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Off-grid electrification experience in South Asia: Status and best practices

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1.0 Introduction

Rural electrification is the availability of electricity for use by rural communities irrespective of the technologies, sources and form of generation [Barnes 1988]. Although the rate of rural electrification worldwide has increased and has made significant gains in terms of percentage of access to electricity, there is no significant decrease in the absolute number of people without access to electricity worldwide. This could be due to faster growth in demand for electricity than the growth of supply, which is constrained by financial, technical and trained human resource shortages, and to increase in the absolute number of people. This has been the concern of many developing country governments. The benefits of rural electrification are immense, but the dilemma faced by many such governments is that while they recognise the benefits of rural electrification, many cannot afford to extend the electrification coverage because of due to shortage of resources.

The importance of electrification, especially rural areas, for achieving both human and economic development has been well documented in various literatures (DFID 2002; GNESD 2007; World Bank 2008; NRECA 2002). Literature also points to the fact that the positive contribution of electricity to the Human Development Index is strongest for the first kilowatt-hour (EDF, 2002), reflecting that the BoP (base of pyramid) population are most likely to benefit from even minimal electricity inputs. At the same time, evaluation by World Bank (2008a) points to the fact that electrification favours the non-poor, although more of the poor are included as the grid is extended. Project benefits would be greater if explicit attention were paid to extending the grid to those least able to connect and to ensuring that poor customers use electricity efficiently.

An ESMAP (2002) study of the economic and social benefits of rural electrification in the Philippines captured a variety of direct and indirect benefits through detailed survey based research and a theoretically analytical framework. One of the general survey findings was that those households lacking electricity were much poorer and less educated than their electrified counterparts. The major conclusion of this study is that the benefits of electricity are derived from a variety of sources, some of which overlaps. Lower cost and expanded use of lighting and lower cost and expanded use of radio and TV can directly increase the households' consumer surplus. The total benefit of providing electricity to a typical, non-electrified Philippine household was estimated at US$81-US$150 per month, depending on the household's number of wage earners and whether it runs a home-based business. Impact study of the rural electrification programme in Sri Lanka also strongly corroborates the direct linkage of electrification and poverty eradication [Gunaratne 2002a]. The study observes that there are localized benefits of electricity to households with improvement in quality of life, better health and improved air quality because of rural electrification. The study further says that all these attributes of electricity can bring longer tern benefits to the community leading to a sustainable economic growth. Yang and Yu (2004) also opined that although rural electrification may not viable financially, it is however found to be economically sound and socially beneficial.

Though electrification can provide the required start up for economic growth, but there is also a need for complementary infrastructure such as roads, markets, buildings, equipment and skilled staff, which are often not provided in tandem with electricity, to achieve the full economic benefits from electrification. Some evidence even suggests that provision of infrastructure in a complementary fashion provides not just additional, but exponential benefits, due to the available synergies (Barnes 2000 cited in Cecelski 2000). Mathur and Mathur (2005) report that in households with electricity, women spend significantly less time collecting wood for fuel and, because of the availability of lighting, are able to spend a portion of their day reading. The benefits of rural grid electrification, are similarly realized in off-grid situations, even though the amounts of power made available by decentralized systems are relatively smaller and the services provided more basic (World Bank 2008b). In most of the cases, the government has been the key driver in extending rural electrification in developing countries. The rural electrification provides little by way of market incentives for profit-seeking private companies and is characterized by geographical remoteness, dispersed consumers, higher costs of supply and maintenance, low consumption and limited ability to pay (Reiche et al. 2000). This may have neglected the provision of electricity to rural areas during the wide-spread privatization and liberalization of electricity sectors during the 1980s and 1990s (Cherni and Preston 2007; Haanyika 2006). Inspite of the limited role currently played by private players in extending rural electrification, organisation such as Alliance for Rural Electrification (ARE 2009) believes that private companies can become a key driver in the field of rural electrification with many companies demonstrating their capabilities by implementing successful rural renewable energy projects throughout the world. However, ARE also observes that the crucial precondition will be an enabling legal and financial framework for rural electrification.

The main objective of this paper is to provide a review of the status of rural electrification in South Asia and to identify best practices in off-grid supply that could be useful to extend the coverage, especially for connecting last mile population, in South Asia and other developing countries. In terms of technology coverage, the report focuses on both conventional and renewable energies and covers conventional grid extension; mini-grid[1] based electricity supply as well as stand-alone systems.

Given that the spatial scope of the review is broad and because data availability on off-grid electrification is somewhat limited, the review had to follow a selective approach in its coverage. Emphasis is given to those countries in South Asia where a significant improvement in the access to electricity has been achieved. While the review does not provide an exhaustive status report of each country in the region, an attempt has been made here to highlight the overview of the sector at the regional level and at the same time capture significant development in some of the countries where off grid electrification has been significant.

The structure followed for the report is as follows: section 1 introduces the report followed by the section providing a review of the electrification and off-grid electricity status in various countries of South Asia; section three looks at four specific country examples, e.g. India, Nepal and Sri Lanka and Bhutan and Bangladesh in the order, selected on the basis of technologies adopted and success of off

[1] 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 (solar PV, wind, small hydro, biomass, etc.) with or without its own storage (batteries) depending on the technologies.

grid electrification in enhancing access to electrification. For each case, the following aspects have been considered:

- History and present status of electrification;
- technology choice and off grid solutions;
- organisational arrangements and financial sustainability; and
- key lessons learnt

This is followed by a review of the rest four south Asian countries (Afghanistan, Maldives and Pakistan). Section 5 presents few successful off-grid country specific case studies. Finally, the last section provides a summary of the report and lessons learnt from the experience of off grid electrification in these countries.

2.0 Electrification and off-grid status in South Asia

Typically, South Asian countries[2] are characterised by high density population with almost one fifth of the world's population inhabiting in only 4% of the world land mass. The Table 2.1 gives certain physical and economic indicators, which reflect the socio-economic divide. This part of the world also consists of both developing and least developing countries, with about 40% of the total population are reported to be below poverty line (less than US $ 2 earning per day). Large percentages of the population in almost all the countries of the region inhabit the rural areas. Historically, the entire South Asian region faces key developmental challenges such as poverty alleviation, health, education, provisions of potable water; sanitation and other basic amenities. This may be because most of these countries were either part of the same country or maintained very close cultural and economic linkages. This indicates that there exists a possibility of greater co-operation between various South Asian countries, in almost all spheres, drawing upon the historic interdependence. Currently, the region is in a period of transition as the constituent countries are striving to implement effective economic, political, social and legal structures to support sustained growth.

Table 2.1: Physical and economic indicators of south Asian region countries

S N	Item	Unit	Afghanistan	Bangladesh	Bhutan	India	Maldives	Nepal	Pakistan	Sri Lanka
1	Land area	' 000 km^2	652	144	38.4	3287	0.3	141	779	65.6
2	Population (2009)#	million	28.4	156	0.69	1166	0.40	28.5	176	213
3	Population density	Persons/ km^2	456	1002	17	329	1163	196	202	306
4	GDP PPP (2009)	billion US$	19.21	201	2.73	2816	1. 515	28.76	392.5	81.16
5	Per capita GDP PPP (2009)#	US $	600	1300	4100	2500	4400	1000	2400	3900
6	HDI (2007) *	no	0.352	0.543	0.619	0.612	0.771	0.553	0.572	0.759

Source: SAARC Energy Centre, 2009; # www.indexmundi.com; * Human Development Report 2009, UNDP

The energy-mix within the region also varies significantly. On one hand, Afghanistan and Nepal has a small and largely undeveloped electricity market; on the other extreme, India ranks fifth in the world

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

in terms of generation capacity. Pakistan and Bangladesh's energy mix is dominated by natural gas, while India relies heavily on coal. Maldives is overwhelmingly dependent on petroleum. The Himalayan countries of Nepal and Bhutan and Sri Lanka have the highest shares of hydroelectric power in their energy consumption mix. Despite the apparent diversity in size and output level, Bhattacharya (2007) highlighted a number of similarities among these countries, including the following:

(a) Per capita electricity consumption in these countries ranks very low by international standard.
(b) The level of electricity access is low, especially in rural areas, between 15 and 50% except Sri Lanka.
(c) Electricity is supplied to certain consumers at highly subsidized rates, often for political motivations, creating distortions in demand.
(d) The state budgetary support constituted the main source of funding for the sector for a long time. But deteriorating financial situation of the state does not allow continuation of the same practices, affecting growth of the sector.
(e) State still plays a dominant role in the electricity sector and often acts as the policy maker, regulator and owner of the electric utilities. In many cases, the state failed to exercise its power in a balanced manner.
(f) The supply quality is poor, often as a result of inadequate supply capacity, poor maintenance and inappropriate policies.
(g) The electric utilities are in a state of severe financial distress due to poor tariffs, abysmal operating performance, and a legacy of inappropriate power procurement practices and policies.
(h) Each country is facing high demand growth due to relatively stronger economic performance in recent years.
(i) Each country has developed its own isolated system, and electricity trade plays a minor role in the region except between India and Bhutan and India and Nepal, although most of the countries share international boundaries.

This following section provides an overview of the present status of electrification in South Asia and indicates the role of off-grid solutions in the electrification efforts. The first sub-section provides the electrification status while the following section is devoted to off-grid solutions.

2.1 Status of electrification in South Asia

About 1.4 billion people, which are 22% of the total global population, do not have access to electricity as on 2008. Of these, almost 614 million people (i.e. 42% of the population) are from South Asia. The current total penetration of the grid in the rural areas of the region is about 50%, leaving one out of every two people in the rural areas - some 614 million people – without access to electricity (Table 2.2). The disparity in rural electrification in south Asia is quite significant. Whereas Sri Lanka has a high rural electrification rate, higher than the global average, only 12% of the rural population in Afghanistan is connected to the grid. India, Pakistan and Bangladesh constitute more than 90 percent of those lacking access to electricity while the rest 10 percent is dispersed in the other smaller countries.

Table 2.2: Electricity access in 2008 - South Asia

Region	Population without electricity (millions)	Electrification rate (%)			Per capita consumption (kWh)*
		Total	Urban	Rural	
Afghanistan	23.3	14.4	22.0	12.0	35
Bangladesh	94.9	41.0	76	28	144
Bhutan	0.2	57.1	96.3	40.0	227
India	404.5	64.5	93.1	52.5	543
Maldives	NA	-	-	-	604
Nepal	16.1	64.5	93.1	52.5	81
Pakistan	70.4	57.6	78.0	46.0	475
Sri Lanka	4.7	76.6	85.8	75	418
South Asia	613.9	60.2	88.4	48.4	
Global	1456	78.2	93.4	63.2	2,595.7

Source: IEA (2009). < http://www.worldenergyoutlook.org/database_electricity/electricity_access_database.htm>
IEA (2009). <http://www.iea.org/stats/indicators.asp>

Of the 600 million un-served rural people in the region, many reside in isolated communities far from the national electricity network. These so-called "off-grid[3]" communities are generally small and dispersed, consisting of low-income households - characteristics economically unattractive to potential private-sector energy providers or even government electrification programs that must prioritize the allocation of scarce resources. Un-served consumers are also found in concentrated rural and peri-urban communities close to the grid mainly due to inability of the households to pay for the connection charges. The electrification approaches and costs required to reach these different classes of un-served populations may differ significantly, and may need customised solutions, which may also differ with countries. The issues that are important for developing rural electrification program in the region may be categorised into general, technical, economic, policy and legal framework, financing and institutional capacities (Urmee et al. 2009). Some of the key issues are:

- High capital cost and lack of innovative financing
- Limited access of credit for the consumer to take electricity connection
- Limited productive use of electricity and no link with income generation
- Lack of policy and legal framework
- Improper use of subsidies
- Donor dependency
- Unrealistic political commitment
- Limited institutional capacity and technical knowledge

[3] The term "off-grid generation" 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 single installations to serve individual buildings, such as solar home systems

2.2 Status of off-grid solutions in rural electrification in South Asia

There is a mixed trend to the progress in the use of off-grid solutions for rural energy supply in the south Asian region. The most common technologies that have been used for off grid electrification are solar PV and mini/micro hydro systems. While mini/micro hydro has been used to create mini grid to supply electricity locally, solar PV technology applications covered both solar home systems as well as solar PV mini grids. In addition, biomass gasifier has also been used as one of the technology in India for off grid electrification. In terms of country coverage, Sri Lanka and Nepal has extensively used micro hydro power based mini grids to provide electricity services. Bangladesh, on the other hand, relied more on solar home systems for covering households with access to grid electricity. India has tested almost all off grid electrification technologies but solar PV and biomass gasifiers have been received more attention that other technologies. Other countries in the region such as Afghanistan, Bhutan, and Pakistan have relatively lesser penetration of off grid systems.

While most of the country off grid projects/programme were grants and donor driven and continue to be so in the South Asian countries such as Nepal, Pakistan and India; free markets have started to developed in some countries especially for the solar home systems market such as in Bangladesh and Sri Lanka and even in India showcasing innovations in system design as well as in financial and institutional mechanisms. Further, it is also observed from the case studies of different countries, community based models were mostly adopted for off-grid electrification in the region albeit with different names such as VEC (village energy committee), VDC (village development committee), Fee for Service, Rural Energy Service Company, and Rural Electricity Cooperative.

Despite the variations in technology use, institutional and financial models, level of penetration etc, some general observations can be made as follows:

- Donor-led electrification programmes such as ESD (Energy for Sustainable Development) in Sri Lanka, ESAP (Energy Sector Assistance Programme) etc are providing access to clean energies to off-grid areas.
- Past experiences also show that a large number of off-grid electrification projects failed because focus is generally on technical installation without paying sufficient attention to the long-term sustainability (Kumar et al. 2009). Taking solar PV as an example, the experience from South Pacific has attributed institutional aspects (as compared to technical ones such as inappropriate design, use of unreliable components, improper installation and poor maintenance) as main reasons for failure of PV systems. Several institutional models have been used to introduce PV systems in the Pacific, based on ownership of equipment, nature and manner of technical support, collection of fee/charges, etc. All but one (Tuvalu Solar Electricity Cooperative Society) have failed, mainly because of poor maintenance and inability to collect fee. The paper concludes that maintenance of PV systems by user is rarely successful, fee collection should be by a third party and not from the community, and spare parts and technical assistance should be readily available [Jafar 2000]. Yordi et al. [1997] highlighted the unavailability of skilled technicians required for promotion and installation of the systems in developing countries as a barrier, while credit risk was found to be a serious concern of both financiers and dealers of PV systems and therefore credit sales of solar systems were found to be particularly challenging (Martinot 2000).

