2011) also share that in Nepal, loans were used to cover 55% of the capital cost of SHS, followed by subsidy (27%) and owner's equity (18%). The financial mix for mini/micro hydro power reveals that the proportion of subsidy at 55% followed by local community contribution as equity (33%), loan (11%) and additional loan from local government (1%). Further, there has been increasing trend in community contributions towards meeting a percentage of the capital cost of systems in Nepal which can be viewed as an indicator that RE is moving towards sustainable business.

In India, the RVE and VESP provide direct subsidy to implementing agencies at 90% of the project cost, up to a predefined maximum of INR 18,000 per household. The balance 10% can be financed through state or other central government support or by the users. Currently, the JNNSM provides capital subsidy on off-grid solar products (INR 90/Wp) and soft loan at 5% per annum (MNRE, 2010). Further, to meet unmet community demand for electricity or in un-electrified rural areas, standalone solar power plants with mini-grid, capital subsidy is provided at INR150/Wp and soft loan at 5%. On the other hand, the DDG program of RGGVY considers technology with the lowest marginal cost for a given area and extends subsidy of 90% of the project cost and some operational subsidies. The subsidy is released on annuitised basis based on performance of the system for five years. However, it is also observed that commercial finance for off-grid electrification has been very minimal. Jaisinghani (2011) observes that most companies active in off-grid distribution are not able to access sufficient capital to expand. He further argues that off-grid electrification is also hindered by non-uniform technical approaches, undeveloped non-technical processes (such as tariff collection, and response to system abuse) which are also hindering access to finance at the early project stage.

Specific challenges

There are many challenges – technical, financial, regulatory, and institutional – hindering electricity access in the region. In spite having moderate to high village electrification rate, the household connections in rural Bangladesh and India continue to be low. In case of SHS, the lowest strata of the society find it difficult to procure SHS on the available financing options. Difficult terrain and poor economic condition also seem to be hindering the electrification efforts in Nepal. In Sri Lanka, the SHS market is diminishing with extension of grid and it is reported that people are defaulting on their loan repayment after taking grid connection. Some of the specific challenges, inhibiting the growth of the sector, are discussed here:

- A large number of off-grid electrification projects have not succeeded as focus has been on technical installation without paying sufficient attention on whether they can be sustainable in the long run (Kumar et al., 2009). Palit (2003) highlighted, based on specific examples from north eastern region of India, that lack of availability of adequate maintenance facilities and inadequate capacity building of the technicians acted as a barrier. On the other hand, Martinot et al. (2001) observed that credit risk tends to be a serious concern for both financiers and dealers of SHS and makes credit sales particularly challenging.
- A TERI study on biomass gasifiers for off-grid electrification highlights a number of sustainability challenges (TERI, 2009b). Some of them are low concentration of electricity demand (making distribution expensive[18] and difficult); low economic activity (implying low demand for electricity); difficulty on the part of users to pay for electricity; difficulty in operation and maintenance due to remote project location; limited technical knowledge of VEC members and weak biomass fuel supply chain linkages.
- Mini-grid projects encounter many challenges for financial sustainability because most of these projects are set up in remote villages resulting in high transaction cost. These challenges lead to a feedback loop, wherein lower plant load factor of the systems lead to higher cost of generation (Kumar and Banerjee, 2010), which do not match with the ability to pay by the consumers. For example, a biomass gasifier system does not function when the load is less than one-fourth of the rated plant capacity of the plant. The consumers become reluctant to pay when the plant does not function and the discontinuation in payment makes it further difficult to run as the operators lose interest. While the issue is also prevalent in the remote villages covered by utility's grid network, the issue gets addressed through regulatory measures such as cross subsidization of the consumer tariff (Palit et al., 2011).
- Grid connected projects have advantages in terms of reliability because the grid acts as a balancing sink or source and also supplements power in the local area during periods of plant shutdown. Further, grid can also support productive loads,

