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Off-grid Rural Electrification Experience Outside South Asia: Status and Best Practices

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Abstract

This paper provides a detailed review of the status of rural electrification outside South Asia with an emphasis on off-grid electrification. It covers the experience from other Asian countries such as China, Thailand, Indonesia and the Philippines, countries from South America and Sub-Saharan Africa. The review has covered both successful cases and not-so-successful cases and an attempt has been made to capture any significant development at the regional level and where appropriate, references to country cases have been made.

The study finds that many countries outside South Asia have made significant progress in terms of electrification but the rate of success has depended on the level of government commitment, will and financial support to the process. In all cases, the electrification process has heavily relied on state subsidies for infrastructure development and in many cases for system operation. It also finds that grid extension has been the most commonly used electrification method around the world and off-grid has not been used as the preferred option in most cases. Whenever off-grid solutions have been used, they have catered to limited needs of the consumers and there have been very limited efforts to use hybrid systems or integrate productive applications. Most countries have used top-down approach to electrification with the exception of China where a decentralised bottom-up approach with emphasis on local energies has been used. Some countries, particularly in Africa have created a separate agency for rural electrification and have established a Rural Electrification Fund but the rate of electrification has not improved much.

The paper asks whether the Chinese model can be replicated elsewhere. Linking productive use of energy with electrification projects (particularly for off-grid projects) is essential to enhance project viability. It also suggests scope for further studies to look into the rural electrification agency/ funds issue to see how these organisations can be better organised to improve electrification in developing countries.

Key words: rural electrification, China, South East Asia, South America, Sub-Saharan Africa, status, off-grid,

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1.0 Introduction

There is a well-developed literature on the experience of rural electrification and the experiments being carried out for ensuring universal access to electricity. Although this research project is about South Asia, the experience of other countries and regions can be helpful in identifying options, for developing viable solutions and for formulating policies through a process of cross-learning. Accordingly, this working paper presents a review of rural electrification experience with a special emphasis on off-grid electricity generation and supply outside South Asia.

The main objective of the paper is to provide a review of the status of rural electrification in various parts of the world and to identify practices in off-grid supply that could be useful for South Asia. In terms of technology coverage, the report focuses on both conventional and renewable energies and covers mini-grid based electricity supply as well as stand-alone systems, although rural electrification also includes extension of central grid-based supply.

Given that the 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. The review has covered both successful cases and not-so-successful cases and an attempt has been made to capture any significant development at the regional level and where appropriate, references to country cases have been made.

The report is organized as follows: the first section introduces the report; second section provides a review of the electrification and off-grid electricity status in various regions; section three looks at three regions – East and South-East Asia, Africa and South America. A few specific country examples have been taken including those of China, Brazil, and South Africa. This is followed by a review of few off-grid experiences. Finally, the last section provides a summary of the report and some concluding remarks.

2.0 Rural electrification and off-grid status outside South Asia

This section provides an overview of the present status of electrification on a global scale 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 various regions

The regional picture of electrification is presented in table 1 (IEA, 2010)[1]. In 2009, more than 1.4 billion people (i.e. about 22% of the global population) did not have access to electricity. Two regions stand out in this picture: South Asia, with 614 million (or 42% of the population) without access, comes first while Sub-Saharan Africa comes second with a population of 587 million (or 40% of those) without access to electricity. Outside these two regions, only East Asia has 195 million without access to electricity (or about 13% of those without access).

Table 1: Level of electrification in various regions

Region	Population without electricity (Millions)	Electrification rate (%)		
		Overall	Urban	Rural
North Africa	2	98.9	99.6	98.2
Sub-Saharan Africa	587	28.5	57.5	11.9
Africa	589	40.0	66.8	22.7
China and East Asia	195	90.2	96.2	85.5
South Asia	614	60.2	88.4	48.4
Developing Asia	809	77.2	93.5	67.2
Middle East	21	89.1	98.5	70.6
Developing Countries	1453	72.0	90.0	58.4
Transition economies and OECD	3	99.8	100.0	99.5
Global total	1456	78.2	93.4	63.2

Source: IEA (2010).