- A study on the functioning of the biomass gasifiers for off grid electrification implemented under the Village Energy Security Programme in India have revealed a number of challenges that need to be tackled at village level to ensure the sustainability of the project interventions: Some of these challenges are low concentration of electricity demand (making distribution expensive 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 (village energy committee) members and weak fuel supply chain linkages (TERI 2009)
- Off-grid investments usually have a lower rate of return than grid extension because the costs are more and the benefits are less (World Bank 2008b). A micro grid might be a financially more attractive option for the user, energy service company and the community if the village has a large number of households, is densely populated and lies in a geographically flat terrain. However, in rough terrains solar home systems (SHS) might be a better option if the community is small and sparsely populated.

Off-grid electrification, or distributed generation[4] as it is sometimes referred to, is yet to be tried on a very large scale in rural electrification projects in any of the South Asian countries. There are still many barriers—technical, financial, regulatory, and institutional. A clear and well-established framework is required to design, implement, and mainstream such schemes (Chaurey et al 2004). This necessitates the need for developing and benchmarking the systematic approaches, which could be followed for project planning and formulation and also developing business models which will not only take care of the installation but at the same time ensure sustainability and replicability of the project. Kumar et al. (2009) made a modest 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. With decentralised systems holding great relevance for off grid rural electrification on account of the key challenges of ensuring energy security to all communities, as well as at the global level on account of climate change concerns and meeting the MDGs including education, health, environment protection and livelihood generation, effective service delivery and innovative financial models are need of the hour to provide the required thrust to the sector. On the basis of the literature search and the global trends, Chaurey and Kandpal (2010) and Palit (2009) independently suggested new paradigms within which decentralised systems seem to be finding newer markets apart from the off grid electrification. Some of these are:

- Improving household electrification level in electrified villages where households are scattered and grid extension is not very feasible.
- Augmenting the electricity supply in electrified villages for achieving better healthcare, education and community services.
- Providing dedicated power to livelihood activities such as food processing, rice hulling, computer kiosks, small shops and skill-development centres, etc. for boosting the local economy.

[4] DG be defined as the installation and operation of electric power generation units connected directly to the distribution network or connected to the network on the consumer site.

- Managing the periods of low demand such as street lights, compound lighting in the night in institutions/campuses where large diesel gensets run for daytime peak loads
- Pre-electrifying villages which are likely to be electrified in near future for intruding basic electricity services initially and subsequently facilitating load growth for making grid extension viable in future.
- Meeting universal service obligations by improving the household electrification level in electrified villages and providing electricity in de-electrified villages.

Figure 2.1 (based on a study by TERI in rural Rajasthan in 2004) presents the relevance of distributed generation sector in the current scenario where the aspirations of rural communities and status of the electricity sector per se, demands innovative approaches beyond the experiences so far of using renewable either in isolated energy projects or off-grid mini-grids serving limited requirements of the community

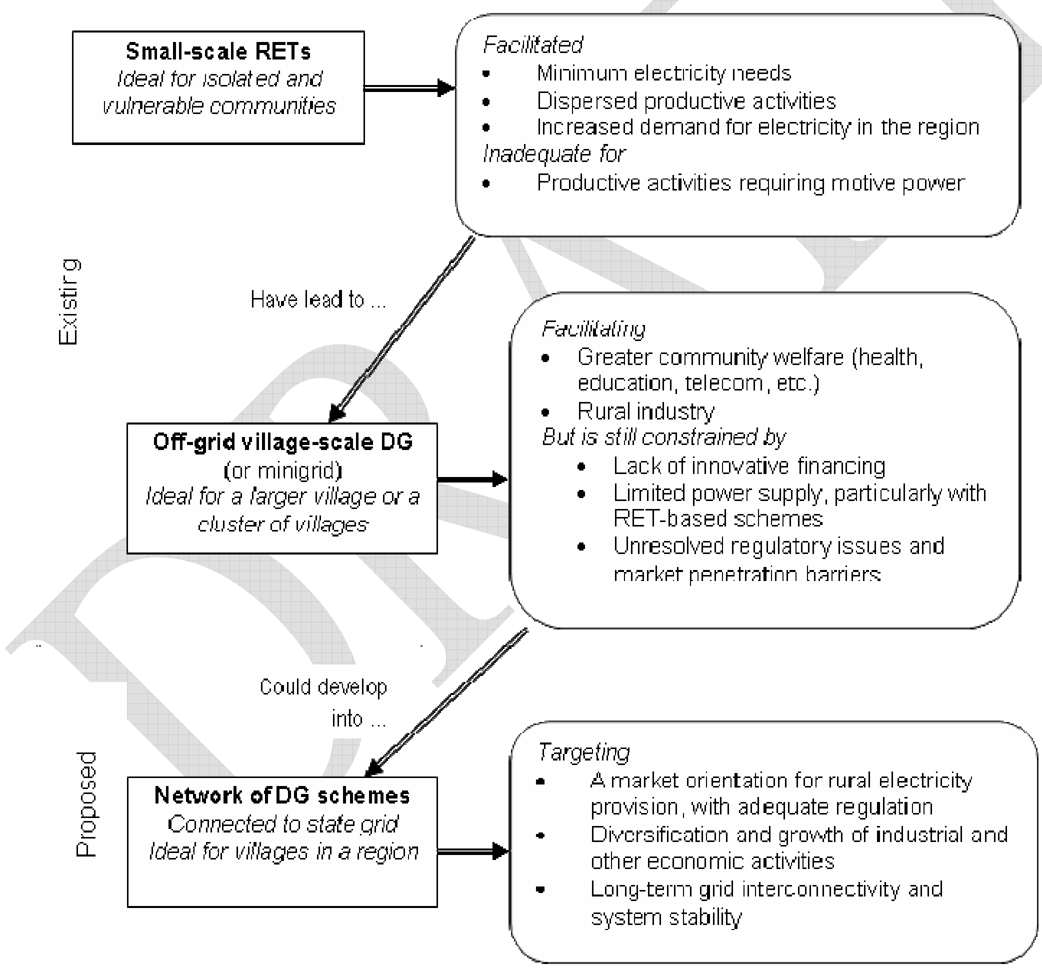

Fig 2.1 Framework of DG schemes for electricity provision in remote rural areas

3.0 Review of rural electricity and off-grid experiences in South Asia

This section extensively reviews the available literature on rural electrification with a specific focus on off-grid electricity supply in some key countries in South Asia.

3.1 Experience from India

3.1.1 Status

The Republic of India is the seventh-largest country in the world with respect to its geographical area, covering 3.29 million square km spreading across 28 states and 7 union territories. With the largest rural population in the world, currently India is facing a huge electrification challenge. Statistics on access to electricity services in India stand at about 93 percent of villages and 60% of the rural households (MoP 2010). 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 in the rural areas, the household electrification rate and power availability is still far below the world average. Electricity consumption per capita is among the lowest in the world, equaling 543 KWh per capita (IEA, 2009).

This above scenario may be due to the fact that during the initial years of the country's independence, household electrification was not provided the due importance. Infact, some researchers argue that electrification as a part of the Green Revolution in agriculture was the main driver for rural electrification. According to Bhattacharyya (2006) and Krishnaswamy (2010), the energization of irrigation pump-sets was the principal aim of rural electrification for a long period. Bhattacharyya (2006) also observes that major economic benefit of rural electrification was captured mainly by the well-off farmers, leaving aside rural industries and trades which were not targeted as part of the electrification process. Thus, the level of electrification was not measured as a percentage of electrified households but in the extension of electricity lines to a particular area expressed by the percentage of electrified villages. However, since 2004, as a consequence of the new definition of village electrification adopted, many villages that were previously considered electrified fell by definition into the un-electrified category (Box 3.1).

Box 3.1: Village Electrification: Definition

The impetus on pumpset energization was reflected in the definition of village electrification accepted till October 1997:

> *A Village should be classified as electrified if electricity is being used within its revenue area for any purpose whatsoever".*

After October 1997

> *A village will be deemed to be electrified if the electricity is used in the inhabited locality, within the revenue boundary of the village for any purpose whatsoever*

However, according to this definition, if only one light bulb was kept lit for a nightly hour in the centre of a village or one irrigation pump was powered, the whole village was considered electrified. Realizing this inadequacy and the statistical bias that came with it, the government of India changed its definition for rural electrification in February 2004. declared as electrified, if :

- Basic infrastructure such as Distribution Transformer and Distribution lines are provided in the inhabited locality as well as the Dalit Basti hamlet where it exists;
- Electricity is provided to public places like Schools, Panchayat Office, Health Centers, Dispensaries, Community centers etc.
- The number of households electrified should be at least 10% of the total number of households in the village.

Source: Ministry of Power, Government of India <http://rggvy.gov.in>

There also exists wide disparity of access to electricity among urban and rural areas and also among various states. The latest round (64th) of NSS (National Sample Survey) Survey of the Government of India on household consumption expenditure has revealed that only 60.2 per cent of the rural households use electricity whereas the figure is much higher at 93.8 per cent for urban areas. As of July 2009, only 7 states had achieved cent percent village electrification, with five of them being smaller states. Though Andhra Pradesh and Tamil Nadu are considered to have achieved cent percent village electrification, the report from the field indicate that there are many hamlets and forest fringe villages in these states where any form of electricity – on grid or off grid are yet to reach. Some of the larger states such as Assam, Bihar, Jharkhand, Uttar Pradesh, Rajasthan and Orissa and the northeastern region are woefully behind in village electrification. Krishnaswamy (2010) argues that the main reason for poor electrification in these states is primarily poor governance. Sometimes structural factors are also employed for explaining disparities in the share of electrified villages between regions and states (see, e.g., Chaurey et al., 2004; Kemmler, 2007). Bhattacharya (2006) while comparing the variation in electricity consumption by expenditure class in rural and urban areas shares that "electricity consumption per capita increases with higher level of income; (b) for similar level of income, urban consumption is much higher than rural consumption and (c) low-income groups appear to use electricity mostly for lighting whereas very high level of electricity consumption in highest income groups of urban areas can only be achieved through significant appliance use".

In the power generation sector, although India has considerably improved its generating capacity over the years, with installed capacity has grown manifold from 1362 MW in 1947 to more than 151

073 MW as on 31 July 2009 (CEA 2010), the supply of electricity across the country currently lacks both quality and quantity with an extensive shortfall in supply, a poor record for outages, high levels of technical losses (because of overloading of transformers and conductors, for instance) and commercial losses of electricity (because of low metering efficiency, poor billing and collection, large-scale theft of power) and an overall need for extended and improved infrastructure. At the end of 2009, the peak supply of electricity was 96,785 million kWh while the demand was 109,809 million kWh (CEA 2010). The losses averaging, around 33.7% of total generation in 2006/07, are among the highest in the world, even comparable to some countries in sub- Saharan Africa (IEA, 2007).

Box 2: Rajiv Gandhi Grameen Vidyutikaran Yojana

The overall objective of RGGVY is creation of requisite rural electricity infrastructure in the country so as to provide access of electricity to all rural households. Specifically the objectives of RGVVY are:

- Electrification of about 1.15 lakh un-electrified villages and electricity connections to 2.34 crore BPL households by 2009
- Quality and reliable power supply at reasonable rates; and
- Minimum lifeline consumption of 1 kWh per household per day as a merit good by year
- 2012." (Ministry of Power, 2008)

In January 2008, the RGGVY was further extended into the 11th plan period (2007-2012) with the following new conditions for its better implementation:

- States are to ensure a minimum of 6 to 8 hours of power supply;
- States are to ensure quality and reliable power supply at reasonable rates;
- The deployment of franchisees is mandatory for the management of rural distribution;
- Introduction of the three-tier Quality Monitoring Mechanism to ensure quality of materials and implementation; and
- States are to notify their rural electrification plans to the Rural Electrification Corporation (REC) within six months.

The scope of the scheme covers provision of:

- Rural Electricity Distribution Backbone (REDB) with 33/11 KV (or 66/11 KV) sub-station of adequate capacity in blocks where these do not exist.
- Village Electrification Infrastructure (VEI) with provision of distribution transformer of appropriate capacity in villages/habitations.
- Decentralized Distributed Generation (DDG) Systems based on conventional & non conventional energy sources where grid supply is not feasible or cost-effective

Source: Ministry of Power, Government of India <http://rggvy.gov.in>

Over the years, through a number of programs (such as Kutir Jyoti, Minimum Needs Program, Accelerated Rural Electrification Program etc) attempted to enhance electricity access either as part of overall rural development or specifically targeting rural electrification. However, Bhattacharya (2006) argues that multiplicity of programs made funding for each of them inadequate and program implementation was also not properly coordinated or managed. Due to the financial burden that the program imposes, the electricity utilities often showed less interest in promoting these schemes actively and even the targets set by the utilities were not met. Further, the high cross subsidy for rural electricity supply also made the utilities lukewarm towards electricity supply to rural areas.

During the last decade, rural electrification has come back to political center stage, driven by the realization of its neglect over the years, with the central government creating the necessary enabling environment through the REST Mission in 2001, Electricity Act 2003[5], National Electrification Policy 2005[6] and Rural Electrification Policy 2006[7]. In 2001, the government declared the objective of 'power for all' by 2012 under the REST Mission and continued it with the launch of a large-scale electrification effort, the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) scheme in February 2005 to speed up rural electrification (Box 2). These policies have improved the financial and institutional status of the state utilities and have widened the state governments' scope of action in rural electrification efforts.