[18] Technically, distribution line should not be more than 1–2 km for optimal voltage level and costs. However, because of low demand per household (only lighting load) and there is a critical minimum capacity of biomass gasifiers (which is 10 kW), mini-grid is extended to cover households in a wider area (for higher load factor) resulting in high cost. Longer distribution line also introduces higher cost for service and maintenance.

irrigation pumps and agri-processing on demand in contrast to the capacity constraints of small off-grid projects (TERI, 2009b)

- The REB experience (Bangladesh) shows that while some co-operatives have a good customer mix including industrial customers and have achieved break even, those in the remote areas are finding it difficult to produce positive margins, even after years of operation. Subsistence level energy consumption activities such as lighting account for bulk of the power consumed in such areas (resulting in lower load factor than the threshold load factor for viability) and with most domestic rural consumers falling within the minimum tariff slab, the revenue generated from such areas is low as compared to cost to provide the services.
- India, Bangladesh and Nepal face a severe electricity supply constraint[19] which is one of the key factors impacting the RE sector. On the other hand Sri Lanka has fully utilized its micro and small hydro potential in a planned way and has also introduced small power producers program based on dendro-thermal and other renewable resources to augment the supply situation in the rural areas. The annual available biomass energy potential for electricity generation in Bangladesh is in the range of 184 and 224 TWh (Hossain and Badr, 2007), which could probably be utilized for decentralized electricity generation to augment rural supply situation. Similarly, small and micro hydro power can be fully tapped in Nepal to augment the supply in rural areas. A World Bank study (2010) for India also shares that distributed generation and supply model, mainly biomass and small hydro power, could well be utilized to improve RE efforts.

Summary of key findings

Across South Asia, a wide variety of RE models and technologies have been implemented. While on the one hand because of such a wide range of implementation efforts, it is difficult to identify and fully analyze all, or to create clear directives for best practices, the range of options also presents the opportunity to glean lessons. This review presents a number of interesting findings and lessons as summarized here:

a) While the village electrification level in Bangladesh and India is moderate to high, the actual number of connected households is comparatively low. In fact, the current definition of village electrification is India requires electrification of only 10% of households, for a village to be considered as electrified. In both these countries, the key issue is 'how to improve the household level connection' and also 'how to ensure sustained electricity supply to rural areas in line with the demand'. Sri Lanka, by adopting targets and milestones for connecting rural households and arranging micro-lending for poor households desirous of taking electricity connection could achieve a high household connection level. The country is also utilizing its local hydro resources potential to augment supply especially off-grid areas. Further, the better economic condition of households in Sri Lanka may also have contributed to their decision to take electrical connection as compared to Bangladesh and Nepal. Nepal, because of its hilly and forested terrain is finding it difficult to extend grid coverage and sustaining the same. Another interesting fact in India and Bangladesh is that the SHS are not considered in the RE figures as they cater only to lighting needs, while Nepal and Sri Lanka considers SHS also as a means of electrification.

b) All RE projects examined have involved a significant subsidy component especially capital subsidy. However, different approaches have been adopted for grid based and off-grid electrification. 'Top down' approach has been primarily adopted in extending grid to rural areas with the planning and implementation undertaken by central or state level agencies, Off-grid electrification, through mini-grids or otherwise, has been mainly through community centered projects or involving non-governmental organizations and thus lacks a organized delivery model.

c) The rate of success is directly dependent on the government's commitment in creating an enabling environment such as clear cut policy framework and milestones, systems for defining and enforcing appropriate technical standards, standardized operational metrics, financial support mechanisms and support towards R and D and training. Market has a very minimal role for central grid based electrification. Bangladesh and India are two examples where we can see that the creation of REB and launch of REST mission and later the RGGVY assisted in sharply increasing the village electrification rate. At the same time, specific targets, milestones and institutional responsibilities adopted in the Sri Lanka Energy Policy for improving households connections – both through grid connected and off-grid model – along with the 'Power Fund for the Poor' project helped in achieving high household electrification level.