A closer look at the data shows that about 70% of those lacking access to electricity reside in just 12 countries while the rest 30% is dispersed in all other countries (see table 2). The rural population in most of these countries is lacking access, although in a few countries the urban population also lacks access. While the total number of people without access to electricity is high in South Asian countries, Sub-Saharan Africa fares worse in terms of rate of electricity access. In fact, out of 10 least electrified countries in the world, nine are from sub-Saharan Africa and Myanmar is the only country from Asia (see Table 3).

[1] See also UNDP-WHO (2009) for a detailed review of energy access.

Table 2: Major concentration of population without access to electricity

Country	Rank in terms of population	Population without electricity access (Million)	Share of population without access (%)		
			Urban	Rural	Total
India	2	404.5	6.9	47.5	35.5
Bangladesh	7	94.9	24	72	59
Indonesia	4	81.1	6	48	35.5
Nigeria	8	80.6	31	74	53.2
Pakistan	6	70.4	22	54	42.4
Ethiopia	15	68.7	20	98	84.7
DR Congo	19	57	75	96	88.9
Myanmar	24	42.8	81	90	87
Tanzania	30	36.6	61	98	88.5
Kenya	32	32.8	48.7	95	85
Uganda	37	29.1	57.5	96	91
Afghanistan	44	23.3	78	88	85.6

Source: IEA (2010).

Interestingly, the most populous country in the world, China, has achieved a very impressive record of providing electricity with only 8 million population (or about 0.6% of its population) lacking the facility. Similarly, a number of South East Asian countries such as Thailand, Malaysia, Vietnam and the Philippines have made impressive progress on the electrification front. In South America, Brazil, the most populous country of the region, has achieved an impressive record of about 2% of its population without access to electricity, most of whom are located in the Amazon region. These examples can therefore provide interesting insights for South Asia. In addition, Africa has seen a number of initiatives to improve its access record and such initiatives could also provide some lessons for South Asia. Simultaneously, despite major efforts and initiatives some countries have not progressed as expected – Indonesia and Kenya could be grouped in this category. Their experience can also provide lessons for others.

Table 3: Ten least electrified countries in the world

Country	Population without access to electricity (%)
Zambia	83.0%
Madagascar	83.5%
Tanzania	84.1%
Malawi	85.2%
Ethiopia	86.9%
Burkina Faso	87.6%
Myanmar	87.7%
Uganda	88.9%
Mozambique	90.3%
DR Congo	91.3%

Source: IEA (2009)

Accordingly, this paper tries to capture the following:

a) It provides a brief review of the regional situation.
b) Presents examples of successful cases (e.g. China, Brazil, Vietnam, Thailand and the Philippines) and examples of not-so-successful cases (e.g. Nigeria, Kenya, Indonesia, and Tanzania among others);
c) It identifies factors influencing the success of rural electrification and captures lessons from various experiences.

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

The progress in the use of off-grid solutions for rural energy supply is more difficult to trace. This arises because of a number of factors:

a) their specific characteristics - small scale operation and demand-driven systems (Kaundinya et al, 2009) and dispersed nature of the installations make accurate data availability difficult without a significant cost;
b) bias in the available literature towards technical and project-implementation type reports (Zerriffi, 2008);
c) data bias arising from three factors identified by Zerriffi (2008) – lack of data for small projects, lack of data on older projects and possibility of biased information arising from data made available by participants or firms themselves.

Despite such difficulties, some general observations can be made as follows:

- Both conventional fossil-fuel based systems and renewable energies are used in off-grid and decentralised systems. According to World Bank (2008), portable 5-10 kW diesel generators are widely used as the conventional solutions and have been used among others in Cambodia (where more than 1000 enterprises have provided supply to more than 60,000 households), Guinea and elsewhere. Zerriffi (2008) indicates that this is also commonly used in the Brazilian Amazon. However, due to environmental concerns of diesel (or fossil fuel) use and the volatility in crude oil prices this solution is becoming less attractive.
- In the renewable energy side, while biomass and hydropower are used widely, according to IFC (2007) and World Bank (2008), the solar photovoltaic (PV) and the Solar Home Systems (SHS) have emerged as the preferred off-grid technology for rural areas. IFC (2007) estimates that between 0.5 and 1 million households in developing countries are using these technologies for their electricity needs. IFC (2007) indicates that through various projects supported by the World Bank and the IFC group, more than 1.3 million solar PV systems have been installed worldwide (see table 4). This has added more than 60 MWp capacity at a cost of USD 680 million. PV has emerged as the preferred off-grid technology not because of a bias by planners but due to its specific characteristics such as rugged construction, possibility of functioning virtually anywhere, and minimal maintenance requirement (World Bank, 2008).