However, the overall achievement of the RGGVY against the targets set to be attained at end March 2012 is not very encouraging. At the end of the 10th plan period (31/03/2007), 38 525 villages were electrified and 672 000 BPL households had been provided with electric connections. Currently, less than half BPL households and about 67 percent of the villages had been electrified till May 2010. Further, Rejikumar (2005) argues from a range of perspectives as well as the pace of electrification, the timescale applied to the targets seems to be highly infeasible. To achieve the more modest target of village electrification in five years would require connecting 20,000 villages a year—based on the definition in Box 2 (Rejikumar, 2005). Though this pace was achieved during the 1980s, it was only according to the old, far more modest definition of village electrification. Dubash (2004) observes electrifying all households by 2012 would require connecting 10 million households a year, ten times the average historical pace of household electrification and argues that that 2020 is a more realistic date by which to achieve the government's targets (Dubash and Bradley 2005).

3.1.2 Technology

In India, the grid connection has been the most favored approach to rural electrification for the majority of rural households. In addition, renewables based off grid technologies such as solar PV, mini/micro hydro, biomass gasifiers, bio fuel powered generator, and small wind aero generators in hybrid mode have also been disseminated for areas which are either inaccessible for grid connectivity such as remote, hilly and forested villages or islands or hamlets having not recognized as villages as per national census records. Further, privately owned diesel generators also supply electricity to both un-electrified and electrified villages (that do not receive electricity in the evening hours due to deficit supply situation, usually referred to as *chotti bijli* in local parlance), especially to the rural markets and economically better off households in many states on a light point basis.

In case of centralized generation, thermal and hydro are the major sources. According to the Central Electricity Authority (CEA) of the Ministry of Power, on 30 April 2010, India's total installed capacity had reached 159 648.49 MW. Thermal power (coal, gas, and diesel) accounted for about 64 percent

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[5] The Electricity Act 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 endeavour to supply electricity to all areas including villages and hamlets. Section 5 further mandates the formulation of national policy on rural electrification focusing, especially, on management of local distribution networks through local institutions. The EA2003 in Section 4 also frees stand-alone generation and distribution networks from licensing requirements

[6] The National Electricity Policy 2005 aims at achieving a minimum consumption of one unit per household per day by year 2012.

7 The REP identifies that DG either through conventional or non-conventional methods as the probable option where grid extension is not feasible or not economical.

of total installed capacity with 102703.98 MW, large hydropower for 23 percent with 36863.40 MW, grid connected renewables for about 10% with 15521.11 MW and the rest nuclear power (CEA, 2010).

3.1.3 Off grid options

The off grid technologies have been used either through creation of local mini grid or disseminating household level technology such as Solar PV for lighting and other low consumption activities. It is reported that off-grid capacity in India is around 13,000 MW, of which 10,000 MW is diesel and 3,000 MW is renewable energy (Banerjee, 2006). The Ministry of New and Renewable Energy statistics indicate that about 5, 83,429 solar home systems and 7, 92,285 numbers of solar lanterns have been deployed till 31 March 2010. The off-grid power plants based on renewable energy are typically in the range of 1–500 kWp, and within dependent distribution network (mini grids). About 404.56 MWp of cumulative off grid/ distributed renewable power (including captive/CHP plants) exists in the country (MNRE 2010).

Most of the off-grid systems have been promoted under the Government of India schemes. Some of the common schemes are Remote Village Electrification Programme, Village Energy Security Programme and the Technology Demonstration Programme. In addition, NGOs have also been in the forefront to create electricity access through off grid options in rural areas with funding support from various bilateral and multilateral agencies.

The RVE program of MNRE was initiated in 2001 for covering un-electrified census villages and hamlets that are not likely to receive grid connectivity. By focusing on remote villages and hamlets of electrified census villages, the RVE aims at bringing the benefits of electricity to people living in the most backward and deprived regions of the country. Under the RVE programme, solar home systems, solar photovoltaic power plants, small hydropower plants, biomass gasification systems in conjunction with 100% producer gas engines or with dual-fuel engines using non-edible vegetable oils, non-edible vegetable oil-based engines, biogas engines, have been envisaged to be promoted. However, the vast majority, almost 95% of remote census villages taken up for electrification under the programme are provided with solar home systems or solar power plants. The number of villages electrified under RVE as on March 2010 is 5348 villages and 1408 hamlets.

The VESP was conceptualized as a step forward to the RVE program attempted to addresses the total energy need for cooking, electricity, and motive power in remote villages through use of the locally available biomass. Currently, VESP is in pilot phase with 81 sanctioned test projects in twelve states. Of these, thirty-three test projects have been commissioned and the other projects are in different states of implementation.

Though the Jawaharlal Nehru National Solar Mission, launched in November 2009, as part of the 2008 Indian National Action Plan on Climate Change (NAPCC) has not been established to foster rural electrification per se, it does mention the use of solar energy as a means for rural electrification. It is envisaged that by the end of the 13th Five-Year Plan, in 2022, the JNNSM should have led to the deployment of 20 million solar lighting systems in rural areas (MNRE 2010).

3.1.4 Organisation and financial viability of electrification

'Electricity' is in the concurrent list of the Indian constitution and hence both state as well as central government have jurisdiction over it. The state governments' jurisdiction includes generation, intra-state transmission, distribution and intra-state trading of electricity. The central government's purview includes policy formulation, generation plants catering to more than one state, inter-state transmission and inter-state trading of electricity. Further, with the reforms in the electricity sector, the Central Electricity Regulatory Commission (CERC) has been established to regulate central and interstate-level power-related activities, while the State Electricity Regulatory Commissions (SERCs) work on state-level licensing, state level electricity tariffs and competitive issues. In the rural electrification sector, the principal actor has traditionally been the state electricity utilities as they were responsible for the distribution of electricity in the states. However, in accordance with the Electricity Act of 2003, the role of the central government became larger, as both central and state governments took over joint responsibility for rural electrification.

As part of the RGGVY, state governments, through the designated agency for rural electrification, prepares rural electrification plans designed to assess in detail the means by which electricity is to be delivered – i.e. through grid extension or stand-alone systems – to the un-electrified households. These plans are then coordinated between state governments, state utilities and other agencies by REC, the nodal agency for the RGGVY. State governments are also required to ensure tying up generation from various sources and ensure supply electricity to the rural areas for atleast 8 hours, to deploy franchisees (input based or revenue franchisees) for electricity distribution and ensuring revenue sustainability and provide subsidy to their state utilities if electricity is provided at a tariff below what is set by the SERCs. At the central level, the Ministry of Power formulates rural electrification policies, sanctions projects, releases funds for project implementation through REC and also monitors the RGGVY's progress through a 3 tier quality monitoring framework.

It is reported that during the 10th Five Year Plan, 235 projects (in 234 districts) were sanctioned at an investment of INR 97.33 billion[8] (approximately USD 2.07 billion) covered the electrification of 68 763 un-electrified villages and provision of free electricity connections to 8.31 million BPL households (MoP, 2010a). As on 15 May 2010, a total of 573 projects had been sanctioned under the RGGVY, covering the electrification of 118499 villages, the intensive electrification of 354 967 already electrified villages and the free electricity connections of 24.65 million BPL households at an estimated cost of INR 263.54 billion (approximately USD 5.61 billion (MoP, 2010b). The total costs of schemes under RGGVY have recently been estimated to reach INR 280 billion (USD 595.94 billion) including a budgetary provision of INR 5.4 billion for village electrification through DDG. Under the RGGVY scheme, 90% of the project costs are funded by the Ministry of Power and the state governments funding the remaining 10% through either long-term loan from the REC or other financial institutions, or out of their own budgets. The household connection charges are borne by the individual households wishing to take connection. However, for un-electrified households below the poverty line, the household connections are also 100% financed by capital subsidies.

[8] On 24 May 2010 INR 1 was equal to USD 0.0212834 (source: http://www.xe.com). All values given in this chapter are converted at this rate.

In case of RVE and VESP, the total cost for the implementation of is estimated to amount to INR 17.750 billion (USD 377 million) over the 11th Five-Year Plan (MNRE 2006). Similarly to the RGGVY, subsidy from MNRE covers up to 90% of the cost of the project implementation, up to a predefined maximum of INR 18 000 (USD 383) per household (MNRE 2006). The balance 10% cost of projects can be financed through sources such as PMGY, MNP, RIDF, Ministry of Tribal Affairs, MPLAD and MLALAD and the corporate sector. In line with current practice under the RGGVY, the MNRE also offers a 100% capital subsidy for BPL household connections. Table 3 provides the cost norms defined under the RGGVY, RVE and VESP.

Table 2.4: Subsidies for rural electrification schemes in India

Scheme	Target under the scheme	Subsidy vehicle	Amount of Central Financial Assistance
RGGVY	100% household electricity access throughout India by 2012	Capital Subsidy	90% grant is provided by GoI 10% as loan by REC to the State Governments. Total subsidy disbursed Rs 25679.64 crore till 01.01.09
VESP	1000 villages to be electrified within the current 5-year plan	Capital subsidy	90% of the total project cost *Maximum CFA per household is Rs.20, 000*
		Operational subsidy for first 2 years	10% of the total project cost
RVE	Electrification of census villages and hamlets of electrified villages that are not likely to receive grid connectivity	Capital Subsidy subject to upper limits	90% of total costs of electricity generation systems Maximum Subsidy: Solar home systems: Rs 11250 SHP systems10-1000 KW: 68400 to 98100 per kW Biomass Gasifier: 43726 to 68040 per kW *Maximum CFA per household is Rs.18, 000*

The promotion of renewable energy in the country is the responsibility of the MNRE. Till 2008, MNRE (at the central level) and the various state renewable energy development agencies were the only government agencies carrying out off grid electrification. However, with launch of the DDG Programme under the RGGVY, Ministry of Power and REC has become the key actors for extending off grid electrification to the remote areas. In DDG projects of the RGGVY, the renewable energy technologies currently used are diesel generating sets powered by bio fuels (non-edible vegetable oils), diesel generating sets powered by producer gas generated through biomass gasification, solar photovoltaic, and small hydropower plants. The general rule of thumb supposes that the technology with the lowest marginal cost and which is considered the most appropriate and effective technological option for the area will be chosen. Further, all infrastructures must be grid-compatible in order to ensure that when a village is ultimately connected to the grid, prior investments are not lost. The scheme also encourages clustering of projects, and the villages are to be finalized in consultation with state utilities and MNRE. The villages and hamlets included under MNRE program shall be excluded under the DDG component of RGGVY. However, the villages where solar home systems were provided under MNRE program could be considered. Both hardware and soft costs (including DPR preparation and social engineering costs) shall be supported under the scheme with 90% as grant payment and 10% to be arranged by the project developer. Under the program, private developers are being planned to be involved and the subsidy to be released on annuitised basis based on performance of the system for five years.

3.1.5 Key lessons

Some of the lessons of the rural electrification programme in India are highlighted below:

- The government support is essential to the development of a successful rural electrification plan. The Indian government showed the required visionary approach and launched the "Power for All by 2012" initiative, with all the electricity laws that followed, paving the way for the effective implementation of rural electrification efforts in India. The laws and reform in the sector have shaped the institutional and legal framework, and with effective long-term planning, with centrally determined objectives and target years, is attempting to achieve in two plan periods, what the country could not achieve during the first nine plan periods. Thus without firm implementation policies and goals, enforced through legislation, the electrification process is difficult to achieve.
- The creation of franchisees for the management of local power distribution in rural settings is reported to have been introduced efficient billing and revenue collection, thereby ensure stable delivery of electricity. TERI studies (2008, 2009, 2010) indicate that franchisees are particularly effective in the management of electricity provision and recovery as they are in close contact with the targeted communities, and this has led to a stronger sense of ownership of the electrification process.
- The three tier quality monitoring mechanism set up under the RGGVY is reported to be ensuring proper implementation of projects thereby contributing to their efficiency and long-term sustainability. Similarly, the five year performance warranty and annual maintenance contracts for all installed systems under the RVE is securing proper and sustained energy supply services in areas covered under the programme.
- Involving rural communities in the decision-making process has substantially contributed to the effectiveness of the off grid electrification programme. The involvement of rural communities in the process, particularly their participation in decision-making committees, has added value to the planning process and given the communities a sense of ownership of the process.
- A study undertaken by TERI for the World Bank in 2008-09 to review the off grid and grid connected distributed generation projects came out with some interesting observations: Some of the lessons learnt from the study are provided below:
    - Grid connected projects have advantages in terms of reliability and quality of supply as the grid acts as a balancing sink or source and also supplements power in the local area during periods of plant shutdown. The productive load, irrigation pumps and agri- processing can be served on demand which otherwise are not being served in case of small off grid projects. There also seems to be a higher aspiration of community for grid connected power because of limited hours of supply from off-grid projects.
    - Off grid projects encounter lot of challenges for sustainability as most of these projects are set up in remote villages. These challenges lead to lower plant load factor of the system and low uptime leading to higher cost of generation, which don't match with the ability to pay by the users. The users become reluctant to pay when the plant don't function and the discontinuation in payment make it further difficult to run as the operators loose interest . This creates and vicious cycle in the system which is sometime difficult to overcome.

3.2 Experience from Nepal

3.2.1 Status

The Federal Democratic Republic of Nepal is a landlocked country in South Asia and the world's most recent nation to become a republic. Although electricity is an absolute necessity of development IEA statistics (2009) indicate that almost 16 million people in the country do not have access to electricity. Though Nepal has a huge potential of hydropower generation, its exploitation is very minimal. Various studies show that the feasible potential is about 83 GW, of which about 42 GW is considered as technically and economically viable. The actual generation capacity of hydropower is limited to only 0.64 GW [NEA 2008], due to the lack of necessary investment.