d) Bangladesh and Sri Lanka have had success in disseminating SHS following a market based approach which indicates that it is possible to successfully implement off-grid programs in association with the private sector and MFIs. Improved access to capital, development of effective after-sales service, customer centric[20] market development and regular stakeholder involvement assisted in scale-up. In both the cases, output focused approach offered private companies and MFIs/NGOs incentives to enter new markets and deliver pre-defined products, while grants increased product affordability and covered a portion of the incremental costs of introducing clean energy products. While these experiences may be true for delivery of individual systems, the design principles key to their success can also be extended to cover other off-grid technology. In fact, both projects are also providing other off-grid and rural energy services (such as financing for setting up of solar and gasifier based mini-grids and biogas plants) in their area of operation.

e) The success of the cooperative or community centric delivery model has been due to equity, commitment and transparency in decision making. However, they may also be vulnerable to cooption and coercion by local power brokers, if appropriate checks and balances are not put in place. An appropriate institutional environment, whether a government regulatory body or a decentralized membership based self-regulating body such as NACEUN or Federation of Electricity Consumer Societies in Sri Lanka, could create a highly favorable delivery mechanism for rural electrification.

f) The community approach has been particularly successful in cases where the project has also worked at improving the productive uses of electricity (to increase daytime demand) and the capacity of the consumers to procure electrical appliances (Yadoo and Cruickshank, 2010). VESP in India also indicates that revenue realization is comparatively better in projects where villagers are having cash income because of either existing income generation

[19] The access to electricity grids does not necessarily mean that there is reliable electricity supply to meet the needs of the rural people. In India and Bangladesh, the Central Electricity Authority and Bangladesh Power Development Board statistics indicate that the peak power deficit was more than 10% and 27% respectively during the year 2010. Similarly, Nepal Electric Authority reports that the annual energy deficit was more than 20% of the demand during 2008–09 and load shedding period was up to 16 h a day in the rural areas. As priority is always provided to meet the urban and commercial demand, due to expectation of higher returns (as tariff is high in such areas), the rural areas are neglected and is impacted by frequent blackouts.

[20] Many government programs sometimes are not in line with what consumers wants. For example, consumer surveys are not undertaken to ascertain the type of luminaire or appliances s/he plans to use after getting electricity connection and design the system capacity accordingly, or whether the consumers will prefer SHS or mini-grids in off-grid areas etc.

activities or newly introduced activities after being electrified (TERI, 2009b). On the other hand, VESP and REB also suggest that not all areas are equal in terms of their suitability and prospects for productive or micro-industrial end uses. Subsistence-based economies, a feature of off-grid areas, with little market for local consumption have very little prospects for micro-enterprises and thus cannot make full use of electricity to power them.

The RE boosters

Based on the analyses, we observe that all the countries do not have similar issues related to electrification efforts and so may need a differential approach to enhance the level of electrification. While there is no doubt that conventional grid extension has been and will continue to be a preferred approach, distributed generation can also be attempted to enhance power supply as well as extend electrification to remote areas. This section raises some pertinent questions and attempts to suggest measures to improve the pace of RE in the region.

How to improve the household electrification level?

While the extent of village electrification level in India and Bangladesh is good, the electricity connection at the household level is low. The key task is to improve the overall household connection level at a rate that exceeds the rate of population (or number of households) growth. The micro-financing of household connection experience from Sri Lanka will be particularly useful in expanding the household electrification level in countries such as India and Bangladesh where Government support is currently being used to expand the network to the rural areas. With both these countries are having a strong MFI network, the tasks should be easier. Rural distribution utility in these countries can tie up with local MFIs and attempt to develop schemes whereby the MFIs can bear the cost of connection charges (including cost towards energy meter) and the money can be recovered by the utility through monthly electricity bills.

Do we need regulatory measures to ensure viability of mini-grid projects?