- Small hydro plays an important role in certain countries. For example, it is reported in China Statistical Yearbook (2008) that more than 27000 hydropower stations are operating in rural China with a total installed capacity of about 14 GW. Outside South Asia, small hydro systems are also used in the countries along the Andes (Peru and Bolivia) and in the hilly areas of the Philippines and elsewhere.[2] Paish (2002) indicates that small hydro (<10 MW) contributes about 40 GW of electricity capacity at present but the potential is believed to be in excess of 100 GW. REN21 (2009) on the other hand indicates that the small hydropower capacity in 2008 reached 85 GW worldwide, with China alone adding 4-6 GW annually during 2004-08. However, the entire small hydropower capacity reported in the report does not seem to be for rural applications alone. Williams and Simpson (2009) suggest that even pico-hydro systems (less than 5 kW) could be a viable option for rural electrification.
- Biogas is another form of renewable energy used in rural areas. Yu et al (2008) reported that 17 million biogas installations in China produced 6.5 billion m3 of biogas in 2005 in rural households for use in cooking, lighting, water pumping and other applications. This replaced more than 4.6 Mt of standard coal and reduced about 14 Mt CO2 eq of GHG emission. Chen et al (2010) provide a more detailed account of the opportunities and constraints of biogas use in China and contend that the number of biogas installations has increased to 26.5 million by 2007 and the gas production increased to 10.5 billion m3. China clearly ranks as the top-most user of biogas plants in the world. Countries in South Asia (such as India, Sri Lanka and Nepal) also use biogas to a lesser extent. The use of biogas is also increasing elsewhere – such as in Vietnam, Brazil and Tanzania.[3]
- REN21 (2009) reported that pico-PV (i.e. systems of 1-5 Watts) along with ultra-low-power white LED has made a significant progress in recent times and a large number of producers have brought solar torch, one-piece solar lantern, and even small SHS. Such systems would have a greater appeal to the poorer section of the population and can make services affordable.

[2] See the Ashden Awards for Sustainable Energy website (see http://www.ashdenawards.org/biogas).
[3] This is indicated in the Ashden Awards for Sustainable Energy website (see http://www.ashdenawards.org/biogas).

Often the off-grid programmes are donor-led or supported. For example, electrification programmes such as Energising Development by Dutch-German governments (EnDev)[4] and World Bank projects in China, Bangladesh, Ethiopia and Sri Lanka are providing access to clean energies. While many countries are now recognising off-grid electrification as a possible option, the emphasis remains on grid extension and the off-grid solutions are used as pre-electrification or stop gap solutions. The following section will show that there has been very limited systematic effort in providing hybrid off-grid solutions to meet the needs of the rural communities.

Table 4: World Bank assisted solar PV programmes

Country	Number of installations	Solar PV capacity (kWp)	Cost USD (million)
Argentina	30000	2843	36
Bangladesh	198000	9900	91.4
Bolivia	60000	2600	38.6
Burkina Faso	8000	300	3
Cambodia	10000	400	4
Cape Verde	4500	129	2.5
China	400000	10000	144.9
Ecuador	2200	110	1.5
Ethiopia	6300	407	5.4
India	45000	2500	24
Indonesia	8500	425	3.8
Laos	4000	160	1.3
Madagascar	15000	625	7.5
Mali	10000	420	5
Mexico	37000	704	12.9
Mongolia	50000	520	5.2
Mozambique	9800	1096	13.5
Nicaragua	6000	21.5	3
Pacific Islands	21000	630	16.5
Papua New Guinea	2500	100	2.2
Philippines	139000	10000	113
Senegal	10000	420	5
Sri Lanka	104400	4176	36.1

[4] EnDev is a joint programme of the Dutch and German governments to enhance access of energy in developing countries. EnDev aims to provide access to 5 million people in rural areas and is being implemented by GTZ and SannterNovem. The programme started in 2005 and has undertaken 23 projects covering cooking energy, lighting, energy for productive use and for social infrastructure. More information is available at http://www.senternovem.nl/energising_development/general_information/index.asp.

Swaziland	2000	100	1.3
Tanzania	40000	2500	30
Other countries	84000		25.3
Total	1307200	51086.5	632.9

Source: IFC (2007).