The national electrification rate in 2008 is 64.5 percent with very uneven regional and urban-rural distribution (IEA 2009). In urban areas, where less than 20% of the population live, the household electrification rate is 93.1 percent, the rural electrification rate is only 52.5 percent - being highest in the accessible lowland regions (the Terai) and lowest in the mountain communities. In terms of per capita electricity consumption, it is only 81 kWh, one of the lowest in the world (IEA 2009). However, the access to grids does not necessarily mean that there is a reliable electricity supply to meet the needs of the people. The electricity demand is more than the supply capacity and there are frequent blackouts. At present, the situation is further worsened due to the increase in energy demand (10.58 % growth recorded in 2008-09) and no additional power plants being commissioned. During the winter of 2008-09, the load shedding period was up to 16 hours a day [NEA 2009], the annual energy deficit more than 20 percent of the demand. However, the situation usually improves during rainy season when the run of river type power plants could generate their full capacity. Nepal need to devise ways to cope with this situation as the peak demand is expected to increase in near future. The peak power demand of the Integrated Nepal Power System recorded in 2009 was 812.5 MW and is expected to rise to 2052 MW by the year 2020. On the other hand the annual energy requirement is expected to increase from 3859 GWh to 9562.9 GWh during the same period (NEA 2009).

Though the electrification rate can still be considered as low, the country has made significant progress since the beginning of this decade to extend electrification to the rural areas. The electrification rate was on 40 percent in 2002 at the start of the 10th Five Year Plan. Due to concerted efforts by the Government of Nepal, the overall electrification rate increased to 55 percent at the end of the Plan period (ESAP 2006). An interesting feature is that almost 30% of the access to electricity services in the rural areas is through off grid route (REP 2008). The use of alternative energy sources for rural electrification happened because of the early realization by the Government of Nepal that the central electricity grid may not reach most rural populations. Thus, various renewable energy programs were set up with the common objectives of strengthening the rural economic system, improving the quality of rural life by supplying energy, increasing the opportunity of employment and contributing to environmental sustainability.

The hydro power policy 2001 is by far the most relevant policy in existence for the rural electrification sector in Nepal (NDF 2004). It emphasized the tying up of electrification with economic activities and encouraged establishing small and mini hydropower projects at local levels. Under the policy, communities, cooperative institutions, local bodies and the private sector were encouraged in the generation, transmission and distribution of hydropower. The electrification was encouraged in the rural areas directly affected by the electricity generation projects. The energy royalty on the electric energy consumed was exempted for the first fifteen years from the date of commercial operation of the projects and one percent of the royalty received by the government from hydroelectric projects was provided to those village development committees that are directly affected by the structures of such projects. The government provided grants to the domestic private sector to generate and distribute electricity by building projects of up to 100 kW capacity at the rural level.

Zahnd and Kimber (2009) observes that about 10 million people, out of Nepal's estimated population of 28.5 million (at the end of 2006), live in such remote locations that neither a road nor the national electricity grid will reach them for decades to come. The Water Resources Strategy also recognized this fact way back in 2002 that providing electricity to rural populations is a major challenge in Nepal due to the scattered nature of the population in remote mountainous areas. A combination of grid extension, isolated generation (small and micro hydro) and reliance on alternative approaches was therefore envisaged. The strategy also emphasized active participation of rural communities and private entrepreneurs. It aimed at electrifying 43%, 60%, and 80% of the nation's households respectively by the end of years 2007, 2017 and 2027 (NDF 2004). An investment requirement to the tune of INR 95 billion has been estimated to meet the demands of rural electrification by grid connection or isolated energy systems over the 25-year period of the strategy. Since much of the rural electrification investments will have to be subsidized, it is recognized that the targets in rural electrification can only be met with donor support (NDF 2004).

3.2.2 Technology choice

Nepal has used both conventional and renewable energies for electrification of its rural areas. The sector can be basically divided into two sub-sectors based on the technology, viz. the on- grid and the isolated (off-grid). While grid-based electrification has been carried out through the extension of the national grid, the isolated (local) grids are mostly supplied by mini and micro hydro plants. During 2008-09, the NEA (2009) statistics indicate that the electricity supply for the grid connected areas was mostly from medium and large hydro power, which constitutes 88.33 percent of the total installed capacity including 29.57 percent contribution from IPP (Independent Power Producers). Besides hydropower, there is also thermal generation capacity of about 53 MW, which is not in regular operation though (NEA 2009). Additionally, Nepal also mport power from India to meet its demand.

With the country receiving an ample amount of solar radiation (average of 3.6–6.2 kW h/m2/day, for about 300 days a year), Nepal started use of solar PV for domestic electrification in 1991–1992 (Bhandari and Stadler, 2009). Mostly solar home systems (capacity range between 10Wp and 120Wp) and small solar home systems (locally called solar tuki, capacity ranges between 2.5Wp and 10Wp) systems have been disseminated in the country to provide electricity access the residential sector in the remote villages under various donor supported programs.

3.2.3 Off-grid options

Nepal has a long experience with community based mini-micro hydro power for electrification of the rural areas. The Agricultural Development Bank, rural communities and entrepreneurs, and a number of national and international NGOs have supported micro-hydro projects in Nepal. The development of the sector gained momentum with the establishment of the AEPC (Alternate Energy Promotion Centre) in 1999/2000. Under AEPC, donor supported renewable energy programmes namely Energy Sector Assistance Programme (ESAP) and Rural Energy Development Programme (REDP) assisted in a substantial way to promote renewable based off grid energy supply in Nepal. 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 rural electrification rate from 30 percent in year 2001 to 36 percent in 2004/05 came from off grid solutions in the form of isolated micro hydro power mini grids and stand alone solar home systems (REP 2008). The REDP during its first two phases assisted in installation of 150 new micro hydro systems and 2000 SHS, serving around 30,000 new households (WIN 2006).

The ESAP phase 1 has also been instrumental in supporting AEPC to promote micro-hydro schemes up to 100 kW. Besides loan financing available through commercial banks there was also a provision of financial subsidy for these projects (NDF 2004). Further, a total of 69,411 solar home systems were installed in the country, bettering the programme target of 40,000 systems under ESAP Phase 1 (ESAP 2010). The programme was also successful in establishing guidelines for administering solar energy subsidies and put in place quality assurance and monitoring systems for solar energy projects. Currently, it is reported that 26 pre qualified solar PV dealers operate in the country who sell their systems through retailers trained in the basics of system maintenance and after sales service.

Bhandari and Stadler (2009) share that about 115,000 SHSs had been installed throughout the country (under various government programme and private sales) with the total installed capacity of 3.5MW (as on December 2007). The annual growth rate of SHS installations was an increasing trend until 2002. Thereafter it fluctuated and started to decline due to discontinuation of government subsidy (due to suspension of donor support citing then political situation of the country). After the resumption of subsidy as per Subsidy for Renewable (Rural) Energy 2006, the number of installation increased substantially in 2007, and the trend is expected to continue in coming years as well (Bhandari and Stadler 2009). Almost 83 percent of the installed SHS are smaller than 40Wp capacity indicating that these are mainly used for lighting.

The current phase of ESAP aims to provide energy solutions to more than 1 million households in Nepal through its various programme components namely biomass energy support programme, solar energy support programme and mini-grid support programme (ESAP 2010). The programme is supporting creation of the mini grid, to be fed by hydro power with capacity 5 kW to 1 MW, as pre-grid electrification option. When and if the national grid is extended to these areas, the mini grid can be directly connected to the national grid. (ESAP 2006). ESAP Phase 2 aims to generate the equivalent of 20 MW of electricity to benefit 150,000 rural households served through mini grids across the country (ESAP 2006). Further, SHS are also being promoted to power lights and operate small appliances under ESAP 2. In addition, the programme also plan to support new solutions such as small solar powered lamps (solar tuki) and target to cover 150,000 households with SHS and about 250,000 households by solar tuki systems (ESAP 2010).

3.2.4 Organization and financial viability of rural electrification

Nepal's power sector has been dominated by Nepal Electricity Authority (NEA), a Government of Nepal owned utility, established in August, 1985 under NEA Act 1984 by amalgamating the

Electricity Department, incumbent Electricity Development Boards and Nepal Electricity Corporation (NEC). The responsibility of rural electrification through grid extension rests NEA operating under the Ministry of Water Resources. NEA is responsible for generation, transmission/dispatch and distribution of electricity and undertakes each of these activities under separate business divisions. Nepal being a least developing country, most of the rural electrification programme through grid extension by NEA was funded by bilateral and multilateral funding. The Japanese Government is provided grant of NRs 135 million during 2006-09 to extend electricity to around 5000 households in 17 VDCs. The Danish government provided support of DKK 85 million to the Kailali Kanchanpur Rural Electrification Project, which assisted in extending electricity to 70,000 consumers of 35 VDCs. Similarly, the International Development Association of the World Bank is funding about NRs 859 million to increase the coverage of electricity services to rural areas, benefiting 170 625 people and ADB is providing about USD 37.3 million to cover 277 VDCs. Both these projects are nearing their completion (NEA 2009).

In line with the Community Rural Electrification Rules 2003 and to bring in the operational efficiency (NEA has revenue rate of Rs 6.71/kWh against cost of service of Rs 9.05/kwh) in the distribution sector NEA also adopted a new strategy whereby it sell power in bulk to rural electricity consumer groups after putting up the distribution infrastructure. The rules envisage three community-based rural electrification models: community based rural electrification model for un-electrified areas, community based operation and maintenance model for existing networks and community based generation model for communities located far from the nearest national grid. Under this program, 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. It is reported that more than 230 cooperatives in various parts of the country have entered into agreement with NEA for electricity distribution. A National Association of Community Electricity Users of Nepal (NACEUN) was also established in 2005 to ensure the effective role of communities in rural electrification through users' advocacy, institutional capacity building and national network building. Currently, 109,000 rural households have been electrified through community based rural electrification and the number will increase to 200,000 as pipeline projects are completed. A total of US$ 6.89 million have been invested in community rural electrification as community contribution (NACEUN 2009).

Yadoo and Cruickshank (2010) shares that the community based approach to decentralized electricity distribution and management has been highly successful. Collectively, users in the South Lalitpur area used to spend US$ 455 per month to receive electricity from a diesel generator but now pay their local cooperative US$ 94 per month for the energy they use from the national grid (generated from hydropower). Self-management has reportedly 'demystified electricity' to cooperatives and community user groups and enabled discussions of the distinction between technical losses and pilferage (Pandey, 2005). On average, system losses were reduced from around 25% under NEA management to around 15% within one year of community management (mainly achieved through theft reduction). Similarly, 'unpaid bills from as long as five years were settled once the community took over management' and the NEA was 'paid for the electricity promptly each month based on the bulk sales meter readings' (Pandey, 2005). The CBOs' costs for meter reading and system maintenance are also lower than under the NEA since the linesmen live locally and can 'respond immediately to service disruptions'. On average, the time required to acquire a household meter 'was reduced to one day and the time for a three-phase meter for pumps and industries was also substantially reduced' (Pandey, 2005)

In the off grid sector AEPC, under the administrative control of the Ministry of Science, Technology and Environment, is the apex body for coordinating national level activities and programmes on renewable energy. Several IPPs and NGOs are also engaged in rural electrification with assistance from various donor agencies. The AEPC implements schemes through its various programs such as ESAP, REDP and REP.

ESAP was set up in 1999 with a view to establish a national framework in the rural/ renewable energy sector in Nepal within a 20 year timeframe. The original DANIDA fund made available for ESAP Phase 1 was 154 million DKK. However, during the course of implementation additional fund was provided by DANIDA, Norway and the Government of Nepal to complete the various activities. The ESAP 2 was launched in January 2007, primarily supported by DANIDA and Norway, after successful completion of its 1st phase. While the Danish and Norwegian government have pledged DKK 150,000,000 and NOK 125,000,000 for the ESAP 2, the Government of Nepal has committed Nepali Rupee equivalent of DKK 44 million. Additionally, the Government of Nepal and has also signed a MoU with KfW to avail funding worth Euro 8.5 million to support the solar PV installation under the programme. A Rural Energy Fund (REF) has been established, replacing the financing mechanism created for providing subsidies to poor households under Phase I, to manage the ESAP 2 subsidy fund. The REF will work with local financial institutions to promote access to private loan financing for renewable rural energy solutions (ESAP 2010).

In addition to the ESAP, the REDP and REP are two other programmes promoting renewable energy in the country including off grid electrification through renewable energy. . The REDP, initiated in 1996, with support from UNDP has now entered into its 3rd phase from 1 September 2007 upon the successful completion of its earlier two phases. By linking rural electrification with rural economics, the program has demonstrated an ability to ultimately influence rural livelihoods positively. In its third phase, among others, the REDP is supporting the Government of Nepal to implement the Rural Energy Policy 2006 in all 75 districts.

The REP, started in 2008, is a joint effort of the Government of Nepal and Commission of European Communities (EC) working for the promotion of institutional photovoltaic systems (schools, hospitals, safe water provision, communications, etc) in remote areas of 23 districts in Nepal. The energy service is provided on a 'fee for service' basis to the end-users through community based and owned energy service providers. These Community Energy Service Providers (CESPs) will be one of the key players in providing decentralized energy service of Nepal. The CESP provides electricity services to the end users and operates and maintains the stand-alone PV systems against service fee. The REP will cover the entire cost required for the installation of the solar energy systems, and the end use appliances and necessary infrastructure will be provided by the communities. During the project period 165 CESPs will be created, each serving on average a local population of about 500 households. Out of the total budget of Euro 15.675 million, almost 2/3rd will be used for financing PV related investments and the rest on program administration and capacity building activities (REP 2008).