Most of the mini-grid projects suffer from non viability as cost of electricity generation from such projects is high while the return through tariff is low. The remoteness of projects increases the capital cost, operation and maintenance costs and in turn the cost of generation and supply. Added to this is the low paying capacity of the rural consumers in the absence of any cash disposable income. The financial un-viability results in closure of these projects after few months of operation (Palit et al., 2011). This not only makes the villages de-electrified, but also renders these projects, set up with capital subsidy from the Government, as dead infrastructure. With off-grid projects in many of the countries not covered under the regulatory regime and usual tariff setting by regulatory commissions, the benefits of any cross subsidization, if any, is not extended to rural consumers of such projects, which otherwise could have helped in achieving financial viability. Extending the tariff fixation by regulators in case of off-grid projects and providing tariff subsidy/Output Based Aid[21] (OBA) from a universal service fund can be attempted to bring in viability for project developers/concessionaire to extend electricity to remote areas. The universal service fund can be worked out through a suitable mechanism from the cross subsidization amount and or deploying savings out of the reduction in kerosene subsidy which otherwise is used for lighting in such un-electrified villages. Operating subsidies provided through competitively determined OBA aimed at 'base of pyramid' consumers, along with differential tariffs, can also bridge the financial viability gap.

Can bundling reduce the access gap?

The 'access gap' relates to communities who are beyond the reach of the market due to inadequate income levels or geographical access. Efficient market mechanism and targeted subsidy interventions are needed for attracting business to low load areas. As the off-grid projects are invariably smaller in capacity, concentrating energy loads in a given area or bundling projects can increase the market size. Off-grid projects could be identified depending on the availability of local energy resources and clustered, to ensure economics of scale and scope, and handed over to concessionaire. Philippines have successful Qualified Third Parties to provide retail electricity services along similar lines (World Bank, 2010). Private players may get attracted to become concessionaires for multiple areas, where grid connected distribution business could be bundled with off-grid areas, or bundling projects with different off-grid technologies to optimize costs. Financial institutions/banks would also be interested as project implementation and credit risks would be less.

How is access to credit?

Financial innovation and private sector involvement are the two main factors that have the potential to increase the penetration of off-grid technologies to enhance access. However, for the sector to reach a significant scale, companies need to remove barriers to supply, demand and scalability and at the same time adopt standard process and metrics, which will help them to attract the necessary level of investment. Added to this, there is also need for access to credit and financing to develop necessary infrastructure and technical capacity at the local level for providing after sales services.

What institutional structure will be appropriate for sustainability?

Similar to other developing nations (Monroy and Hernandez, 2005), a key barrier to extend and sustain off-grid RE in South Asia, is lack of appropriate institutional models. While it is observed that the grid extension projects are more organized and managed by a utility (private sector, state level cooperatives or government owned), most of the off-grid programs are implemented through NGOs or local level institutions. Successful programs such as IDCOL SHS or mini-grids in Sunderbans (Ulsrud et al., 2011) and Chhattisgarh (Shukla, 2011) in India implemented through a proper institutional arrangement following a standard set of guidelines corroborates the need for such institutional structure for off-grid case. It is imperative that there must be appropriate (socio-politically acceptable) institutions in place with necessary skills and means to manage the systems on-site and collect revenue, and that the technical knowledge for ensuring sustainability must be available within a reasonable distance. Further, the support system need to be developed at the intermediary level — which provides an integrating link between the national and local levels, ensuring that plans and policies match the needs of consumers, owners and suppliers. The intermediary can provide considerable help in explaining, facilitating and planning a suitable choice of technology and delivery model.

Can economic linkages assist in improving access?

Electricity must result in opportunities for enhancing the local economy and adequate money flow to the rural households so that they are willing and able to spend a part of the incremental income on purchasing the electricity. While it is observed from this research that correlation exists between the per capita GDP and household electrification, the causal factor cannot be identified in this case.

[21] OBA is a performance-based operating subsidy scheme that links payments to actual electricity output delivered to customers.

This needs further research whether higher economic level contributes to higher connection level or higher level of RE contributes to improved rural economy. Nevertheless, creating economic linkages is particularly important for off-grid electrification as they are usually remote and people have low disposable incomes.

Conclusions

Electrification, highly desired by all rural communities, does have developmental benefits and its expansion is a political priority. Though all the countries reviewed here have developed policy frameworks and envisage bringing more areas under electrification, our study shows that there are no specific initiatives to improve the overall household connection level except Sri Lanka. RGGVY in India is attempting to provide electricity connection to all BPL (below poverty line) households, though the scheme is ambiguous about APL (above poverty line) households. Further, all the government policy is based on an a priori judgment that renewable energy should be reserved for marginal areas where grid extension is a challenge and so governments are not attempting distributed generation to enhance access utilizing the locally available resources in grid connected areas.

Further, we also observe that all RE programs in the region have a substantial subsidy component either to improve the infrastructure or through cross subsidization of tariffs for poor consumers. In all the countries reviewed, subsidies have served to channel demand to SHS and micro hydro and also had an impact on the formation of market for these two technologies. Even though the word subsidy has become unpopular in the current reforms scenario in India, it still has relevance in many cases in view of the need to electrify low-demand, inaccessible areas (Palit et al., 2011). Government concessions, through a targeted and smart approach and channeled through the service providers (i.e. reflecting the same in electricity bills), may be beneficial if they can continue to encourage access and bring in social benefits, rather than the area becoming de-electrified due to financial un-viability of a project or a poor household reverting back to traditional fuel because of their inability to pay the tariff.

The off-grid technologies prioritized seem to fit to a large extent with the geographical characteristics of the demand, resource potential and delivery model in which the technology dissemination is taking place. The delivery networks as well as the technological performance are comparatively better placed for solar PV than for micro hydro or biomass gasifiers. Despite being an agricultural country with high biomass resources, Bangladesh has not attempted to utilize the resource for electricity generation to address the supply side constraints. Similarly, India has also not fully utilized its small hydro power potential available in its hilly terrain to cover such areas through developing mini-grids[22].

This paper shared the RE experiences and best practices from four selected countries of South Asia for cross learning potential across the region as well as other developing counties. We have also raised some pertinent issues and have attempted to find solutions to these issues. We suggest that India and Bangladesh should focus on improving the household connection level in grid connected rural areas through a targeted approach. While micro-financing can be extended to consumers unable to take connection due to financial barriers, the Palli Bidyut Samities (PBS) and Input Based Franchises (IBF) should also be incentivised to connect more unserved households. In rural areas of India, where franchise system is yet to be introduced, IBF model should be extended for better delivery of services. Secondly, benefits of cross-subsidy also need to be extended to off-grid areas, especially in India, to ensure continuous operation of projects in such areas.

To augment the supply situation in grid connected areas and also for achieving better operational efficiency, twinning distributed power generation, utilizing locally available renewable energy resources, with a suitably structured rural distribution delivery model in India (or PBS in Bangladesh) can result in better utilization of the installed rural distribution infrastructure and in greater economic and social development. The financing for setting up such renewable based distributed power projects in India could be leveraged from the National Clean Energy Fund launched recently. Over the years, as the grid supply situation improves and also the electricity demand, these operators can become distribution franchisees and continue to serve the areas, partly with the local generation and partly from the grid supply.

Nepal needs to address its RE issues with a two-pronged approach — extending the coverage and also utilizing its hilly stream based hydro resources to ensure supply to these areas. Although Sri Lanka has a notable RE achievement through grid extension, the country should ensure that the off-grid mini/micro hydro power projects set up earlier to extend RE remain functional and can feed power to the grid to avoid any future supply constraints in the grid. Pakistan and Afghanistan on the other hand need to formulate clear cut policy framework and executable master plan taking lessons from other countries in the region to extend their RE efforts. Finally, economic linkages, access to credit, bundling of smaller projects and institutional arrangements also need to be organized appropriately, especially for off-grid RE to facilitate successful outcomes in the region.

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