3.2.4 Key Lessons

The experience from Nepal shows that the country has used both hydro power based conventional grid extension as well community based decentralised model for on-grid and off grid electrification. The community approach to grid electricity distribution has been particularly successful where the cooperative has also worked at improving the productive uses of electricity (to increase daytime demand) and the capacity of its members to pay for electrical appliances and invest in new businesses (Yadoo and Cruickshank, 2010). Though local participation can lead to greater equity and empowerment if appropriate checks and balances are put in place, community-based delivery may be vulnerable to cooption and coercion by local power brokers (Cornwall and Jewkes, 1995). Therefore, strong and effective regulation is necessary to prevent the exacerbation of existing power structures and income, ethnic, age or gender divide. An appropriate institutional environment must be created, be this a government regulatory body or a decentralized membership based self-regulating body, such as NACEUN in Nepal to create a highly favourable delivery mechanism for rural electrification in developing countries.

Because of successful PV promotional programmes from the government as well as from the private sector, the PV expansion has been expected to increase in the future, at least until the government continues providing subsidy for the PV systems. However, Bhandari and Stadler (2009) observe that subsidy plans should not be targeted with an open end time frame. Instead, if subsidy money could be invested for creation of productive micro enterprises, community would ultimately have access to the invested money, and they can invest it to buy a standalone energy generator (e.g. solar home systems) or take electricity connection. In areas, where people are not able to contribute any money (on top of subsidy) for stand alone system, they could be provided energy access through introduction of a community operated battery charging station. The most important lesson that emerges from ESAP solar PV programme is that a market-driven approach depends on the timely delivery of quality-assured services by the private sector, hence capacity building across the sector should be given appropriate priority. A local support structure is also crucial for the long-term sustainability of a programme for prompt and effective delivery of energy services to rural communities. Appropriate credit is as equally as important as subsidy for success of a programme (ESAP 2010). The assessment of REDP (WIN 2006) indicate that the programme's introduction, adoption, operation and finally internalization of modern appropriate technologies played an important role in creating various employment opportunities for rural population and community development. A big number of agro processing units such as water-power driven, or electricity driven grinders, hullers and oil expellers have been installed in local communities after REDP intervention. The manual agro processing which was done by an average of 40% of households in villages reduced to about 20% with average annual income of the mill owners being US$ 342/-, after meeting all expenses, which is more than the national average rural income. At the household level, the average monthly demand of kerosene of a household decreased from 3 liters to 1.4 liters after initiation of the REDP electrification scheme. Monthly demand of batteries per household also decreased. The Nepal experience indicates that the mini-grid solutions based on micro-hydropower and standalone solar home systems installed under ESAP and RDEP has proven its validity as a viable electrification option for village communities not supposed to be reached by the country-wide electricity network within the period of 5 to 10 years.

3.3 Experience from Sri Lanka

3.3 1 Status

Comprising a total terrain of 65,525 km², Sri Lanka is home to a population of about 20 million. Approximately 76% of the population lives in rural areas. The country's energy sources consist primarily of biomass, hydro-electricity and petroleum. Sri Lanka stands out among the South Asian countries for its high rate of household electrification. During the ten year period 1986 to 2005, the national electrification rate improved significantly from 10.9 percent to 76.7 percent (ADB 2007). Currently, almost 75% of the rural households are connected to the electricity grid (IEA 2009) while another 2% of the households are provided with basic electricity connection through the off grid option. However, disparities in access to electrification also exists with the relatively economically backward districts recording less than 50% electrification and the estate plantation sector having an electrification rate of about 50% (ADB 2007). ADB (2007) observes that deterrents to access includes eligibility criteria used to select electrification projects, politicization of the decision making process and also poor affordability of the potential consumers to pay the connection charges. To improve the electricity rate, the 2006 National Energy Policy of Sri Lanka envisaged extending electricity to 98% of the households by 2016 through grid and off grid energy systems (Ferdinando and Gunawardana, 2008).

In the electricity generation sector, Sri Lanka has been a front runner in the promotion of hydro power since the early 1900s. However, the growth also resulted in several constraints namely, grid substations reaching their full capacity and hydro power reaching the permissible levels of non-dispatchable generation in the system. Further, most of the economically viable hydropower potential was already developed. Thus, with growing demand (approximately @ 8% annually) for electricity and no additional hydro capacity, the share of energy from hydropower in the power generation mix declined from 99.7% to 39.4% during the period 1986 to 2005 (ADB 2007). One tenth of the hydroelectricity was provided by small (less than 10 MW) power plants built and operated by the private sector, under the standardised power purchase agreements. Infact, the country intends to reach a goal of providing 10% of the grid electricity supply from non-conventional sources of energy, through a mix of small hydro, wind, biomass and waste-fired power plants, by 2015 and 6 % of the households through off-grid electricity systems by end 2010.

3.3.2 Technology options

The mode of grid connected electricity generation in Sri Lanka, operated by the CEB, is largely hydro and thermal (diesel, furnace oil and residual oil). In addition, the Independent Power Producers (IPPs) operate oil-fired thermal (diesel & furnace oil) plants to feed electricity into the national grid. The total installed power generation capacity, at the end of 2008, amounted to 2,645MW including the capacity of IPPs of 887 MW (CEB 2009). Out of the total power fed into the grid, about 150 MW is also from the non conventional energy, mostly private owned micro hydro plants. Though the country was in the forefront to promote clean technology in the form of hydro resources, however to meet the additional demand, CEB is now providing importance to coal based generation. By 2021, the CEB is planning to have almost 86% of the installed capacity (7630 MW) from coal based generation.

In the off grid sector, small hydro power has been the preferred option with the first off grid village hydro scheme commissioned in 1992. Since then the village hydro schemes became very popular, especially in the Southern and Sabaragamuwa provinces, to provide power to rural households far from grid electricity. These village hydro schemes were built, owned and operated by rural communities through electric co-operative societies that are set up for the purpose. Apart from the micro hydro, solar photovoltaic home systems have also been used to a large extend to provide access to electricity. Infact, Sri Lanka has one of the most successful solar home system programme, promoted through innovative financing schemes such as ESD (Energy Services Delivery) and RERED (Renewable Energy for Rural Economic Development) project with private sector involvement.

3.3.3 Off grid options

The CEB started popularizing solar PV for rural domestic lighting in the early 1980s by providing solar PV systems at a subsidized rate to rural consumers. Thereafter, the first major attempt for the off grid electrification was through the ESD project, introduced in 1997. The ESD project provided the basis for a market-based approach 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 photovoltaic electrification of rural homes. Under this project, the private sector initiative was instrumental in reaching rural households on a large scale for supplying solar home systems of modular sizes, mainly 24 Wp and 50 Wp (Gunaratne, 1994). The ESD credit programme resulted in a dramatic increase in the development of grid-connected and off-grid renewable energy projects, prepared and implemented by the private sector and village communities. The project catalyzed the solar market by installing 20,953 solar home systems, with a total capacity of 985 kW, against a target of 15,000 systems; 31 MW of mini hydro capacity installed through 15 projects against a target of 21 MW; and 350 kW of capacity through 35 village hydro schemes serving 1,732 beneficiary households against a target of 250 kW through 20 schemes (RERED, 2010)

After the successful implementation of the ESD project, the Government of Sri Lanka, with the assistance of the World Bank and the Global Environment Facility (GEF) established the RERED Project. This project, implementation of which started in the year 2002 aimed provide off-grid electricity services to invigorate the rural economy, empower the poor and improve their standard living. RERED also aimed at setting up of grid-connected investment projects to encourage competition in the power sector, provide capacity addition and diversity, and achieve greater sector efficiency and transparency. The RERED and its predecessor ESD project, through off grid mode, fully complemented the grid-based extension undertaken by the Ceylon Electricity Board. Over the past decade, the project has electrified more than 130,000 rural households through solar home systems and independent mini grids and 1,000 off-grid electricity connections to small and medium enterprises and public institutions thereby helping thousands of rural households to switch from poor-quality kerosene lamps to more efficient electric lighting (RERED 2010).

The rapid growth in the SHS market was mainly due to the financial incentives provided both by the World Bank through the ESD Project (and its successor RERED Project) and by some provincial governments. The aggressive marketing initiatives of the several competitors in the SHS market have also strengthened the efforts towards expansion of the SHS market. This rapid growth in SHS sales in the country also gave rise to many concerns such as the financial burden on the rural people due to the high cost of SHSs (about US$ 250 for a 24 Wp system), the possibility of the customers not being allowed to take informed decisions because of aggressive marketing initiatives and the likelihood of the SHS dealers not providing proper after-sales service. Wijayatunga P D C and Attalage R A (2005) investigating the social, economic and environmental impact of SHSs in rural Sri Lanka found that a little over 15 % of the households' income has been spent on the SHS repayment, whereas the expenditure on kerosene and battery-charging before SHS installation was only around 10 % of their income. However, the quality of life, in terms of activities such as longer study hours of children, longer TV watching hours for the family and lessening the risk of fatal kerosene lamp accidents, has improved with the introduction of SHSs. The study concluded that the large-scale penetration of SHSs in Sri Lanka has helped rural communities both in terms of improved socio-economic conditions and reduced adverse environmental impacts, contrary to the belief that the financial burden of such systems imposed on the families outweighs the benefits.

3.3 4 Organization and financial viability of rural electrification

CEB was created by an act of Parliament in 1969 as a state-owned, vertically integrated utility. It is under the jurisdiction of the Ministry of Power and Energy, and is responsible for power generation, power transmission, and about 86% of electricity sales in Sri Lanka, serving 89% of all customers (ADB 2003). In addition, the Lanka Electricity Company (Pvt) Ltd (LECO), a subsidiary of the CEB also distributes electricity in some of the urban coastal areas. ADB is supporting the Sri Lanka government in a big way to achieve its electrification goals. Similar to other developing countries, connection prices were a barrier to electrification in many villages within the distribution areas of the national grid. To address this issue, ADB designed a $1.5 million grant from the Japan Fund for Poverty Reduction titled "Power Fund for the Poor" (ADB 2009). This was a revolving fund created to support grid connections for poor households through micro-lending. 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. From 2004 to 2009, this revolving fund, handled by local Sri Lankan microfinance institutions, brought electricity to nearly 15,000 households. Building on the success, ADB approved in April 2009 an assistance package of $164 million for a Clean Energy and Access Improvement Project, which includes a $3.5 million loan for another revolving microfinance fund. The new credit program aims to bring at least 15,000 households into the grid by 2010 and a further 60,000 by 2016 to support the government's goal to raise countrywide electricity coverage to 88% in 2016. Most of the work of promoting the program and handling the loans is undertaken by Sarvodaya Economic Enterprise Development Services (SEEDS), a nonprofit grassroots organization. SEEDS disbursed 7,000 loans, assisted by a remarkable loan recovery rate of 97%, provided a further 7,000 second generation loans. Cumulatively, between 2004 and February 2009, SEEDS disbursed 14,639 loans totaling US$ 2 million.

In the renewable energy sector, currently a dedicated agency for renewable energy development and energy efficiency by the name of Sri Lanka Sustainable Energy Authority (SLSEA) is responsible for promotion of renewables (including off grid electrification of villages). Previously, the ESD project was implemented during 1997-2002 by the Government of Sri Lanka. The US$45 million ESD project was assisted by a US$19.7m line of credit from the International Development Association (IDA) of the World Bank and a US$3.8m grant from the Global Environment Facility (GEF).The ESD Project comprised three components - a credit programme, a pilot grid-connected wind farm of 3MW and a capacity building component for the Ceylon Electricity Board (CEB). The Administrative Unit (AU) set up within DFCC Bank was the executing agency for the ESD Credit Programme component and the CEB was the executing agency for the other two components. The loans for individual investments or subprojects were disbursed through participating credit institutions, namely DFCC Bank, National Development Bank (NDB), Hatton National Bank (HNB), Sampath Bank, Commercial Bank and Sarvodaya Economic Enterprises Development Services (SEEDS). Building on the success of ESD project, the RERED Project was initiated with US$75 million line of credit from the International Development Association (IDA) of the World Bank and a US$8 million grant from the GEF Loans for individual investments (sub-projects) were disbursed through PCIs (participating credit institutions), who make their independence credit assessments while ensuring that sub-projects are financially viable, environmentally sound, meet required engineering standards and are economically justifiable.

Since 1997, the off-grid component of the credit programs has received about US$38 million in IDA/GEF support, including some US$3 million in technical assistance (ESMAP 2008). The Administrative Unit (AU) of the Development Finance Corporation of Ceylon Bank manages the credit program. The AU monitors suppliers' compliance with global technical specifications and service standards for SHSs and solar lanterns—thus providing the basis for consumer education and protection - and investigates unresolved consumer complaints. The AU also approves loans contingent on evidence of installation (for SHS) or design approval by a chartered engineer (for village hydropower systems). Beyond its quality assurance role, the AU also facilitates stakeholder discussions to solve implementation problems. The project also offers output-based, co-financed grants, which are disbursed only after pre-defined results are achieved; such grants are transparent and do not cover operation and maintenance costs. To encourage development of a commercial off-grid market, the grants are offered on a declining scale. To ensure technical quality, they are passed on to suppliers rather than final beneficiaries. In the case of SHS grants, the solar company decides what proportion should be used as a price break for customers and what should be spent on market development activities, such as building infrastructure for operation and maintenance.

To develop the full potential of renewable energy, the purchase of electricity to the National Grid under Small Power Purchase Agreement (SPPA) was also announced by the Sri Lankan government as part of the Energy Policy[9]. The tariff and SPPA have been standardized and non negotiable. The tariff is based on cost based and technology specific approach and the developer have the option of selecting either a three tier tariff or a flat tariff. The SPPA are applicable to projects with a rated generating capacity of upto 10 MW and is valid for a period of 20 years. The three tier tariff consist of a fixed rate, operational and maintenance rate and a fuel rate for different types of technologies while the flat tariff is fixed for different technologies and no escalation is allowed over the entire 20 year period. The selection of between options three tier and flat tariff is at the discretion of the developer at the time of signing of the SPPA. As the cost of renewable energy power may be high initially, the government has also created the Sri Lanka Sustainable Energy Fund which provides the viability gap funding to the project developer meet the difference of the cost based tariff and payment by CEB.

3.3.5 Key lessons

To address the challenge of identifying the right beneficiary and assess their ability to repay loans to minimize credit losses, the 'Power Fund for the Poor' project of ADB, the targeted households, in

[9] Source: http://www.energy.gov.lk/pdf/small_power_purchase_eng.pdf

villages connected to the grid for at least a year, who are ready to invest at least 20% of the total cost for connection materials such as wiring.

On the other hand, the success of the off grid projects in Sri Lanka can be attributed, to flexible project design responsive to the needs of implementing organizations, suppliers, and beneficiaries. The work has been further aided by improved access to capital, innovative easy payment schemes introduced by micro-financing institutions and output focused approach adopted by the private companies and nongovernmental organizations. The projects had effective, after-sales maintenance networks in place, particularly for systems financed by the micro-finance institutions, which were trained in basic technical-repair skills. Further strong outreach networks enabled the micro finance institutions to reach the rural customers via effective service delivery channels.

4.0 Experience from other South Asian countries

4.1 Bhutan

4.1.1 Status

Bhutan is a landlocked country situated in the fragile eastern Himalayas. The country got its first electricity in 1964 with commissioning of diesel generator sets at two southern Dzongkhags in Pheuntsholing and Samtse (DoE 2010). This was followed by the development of hydropower, and the first hydropower plant with a capacity of 360kW was commissioned in 1967 to supply electricity to Thimphu. The power sector got a boost in 1988 when Chukha hydropower plant with a capacity of 336 MW was commissioned with support from India. The commissioning of this plant saw Bhutan initiate export of electricity to India, earnings of which started funding its infrastructure requirement such as roads, hospitals, and school, besides providing impetus to industrial development.

In line with the trend in other South Asian countries, there is huge difference in electrification status of urban and rural households in the country. While 96.4% of the urban households are electrified, the figure is only 40% in case of rural areas (DoE 2010). The low level of rural electrification can be attributed to mountainous terrain, scattered pattern of settlement, huge capital investment required to extend the grid lines to such remote areas, and low tariff and demand in the villages. Since a substantial part of the country's revenue comes from electricity export, the Royal Government of Bhutan off late, started providing due impetus to intensify the rate of rural electrification and targets to achieve cent percent electrification by the end of the country's tenth five year plan i.e. 2013. This is envisaged to be done through grid extension, development of mini hydel and individual solar home systems. Another key objective of rural electrification is also to reduce fuelwood consumption in the rural areas for cooking.

Electricity constitutes around 15.7 percent of the total energy supply in the country (DoE 2010). Of the total electricity generated in the country, only 29 percent is consumed in the country and the balance 71percent is exported. The electricity export contributes almost 12 % of GDP of the country [NSB, 2007]. Though the country does not have a strong industrial base, still industries are the largest consumer of electricity in the country (DoE 2007). In 2005, the sector consumed 65 percent of the total consumption with the balance being consumed by the institutional and commercial sector (18.76 % of the total consumption) and residential sector (14.5 % of total consumption). The maximum electricity consumption in rural areas is due to cooking, space heating, and water heating applications, which is an interesting aspect in the country. This is also corroborated by the fact that 78.6 percent of the rural household indicated during the country census in 2005 that they use electricity as the main fuel for lighting as well as cooking (Census 2005). This shows that one of the objectives of rural electrification in the country – to reduce fuelwood consumption – is being achieved successfully. With Bhutan having the distinction of one of the highest fuelwood consumption for energy in the rural areas (Norbu U P and Giri S 2004, Palit and Garud 2010) studies have also indicated that the consumption reduces by about 23%-35% in electrified households in rural areas as people tend to shift to electric cookers (Palit and Garud 2010, ADC 2005). Inspite of the hilly terrain, the T&D loss at 15% is relatively low in the country as compared to other South Asian countries (DoE 2010).

4.1.2 Technology options

The power sector in Bhutan is synonymous with hydropower, with more than 99% of electricity being generated by this route, especially large hydropower. It is estimated that Bhutan has a total hydropower potential of 30 GW of which 16-23 GW is techno-economically feasible for exploitation (PCS 2002, ADC 2005). By the end of 2007, 1485 MW of hydropower had been installed and another 1095 MW was under implementation (DoE 2007). Although solar, wind and micro-hydro are also attractive options, Bhutan has not been able to fully utilise the sources available due to constraints like high installation costs per kW and lack of back-up service and maintenance in the country (Lhendup 2008).

4.1.3 Off-grid solutions

Bhutan experimented with off-grid solutions for remote rural areas in the early 1980s. However, the off grid route was not mainstreamed and the schemes remained at pilot stages only, resulting in very slow progress. Currently, there are about 16 off grid micro hydro plants with aggregate capacity of 1318 kW (DoE 2007). Most of these plants were commissioned in 1986/87. In addition to these, BPC (Bhutan Power Corporation) also operates some off grid diesel generation sets in the central and eastern Dzongkhags. In the solar PV sector, there are 4341 solar home systems installed in the country (DoE 2007) by the end of 2006. In addition, about 4.5 MWp of SPV power plans for telecom operations also exists, majority of which were installed with support from JICA. However, the actual numbers of systems functional currently are unknown.

In 2003, a solar energy project was initiated in Bhutan by the Solar Electric Light Fund (SELF) with support from the Royal Government of Bhutan (RGOB), the Bhutanese Royal Society for the Protection of Nature, the Tshungmed Solar Inc., the Bhutan Development Finance Corporation, and the Bhutan Trust Fund (SELF 2003). The project aimed to bring small solar home systems to about 200 families in the Phobjikha Valley. This project had two critical components for ensuring long-term success. Firstly, solar home systems were not donated free of charge to the families, instead, SELF provided seed capital and a mechanism for families to secure micro loans for purchase the systems. Secondly, SELF also trained local men and women in solar technology, installation, and maintenance, thereby ensuring that the project could be maintained over the longer term after the project implementation period.

Lhendup (2008) observed that it is unlikely that extension of the national grid into the interior parts of rural Bhutan will be financially viable. Therefore, the alternate option for Bhutan is to opt for renewable distributed generation systems such as solar battery-charging stations, solar home lighting systems, small wind turbines and micro/pico hydropower plants. These systems could be one step forward in achieving electricity for all in Bhutan by 2017. If the national grid is extended into the rural areas of Bhutan in the future, the distributed generation systems could also be embedded within the grid network

4.1.4 Organisation and financial viability of electrification

The Department of Energy (DoE) is the government agency responsible for planning and coordinating rural electrification in the country. DoE also plays a small role in rural electrification implementation, overseeing the implementation of off-grid renewable energy systems (e.g., solar PV systems, micro and small hydropower stations with small grids). BPC is the main implementer of rural electrification through the expansion of the national grid. Yeshi (2007) observes that the BPC targets to electrify 25,000 households in the tenth five-year plan.

The funding for the rural electrification was provided by the state and various donor agencies. As discussed in the previous section, rural electrification in Bhutan in the past focused on connecting rural areas to the national grid extensively, and very few alternatives were investigated. This has constrained the progress of rural electrification, with difficulty in extending the grid to scattered settlement in rugged terrain and with limited capital available for grid electrification. ADB estimated the average cost of rural electrification in Bhutan at US$ 1425 per household for households located in relatively accessible areas. The cost could be much higher for more remote settlements. Accordingly, the rural electrification master plan completed in November 2005 attempted to identify the villages where the provision of electricity via grid extension is technically and economically feasible, and the villages that are good candidates for renewable energy such as community-based micro hydropower and solar photovoltaic (PV) systems.

4.1.5 Key lessons

Some of the key lessons from Bhutan are:

- *High dependence on hydro power*: At the moment, the country's power sector is fully dependent on medium and large hydropower. This is a major economic risk because of high dependence on one-country-one-commodity framework. Further, this dependence of hydro is also resulting in poor electricity generation during the lean season compared to peak season (only about 274 MW against 1500 MW). If anything happens to the hydrological system, the country's power needs and economy can be badly shaken. This call for diversifying the energy supply sources, especially tapping the renewable energy sources, to enhance the country's energy security.
- *Limited growth despite huge potential*: Bhutan offers huge potential for off-grid solutions especially solar and micro hydro power because of its geographical location and its configuration (hilly and high altitude with high insolation). Although the country has experimented with micro hydro and PV technology, the country did not use these technologies for its rural electrification programme. With Bhutan almost achieving cent percent urban electrification, rural electrification is now the key. The decentralised

alternative technologies like solar photovoltaic, wind, and micro-hydropower can be cheaper than grid extension for the rural areas in the country.

4.2 Bangladesh

4.2.1 Status

Bangladesh is located in the north-eastern part of South Asia and have a total population of about 140 million with an average population density about 750 per sq. km (among the highest in the world). According to IEA (2009), the overall electrification rate in Bangladesh was 41% in 2008, with 76% of the urban population and only 28% of the rural population having access to electricity. Though the rural household electrification rate is poor, Bangladesh has recorded an impressive rural electrification performance in terms of coverage with about 56.16 percent of the villages covered through extension of electricity grid (REB 2010). The government has committed to achieving electrification for all people by the year 2020 (Power Division, 2005).

Bangladesh's rural electrification program, started in the late 1970s with the assistance of the United States Agency for International Development (USAID), and has since then been growing in size nationwide. It has increased the number of electrified households and has brought numerous economic and social benefits to rural people, including improvements in agricultural productivity and the creation of new jobs (Barkat et al., 2002). Because of the well-designed systems, the REP in Bangladesh is often considered one of the best examples of rural electrification in the international cooperation arena (Gunaratne, 2002b).

4.2.2 Technology choice

The main mode of electrification is the extension of the electricity grid through the rural electricity cooperatives. The PBSs are connected to the grid and receive electricity in bulk from the BPDB which is distributed to their consumers. In addition, Bangladesh also has an impressive solar home systems programme implemented by IDCOL (Infrastructure Development Company Limited) through its partner organisation. Though it has significant potentials for wind and agricultural biomass but they have not received significant attention compared to the technologies mentioned above.

4.2.3 Off-grid options

The country has a long experience with PV technology but often as a pre-electrification strategy rather than a permanent solution. To provide electricity for those without access to electricity, the solar PV program was developed by IDCOL with the help of the World Bank (IDCOL 2010). IDCOL started the program in January 2003 and its initial target was to finance 50,000 SHSs by the end of June 2008. The target was achieved in September 2005, 3 years ahead of schedule. IDCOL then revised its target and decided to finance 200,000 SHSs which was also achieved, seven months ahead of schedule in May 2009. IDCOL now target to finance 1 million SHSs by the end of year 2012, out of which a total of 438,000 SHSs have already been installed as on December 2009.. IDCOL board has also recently approved financing of a a 100-kW solar photovoltaic (PV) based micro-grid at Sandip island in Chittagong district. A 40-kW diesel generator will be integrated into the proposed power plant in order to ensure adequate power supply during periods of low solar radiation. In addition, the REB has also been implementing solar PV projects in different parts of Bangladesh

4.2.4 Organisation and financial viability of rural electrification

The responsibility of electricity distribution in Bangladesh is largely shared by the following institutions: Bangladesh Power Development Board (BPDB) and Rural Electrification Board (REB). While BPDB is responsible for generation and transmission of electricity as well as distribution in urban areas (except Dhaka) Rural Electrification Board (REB), created by the Government of Bangladesh in late 1977, is responsible for the distribution of electricity in rural areas. Thereafter the rural electrification programme was started in 1980 under which 75000 villages were planned to be electrified out of total 86038 villages in Bangladesh. The long-term plan is to bring all the villages of Bangladesh under electrification by the year 2020. The rural electricity program is operated by independent consumer-owned cooperatives, *palli bidyut samities* (PBSs), functioning under the umbrella of REB. The PBSs are nonprofit organizations owned by their members, who are also the consumers of electricity. The role of PBS is to construct electricity distribution facilities in rural areas, manage and operate the facilities, and conduct electric power distribution activities under the supervision of REB. Further, adopting the distribution strategy on the basis of “area coverage rural electrification”, the supply area of each cooperative covers in general 1,000 to 1,500 square km, with 15,000 to 30,000 consumers, and includes some 800 to 1,500 km of distribution lines.

By most measures, the REB has been extremely successful. REB has established and “energized” all the targeted 70 PBSs, energised over 2, 21,833 kilometres of line, electrified 48, 320 villages (out of 84,320 villages) connected 6.99 million households as on March 2010 (REB, 2010). Financially, out of 67 PBS, 54 have crossed the subsidy/grace period, 17 PBS have reached break even point (Choudhury, 2009). The PBS and REB board approve tariff structure of the PBSs, which depend on cost of service, cost of power purchase, operation and maintenance expenses and depreciation and interest experience. The tariffs are set in an attempt to balance the perceived ability of the PBS customers to pay for electricity service and the need for the program to sustain itself economically. 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. At the PBS level, the results are also quite impressive. There have been no defaults on debt, and bill collection rates have remained in the range of 98% throughout the program and average system losses including technical and non-technical are about 15%. However, Taniguchi and Kaneko (2009) indicate that the performance of individual PBSs is not uniform. The governance and management of the cooperatives are clearly instrumental for such variations with the cooperatives with high local participation performing impressively as compared to others.

The solar home system project is implemented by IDCOL through its 23 partner organizations (POs) including Grammen Shakti and BRAC. The IDCOL is responsible for providing grants and refinance the systems, sets the technical specifications for the solar equipment, develops publicity materials, provides training for PO capacity building and monitors PO performance. The role of PO is to select the project areas and potential customers, offer micro-financing to the customers, install the systems, provide maintenance support, ensure that spare parts are available, consultation with the users before installation, disseminate knowledge for productive use of the system, and to provide training to the users and local technician in order to create local expertise and ownership on the system. IDCOL offers refinancing through soft loans (6% interest with 2 years grace period and 10 years maturity) to the POs and channels grants to reduce the SHSs costs as well as support the institutional development of the POs. In addition, the IDCOL also provides technical, logistic, promotional and training assistance to the POs. The POs provide credit to the customers. A customer has to pay 10% of the total cost of the system as down payment and the outstanding amount is to be paid in monthly instalment with a 12% service charge, which covers the maintenance cost of the system.

4.2.5 Key lessons

The experience is the Bangladesh shows that the country has used private supply and co-operative models for rural electrification. The co-operative model has been successful in delivering electricity through state and donor funding support. The key to success is the commitment, discipline, loyalty, and transparency in decision-making combined with the important partnership the REB has created with the rural community through the PBS Board of Directors and management. Following are the summary of some of the keys that continue to contribute to the REB success:

- Engineering and construction standards are used for the development of the system. There are approved specifications for equipment and materials used in the Program. A "system" has been established for developing and monitoring the PBSs, which provide for necessary "checks and balances" to ensure proper performance of the project
- The cooperative model has promoted local involvement of the rural people who are the beneficiaries of the program.
- The system is built on a priority basis and the lines that do not fulfill the revenue requirements are not included for construction.
- The PBSs are responsible for the day-to-day operations, but REB monitors their activities (i.e., management, system operations, commercial practices, etc.) to ensure that accepted levels of performance are maintained.
- The consistency in maintaining a lower system loss (< 15%) and high collection rates (~ 95%).
- Appropriate capacity building at all levels since the program's inception.

4.3 Other country experiences – Afghanistan, Maldives and Pakistan

4.3.1 Afghanistan

Afghanistan is one of the poorest and least developed countries in the world. Meisen and Azizy (2008) analyses the role of rural electrification and argues that many of the problems that exist in rural areas of Afghanistan, such as poverty, healthcare, drug trade, and deforestation, are linked to the lack of access to electricity. With significant destruction of the country's power generation, transmission, and distribution infrastructure, due to prolonged conflict in the eighties and nineties, the country has now started rebuilding its power infrastructure. The total generation capacity, which had declined from about 475 MW in the 1990s to approximately 250 MW (ADB 2009), has now grown to 1029 MW in September 2009 (SIGAR2010). Only about 7 per cent of the country's population (approximately 30% in the capital city Kabul) has access to electricity, according to 2007 government figures, and per capita electricity consumption ranks among the lowest in the world at under 20 kWh (ADB 2009). Nationally seven grids distribute power, with supply coming from domestic hydro generation, imported power and thermal generation. In addition there are also privately owned isolated diesel generation supplying power to rural areas which will continue to play a large role in power supplies. To enhance electrification rate, the Afghan government has set ambitious targets (ANDS 2009) - "by end 2010, electricity will reach at least 65 percent of households and 90 percent of non-residential establishments in major urban areas and at least 25percent of households in rural areas" and "by end 2010, at least 75 percent of the costs will be recovered from users connected to the national power grid".

Currently, he National Solidarity Program (NSP), created by the Government of Afghanistan to develop the ability of Afghan communities to identify, plan, manage and monitor their own development projects, is developing the power projects in the country. Under NSP, a total of 1853 mini hydro projects (up to 25kw), 1692 diesel generator sets, erection of 713 km power line and 2250 photovoltaic system are planned to be implemented (NSP 2010). Of these, 884 mini hydro projects have been commissioned, and 932 are ongoing as on September 2009. Electricity from mini hydro power projects are used only for lighting (60 W-160 W per family). Some of the key lessons from the NSP are the quality of the installed products are poor due to non existence of good quality supply base in the country and absence of advanced technology, and skilled manpower to operate and service the plants resulting in their underutilization.

With Afghan Government identifying energy as a strategic lever to promote the country's development, it finalised the power sector master plan in October 2004. To reinstate the electricity supply, power import was identified as the fastest measure in the short-term and by mid-2009, 80 MW of power started reaching the capital. Inspite of the high cost, the generation of power from diesel gensets have also been considered for areas that cannot be served by the grid and/or to meet the peak demand (ADB 2009). As it may take a number of years to significantly increase domestic electricity generation, it is expected that the country will continue to import most of its requirements. ADB (2009) observes that most of the major increase in electricity supply is expected to come from imports from Turkmenistan, Uzbekistan and Tajikistan, where low-cost hydroelectric and coal-fired generation is readily available.

GTZ has also been supporting Afghanistan since 2001 through the Energy Supply for Rural Areas (ESRA) programme in developing a sustainable energy supply, especially through renewable energies such as hydroelectric power (GTZ 2009) In addition to improving the rural population's living conditions, the programme also aim to stimulate economic systems in the areas under promotion. Micro hydro power was established in Chata, Feyzabad district (112 kW operational since Feb 2008 and serving approx. 400 families as well as a school for boys and girls), Sangab, Baharak District, (125kW in operation since December 2007 for approx. 350 families as well as a school for boys and girls and Jurm district capital with 7 surrounding villages (450kW, operational since July 2008 serving approx. 3,000 families and 5 schools).

Despite progress and efforts to date, the existing governance arrangements and policy framework for the sector are still insufficient to support development of the sector. Some of the barriers identified by ANDS (2009) are dispersed institutional support, lack of regulatory framework, no meaningful commercialization of state energy assets, inefficient and wasteful use of electricity and limited opportunities for private participation. Another study highlighted that the country faces several sustainability challenges in maintaining and growing its energy supply (SIGAR 2010). Specifically, the local government lacks the ability to collect revenue, which limits their ability to independently operate and expand the power system, and the ability to recruit and retain qualified staff. The USAID is in the process of addressing some of the issues and has established a goal of providing reliable and affordable electricity by increasing operational capacity to 1000 MW by 2012 (SIGAR 2010)

4.3.2 Pakistan

According to IEA (2009), the overall electrification rate in the Pakistan was 86% in 2008, with 97% of the urban population and 67% of the rural population having access to electricity. Sheikh (2010) cites that more than 40,000 villages of Pakistan have no access to electricity and it is expected that within next 50 years, it will be difficult to electrify these villages with present pace of development in the energy sector. Khan and Latif (2010) opine that rural electrification has extended the conventional grid in the region and there has been no provision of decentralized power generation and distribution which has resulted in poor quality of power with high voltage fluctuation and long power cuts in the rural areas. In case the villages are electrified also through grid extension, there is less probability that the villages will get power supply. A study by Asif M (2009) indicates that during 2008, the country faced an electricity deficit of over 4000 MW (40% of the total demand). Based on the analysis, he suggests that the already existing gap between demand and supply is set to grow rapidly in the coming years unless quick and meaningful measures are taken to add to the power generation capacity of the country.

The main mode of electrification in Pakistan has been the extension of the electricity grid. A breakdown of county's electricity supply indicates that the grid is mainly served by thermal power (64.25 %), hydel (33.4%) and nuclear (2.4%) and the rest from imports. (Sheikh M A 2010). The responsibility of rural electrification has also been historically with the distribution utilities under the supervision of the National Electrification Administration.

In order to facilitate development and generation of alternate or renewable energy to achieve sustainable economic growth with transfer of technology, Government of Pakistan established the Pakistan Council of Renewable Energy Technologies (PCRET) with two main departments: AEDB (Alternate Energy Development Board) and PCRET. AEDB was provided the mandate of generating 10% of the total installed capacity in the country from renewable energy sources by 2015. However, an appreciable amount of development could not be seen in the country in the renewable energy sector. It is really ironic that Pakistan has not tapped solar PV and micro-hydro for electricity generation inspite of the high proven potential of these resources.

The average solar insolation is 5–7 kWh/m²/day in the country and covers more than 95% of its area with persistence factor of 85% (Shamshad 1998). Despite the favourable conditions, the use of solar energy for generating electricity is still in its beginnings. AEDB electrified approximately 3000 households with total PV power generation of 200 kW in districts of Kohat (North West Frontier Province), D.G. Khan, Rawalpindi (Punjab), Tharparkar (Sindh) and Turbat/Kalat (Balochistan). Each household in each village has been provided with 80 W Solar Panel, Charge Controller and Battery, 4 CFL Lamps, 2 LED lights, a 12 Volt Dc fan and a TV socket. The cost per system was in the range of US$1200 to US$1500 excluding installation cost (Sheikh M A 2010). An evaluation of the installed system by GTZ (2009) indicate that that most of the solar PV systems are being used only for lighting purpose with minimum use of electricity for productive applications. The users are not paying their instalments in the absence of any cash income facilitated by the installation. Apart from these, PCRET also electrified more than 500 schools, mosques, houses through PV power with total generation capacity of more than 80 kW. Further, private PV installations in the country are approximately in the range of 500 kW. Thus, the cumulative installation of solar PV in the country is reported to be to be less than 1 MW (Sheikh M A 2010). Sahir and Qureshi (2008) highlights the major barriers to the promotion of solar energy in the country is due absence of any enabling policy instruments to integrate the techno-economic and socio-political behaviours and actions and inconsistencies of the government policies.

In the micro hydro sector also, less than 5 percent of the total potential of about 1200 MW had been tapped through installation of a total of about 300 projects with co-financing Aga Khan Rural Support Programme (AKRSP), PCRET/MoST, European Union, AEDB and private developers (Sheikh M A 2010). The Agha Khan Rural Support Programme (AKRSP) has also installed over 180 micro-hydro power units in Chitral District, North-West Frontier Province. Lately with assistance of ADB, 100 pico/micro hydel power plants (5 to 50 kW) have also been completed under the Malakand Rural Development programme in NWFP. AEDB is also installing micro hydel power plants of total generation capacity of 10MWin Punjab, NWFP and Northern Area, which are expected to be commissioned by 2012.

4.3.3 Maldives

Maldives, located in the Indian Ocean, comprises 1192 small coral islands of which 199 are inhabited. Like other small island developing states, Maldives also depend overwhelmingly on petroleum import for its electricity production. Almost 99% of the energy needs of Maldives come from imported petroleum and about 1% from biomass. Both the State Electric Company (STELCO) and the Island Development Committees (IDC) are together responsible for the electricity supply in the country.

It is reported that majority of Maldivians live in locations with full day availability of electricity. STELCO provides 24-hour electric power to some 24 of the 200 inhabited islands (including Male') while generators operated by island communities serves an additional 50 islands and private providers serve 6 islands with 24 hours of electricity a day (UNDP 2007). The remaining islands have at least 5-12 hours electricity service. In all the islands, electricity is generated by the burning of fuel oil and diesel. Between US$75.000–150.000 is spent on subsidies each year to support the electrification of the outer islands (Klaas van Alphen et al. 2006). The operation of state owned STELCO, privately owned (e.g. resort islands) and community power providers are all regulated by the Maldives Energy Authority (UNDP 2007)

Both STELCO and the IDCs have received extensive government support in the form of direct or indirect subsidies to develop the electricity infrastructure in the country. The Ministry of Finance and Treasury provided soft loans to STELCO for all outer island projects. Similarly, the Ministry of Atoll Development provided subsidies to the IDC in the form of grants, special loans, and generator gifts for the provision of electricity (van Alphen et.al 2007a). The World Bank and the Japanese government also provided soft loans to the STELCO for purchasing conventional fuel technologies. Furthermore, the ongoing Outer island electrification project, financed through a loan from the Asian Development Bank, is currently working to improve and enhance the diesel power generation on 17 outer islands with 24-h service community generators (Klaas van Alphen et al. 2006).

Weisser (2004) observes that the large scale implementation of the diesel based generation is creating serious economic and financial difficulties, apart from the clear ecological risks. With respect to the rapidly growing energy demand in the Maldives—i.e., an annual growth of approximately 11%

in the last decade (UNDP 2004), it is often argued that the country should move towards a more sustainable energy supply such as application of renewable energy technologies. Currently, renewable energy technology applications are limited to some application of solar photovoltaic in navigation lights and outer island telecommunication systems and the modest use of solar water heaters in Male' and in resorts. van Alphen et al. (2007b) argues that solar and wind diesel hybrid systems for electricity generation are financially feasible and could supplant a substantial amount of the fossil fuel-based generators on the outer islands and the capital city Male.

To promote renewable energy in the country, Renewable Energy Technology Development and Application Project (RETDAP) was initiated in 2004 with UNDP as the implementing agency and the Ministry of Environment, Energy and Water as the national executing agency (UNDP 2007). RETDAP was designed to address the policy, institutional, information, financing and technical barriers, seeking to remove them in order to facilitate the widespread utilization of renewable energy resources in the country. One of the outcomes of the project was installation of the demonstration 12.8 kW solar-diesel hybrid system on Mandhoo Island in 2006 (UNDP 2007). The solar array of 12.8 kWp was envisaged to supplement the existing 32 kW diesel power plant during day time. The total cost of equipment and installation was around US$ 180,000, supported by the French agency ADEME and with a UNDP contribution of US$ 50,000. However, it turned out that even during the day, demand outstrips the solar facility's capacity and the system could not function properly. Apart from these, two solar-wind systems have also been installed with UNIDO support in B. Ghoidhoo (8 kW, to power the community centre) and Fainu (8 kW, providing power for about 130 villagers). Maldive Gas, a government owned company, has also installed solar-wind-diesel hybrid system in Ha Uligam (a 45 kW of solar and wind backed up by a 32 kW diesel generator to provide power to the 450 islanders) and M Raimandhoo Islands (a 40 kW solar-wind hybrid system). A MoU has also been agreed upon between Maldive Gas, State Trading Organisation and a Singaporean company, Daily Life, to install solar-wind-diesel hybrid systems in another 100 islands in the country (UNDP 2007).

Some lessons learned (UNDP 2007) based on the experience of the RETDAP project for future renewable energy installations are:

- Many of the electrical appliances are unique to the manufacturer and thus making it difficult to service by a technician not specifically in the technology;
- The renewable energy application project should be delivered in a running-and-testing mode and should include a regular check-up by the manufacturer after installation;
- Power demand (present and future) should be determined as precise as possible, so that systems is sized in such a way that the power demand can be met in a cost-effective way.

5.0 Case studies of off grid projects

5.1 Solar PV in Sunderban Islands in India

The West Bengal Renewable Energy Development Agency (WBREDA) has been undertaking many initiatives in the Sunderban islands for ensuring rural people's access to quality and clean power. WBREDA initiated its activities in 1996 and currently operates about 18 solar power plants with aggregate capacity of about 1 MWp in the region. WBREDA's model of implementation is usually in the form of a local mini grid mode. Both 11 kV and LT grid network is created by WBREDA depending on the capacity of the power plant and evacuation of power from the plant. To maximize the load factor, WBREDA establishes the plant near the load centre and creates a 2 -4 km of mini grid in the area for supply. Grid quality power from the projects is supplied to the consumers for 6-8 hours rather than only lighting. The mini grids are operated by Sagardweep Rural Energy Development Cooperative Society Ltd, formed by the local people. The responsibilities of the society includes selection of consumers, planning for the distribution networks, tariff setting in consultation with WBREDA, revenue collection from consumers and passing them to WBREDA and consumer grievance redressal. As the capital cost of the system are subsidised to a large extent, the tariff takes into account the operating and maintenance cost of the systems. The rural banks operating in the area worked as intermediaries between the cooperative and individual consumers to collect bills based on actual consumption. A minimum charge has been set that has to be paid by the consumer irrespective of the consumption levels since the plant load factor has to be maintained for sustained supplycooperative societies One of the reasons for success of off grid power projects in Sunderban region is that the tariff has been set according to existing diesel generation tariff as well as in line with the willingness to pay of the consumers. As per WBREDA, the revenue collected from consumers is sufficient to cover 100% of the operational costs in addition to about 20% of the capital costs of the power plants. However, as the projects are not commercial in nature and have been implemented more as a public good, in case of default in payment by consumers, strict action such as disconnection of line etc are not done. The beneficiary committee/ cooperative only resort to social pressure to recover the payment. As 24x7 supply regimes cannot be maintained at a reasonable cost using solar power, WBREDA has also installed some hybrid units like wind-solar and solar-gasifier to keep the cost of power reasonable. Field study in the Sunderban region by TERI and other institutes indicate that the population is happy with the current arrangements of power supply. However, community also aspire for grid connectivity because of the limited supply of power for a stipulated time from off-grid projects.

5.2 Village Energy Security Programme in India

Launched in 2004, the VESP is a community based initiative that aims at providing clean, affordable energy in rural areas—home to around 70% of India's population. The focus has been on finding ways for villages—particularly those located in remote rural areas that are unlikely to be provided grid electricity

in the near future—to achieve energy security based on locally available renewable energy sources (preferably biomass). The programme goes beyond rural electrification to village energization. It therefore places additional emphasis on cleaner options of cooking through improved cookstoves and biogas, productive use of energy for livelihood generation and sustaining the energy systems through captive plantation. Till now, 79 test projects have been sanctioned, of which 55 have been commissioned in eight different states. These test projects have been undertaken in un-electrified remote villages and hamlets that are not likely to be electrified through conventional means in the immediate future. Based on a community centric approach, a one time grant (up to 90% of the project cost) was provided to the village community for installation of energy systems capable of meeting the village community's energy demands. The community, in some cases, also provided an equity contribution (either in cash or kind) to bring in the much needed ownership, required for success of any community centric projects. Based on an assessment, conducted to review the performance, impacts and lessons of the VESP test phase, it was found that the VESP projects emerged as a vehicle to motivate the community especially the youth to attempt develop their skills. Local youths enhanced their skill to operate the installed power generation systems in almost all the

VESP subprojects. Innovations adopted by select PIAs for capacity building of the technology operators helped in better project performance. There is mixed results of social mobilization and leadership of VEC with mobilization and leadership relatively better in the test projects implemented by NGOs as compared to the projects implemented by State departments. Revenue management is comparatively better in projects where villagers are having cash income because of either existing income generation activities or newly introduced activities after being electrified under VESP. Active involvement of Gram Panchayat in some projects helped in developing the required synergy in getting village development funds for VESP both towards project cost and operational expenses. However, along with above mentioned best practises some shortcomings have also been reported. The uptime of the projects, considering their remoteness and various other inherent technical and institutional problems, is satisfactory in some of the projects while it is poor in most of the projects. Some of the challenges for sustainability were found to be because of less concentrated electricity demand in the villages, low economic activity implying lower electricity demand, lower ability to pay by the consumers, difficulty in operation and maintenance, limited technical knowledge of the VEC and weak fuel supply chain linkages. One or combination of the above factors is leading to low load factor and less hours of operation, thereby low capacity utilisation factor. The potential of income generation activities and productive load was also not fully exploited because of absence of proper guidance to the VEC to initiate and execute such possibilities.

5.3 Lighting a Billion Lives©[a] (LaBL) initiative in India

TERI has evolved an innovative renting model for providing access to clean lighting through solar lantern under its LaBL campaign initiative. The campaign launched in 2008 aims to bring light into the lives of one billion rural people by displacing kerosene and paraffin lanterns with solar lighting devices, thereby facilitating education of children; providing better illumination and kerosene smoke free indoor environment for women to do household chores; and providing opportunities for livelihoods both at the individual and at village level. LaBL operates on fee-for-service or rental model where Centralised Solar Lantern Charging Stations (SCS) are set-up in villages for charging the lanterns and providing the lanterns daily on rent to households and enterprises. A typical solar lantern charging station consists of 50 solar lanterns with five numbers of solar panels and junction boxes. The charging stations are operated and managed by entrepreneurs (Self Help Groups/individual youths) who qualify the selection criteria set as part of the LaBL campaign. These entrepreneurs are selected and provided the handholding support by local LaBL implementation partners called LaBL Associate. The rent is collected by the entrepreneur, a part of which is used for O&M of the charging station and for replacement of battery as may be required after 18-24 months of operation. TERI has successfully extended the Campaign in 500 villages spread across 12 states in India impacting more than 125 000 lives.

5.4 Small hydro power experience in Sri Lanka

In Sri Lanka, the plantation industry was instrumental in promotion of Small Hydro Power (SHP) in either electrical or mechanical form from late 1880's with total installed capacity of such power plants reaching almost 10MW by late 1950's. However, with the availability of cheap grid electricity most of these installations went into disuse by 1960's. The oil shocks lead to a renewed interest from mid 1970's and a new enthusiasm in 1980's for promoting SHP projects in the country. The rehabilitation of several estate hydros in late 1980's also set-off a new initiative in SHP.

The first ever grid connected SHP was established in Dickoya set the stage to the development of a Standardised Power Purchase Agreement (SPPA) and a new era of cooperation between the utility and SHP developers was initiated (Herath and Samarasinghe 2009). Thereafter, the SHP sector grew at fast phase due to the conducive environment such as high avoided cost, standard PPA and procedure for implementation, availability of attractive funding from Energy Services Delivery Project and Renewable Energy for Rural Economic Development Fund. The combined capacity increased from less than 5 kW in 1996 to more than 110 kW in 2007. The key success factors for development of SHP in Sri Lanka can be attributed to

- Virtually free from market risks - What ever produced will be purchased & Guaranteed floor price sans a price ceiling
- Availability of a bankable standard PPA leading to simple approach and low transaction costs and
- Resource allocation - First come first served basis and devoid of cumbersome competitive processes
- Financing mechanism in place - two consecutive World Bank projects (ESDP and REREDP) with a sound disbursement procedure. A key element of REREDP was that a long term loan is essential for viability of renewable energy projects. The centre piece of the plan was a 40 year loan package from IDA to Sri Lankan government which made it possible for government to 'on lend' funds to local banks for upto 13 years who then lend the fund to projects exclusively in the renewables arena.
- Technology development keeping pace - Local Engineering know how developed to commendable levels
- Escalating tariffs – avoided cost paid to SHPs in line with increasing thermal share of generation and increase in cost of generation of such plants (the tariff increased from about 3 LKR/kWh in 1997 to about 7 LKR/kWh in 2007).

5.4 Financing solar home systems program in Sri Lanka

The most popular SHS financing model under Sri Lanka's Renewable Energy for Rural Economic Development Project is consumer credit through the microfinance institutions that work closely with solar companies. The project's centerpiece has been the market-based credit program available to PCI (participating credit institutions) - commercial banks, microfinance institutions, and leasing companies that meet eligibility criteria. The solar companies, via their dealer networks, sell SHSs and offer operation and maintenance services. The business model is structured through a memorandum of understanding between the microfinance institution and the solar company, key features of which are a buyback scheme and identification of the consumer service responsibilities of the two parties. The RERED project comprises 11 PCIs namely five commercial banks, two licensed specialized banks, two leasing companies, one finance company, and one microfinance institution (ESMAP 2008). The PCIs can refinance up to 80 percent of their loan amounts. They access credit at the average weighted deposit rate, repayable in 15 years with a maximum 5-year grace period. In turn, they offer households, community-based organizations, and private developers sub-loans which are used to for financing SHS, village hydropower systems, and mini-hydropower projects respectively. The sub-loans have a maximum maturity of 10 years with a 2-year grace period, not exceeding the useful economic life of the equipment financed. The PCIs assume the credit risk on the refinanced sub-loans and repays them according to an agreed-on amortization schedule, regardless of whether their borrowers repay. Following this model, the Sarvodaya Economic Enterprises Development Services

(SEEDS)—the project's key PCI in SHS financing and a recognized leader in off-grid energy services delivery in remote rural areas—financed more than 60,000 systems during the period 2002–06.

5.5 Grameen Shakti solar PV programme in Bangladesh

Incorporated in 1996 as a not for profit company, Grameen Shakti (GS) has developed one of the most successful market based program with a social objective for popularizing solar home systems including other renewable energy technologies to millions of rural villagers in Bangladesh. GS used its Grameen Bank's concept of micro-credit to evolve a financial package suitable for the rural people, especially to bring down the costs. The customised pricing system based on instalments helped GS to reach economy of scale with the increase of sales. The GS business is centred on customer service excellence. The GS engineers pay monthly visits to households during installment payment and offer their services for a small fee, afterwards, if a client signs an annual maintenance agreement with GS. Therefore, the financing scheme perfectly blends with customer's paying ability. GS also undertakes several other activities (such as educational loans, gift schemes etc) that go well beyond the energy service alone and help develop trust between GS and local communities. The total number of installation reached 1 13 736 SHS by the end of December 2009 and GS plan to reach a target of 2, 20,000 SHS by end of 2010 (Grammen Shakti 2010)

5.6 Rural Energy Development Programme (REDP) in Nepal

REDP is a joint initiative of Government of Nepal and UNDP, and was initiated in 1996 as a pilot project in five hill districts of Nepal. The program rests on the two basic pillars of decentralized and participatory decision making process, and holistic development approach. Various studies and awards confirm that REDP has successfully brought about innovation in the energy sector in rural Nepal, contributing to economic, social and environmental goals towards poverty alleviation through the application of holistic and decentralized administrative management. Following successful piloting, the program was subsequently implemented in 15 hill districts. Based on success of the REDP-I & II, as one of the most effective delivery models in the rural hills of Nepal, the World Bank provided additional support to launch the 3rd phase of REDP, covering all the 75 districts in Nepal. At the end of March 2006, the REDP had supported communities to install 150 micro hydro schemes (aggregating 1862 kW installed capacity), 1,945 solar home systems (aggregating 55kWp), 3,900 toilet attached biogas plants and 9,561 improved cooking stoves, providing more than 10,000 new rural households were with access to electricity. The availability of electricity and on-site income generating trainings promoted enterprise development in rural villages ultimately influencing rural livelihoods positively. A Winrock International study (WIN 2006) observed that "*Considering that REDP is providing energy services in an integrated manner, including skills development, enterprise development, information services, institution and capacity building, fuel supply, technology manufacturing, operations and maintenance, etc with encouraging outputs it can be considered as a best practice model operating so far in Nepal*".

6.0 Conclusion and way forward

This review of the rural electrification situation and off grid options in South Asia presents a number of interesting findings and lessons as summarised as follows:

a) The success stories in SHS dissemination in Bangladesh and Sri Lanka demonstrate that it is possible to implement off-grid programs in association with the private sector and microfinance institutions that operate in the rural areas. Improved access to capital, development of effective and reliable after-sales service, customer centric market development and regular stakeholder involvement assisted in project scale-up. While these experiences may be true for only SHS delivery, the design principles key to their success can also be extended to cover other off grid technology. In fact, both projects have now begun to experiment with providing other off-grid and rural energy services in their area of operation.

b) The review also indicates that the rate of success also depends on the extent of government's commitment in creating a enabling environment for promotion of rural electrification. The case of Bangladesh and India are two examples where we can see that the creation of REB and launch of REST mission and later the RGGVY has assisted in increasing the electrification rate substantially. Further, it is also observed that all rural electrification projects examined during the study have involved a significant subsidy component especially capital subsidy. However, in case off grid projects, it is also observed that while donor-assistance or state-supported capital subsidy has allowed implementation of several projects in many cases it has been inadequate for ensuring long-term sustainability & replicability thereby raising the key question of long-term viability and sustainability of such programmes.

c) Almost all the rural programmes reviewed in the region, grid extension has been the preferred mode electrification. The off grid option more act as a pre electrified option with community continuing to aspire for grid connectivity because of the limited supply of power from off-grid projects.

d) Whereas community centric off grid projects have succeeded in some cases, there is also negative fallout of the community centric project. One of the key reasons may be because of the fact that almost all off grid projects are located at remote locations, thereby making it more challenging for sustainability. The remoteness of the project inherently include some common challenges such as less concentrated electricity demand in the villages, low economic activity implying lower electricity demand, lower ability to pay by the consumers, difficulty in operation and maintenance, thereby making it had to achieve success.

The issue of grid electrification vis-à-vis off-grid electrification and user's preference for a particular mode is complex one and need further study on the subject. However, it is clear from the review that effective service delivery model along with innovative financing mechanisms, customised to a given situation, can lead to a success story. What is needed now is development of business models, considering their scaling up potential, and implementing such models covering different socio – cultural- economic- enviro set up to test their viability and replicability potential.

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