In the subsequent sections the presentation will consider, wherever possible, off-grid applications.

3. Review of rural electricity and off-grid experiences outside South Asia

This section reviews the available literature on rural electrification with a specific focus on off-grid electricity supply in some countries/ regions outside South Asia. For each case, the following aspects are considered: history and present status of electrification, technology choice, organisational arrangements, financial sustainability, and lessons from the experience.

Zerriffi (2008) indicated that the literature on DG success/ failure can be categorised into three types:

a) Technology-specific literature indicating the potential and/or some experience of using them. Kaundinya et al (2009) refer to the following literature in this respect:
   a. Siyambalapitiya et al (1991) is an early study analyzing the grid-connected rural electrification options in developing countries. This indicates the low-load factor of domestic demand in rural areas as the main problem for grid extension.
   b. Reddy et al (1990) provide a comparison of grid and off-grid systems taking an Indian case.
   c. Bernal-Agastin and Dufo-Lopez (2006) have performed an evaluation of the Spanish case.
   d. Khan and Iqbal (2005) used HOMER software to analyse the economic feasibility of a hybrid system
   e. Kolhe et al (2006) analysed the economics of hybrid diesel-PV system for an Indian village context.

f. Chakraborti and Chakraborty (2002) analysed the case of solar PV for an island use in Sagar Dweep, India
g. Kumar et al (2003) considered the optimum plant size and cost of biomass use in Western Canada.
h. Rana et al (1998) considered the optimal mix of energy for a rural application in India.

b) Project-related literature at the village level reporting the implementation of a given technology and the outcome of such a project. Some examples in this category include: Cabraal et al (1996), ESMAP (2000a), ESMAP (2005), IEA (2003), IFC (2007), Lemaire (2009), Reiche et al (2000) and World Bank (2000).
c) Business models used - this is a relatively new category and is often overlapping with category 1.

In this paper we consider all the above types of literature.

3.1 Chinese rural electrification experience[5]

3.1.1 Status

China has a long experience of rural electrification and has been successful in providing access to 900 million people over a period of 50 years (Peng and Pan, 2006). But the success in rural electrification started since 1979 when the economic reform began from rural areas. Yang (2003) indicates that up to 1957, the rural areas in China accounted for only 0.66% of national electricity consumption but the level increased to 13.31% by 1978. Yisheng et al (2002) indicated that more than 50% of the farmers did not have access to electricity at that time and the per capita energy consumption in rural areas was one-fifth of that of the urban areas. But the country recorded a rapid growth in electricity use in rural areas since then and the share of rural electricity consumption increased to 31.55% by 1987. The country achieved a tremendous success in ensuring electricity access to 95.5% of households by 1997 (Yang 2003). However, Jiahua et al (2006)[6] indicated that rural electricity use in China is still less than one-half of that in the urban areas.[7] According to IEA (2010), about 12 million people lacked electricity in China by early 2006. The latest statistics from the National Energy Administration suggest that 2 million households still lack access – this represents a population of 9 to 10 million. The government intends to use off-grid and decentralized options to electrify the remaining areas by 2020.

[5] A separate working paper now analyses the Chinese rural electrification experience (see working paper 10). This section provides a brief review only.
[6] This report provides a detailed account of the developments in Chinese rural electrification and is a valuable source of information.
[7] 127 kWh per person on average in rural areas in 2004 compared 270 kWh in urban areas (Jiahua et al, 2006).

The electrification process in China has passed through a number of phases:

a) Centralised control between 1949 and 1977: Until 1957, the access of rural population to electricity was very low and only small hydropower was the main technology used but not much power was supplied to rural areas (Yang 2003). Between 1958 and 1978, the country saw a tremendous growth in rural electricity access and by 1978, 61% of the rural population had access to electricity. Decentralisation of rural electricity supply to local level organisations and promotion of electricity generation through small hydropower for irrigation, agricultural development and rural use through state funding prompted such a major transformation.
b) Market-oriented approach between 1978 and 1997: During the first decade of this period, the focus was on better rural living condition and economic development of rural areas. During this period, rural electrification efforts saw a step change and by the end of this period, 78% of the rural population had access to electricity. Industrial activities through town and village enterprises were promoted during this phase. Decentralised operation was continued but in addition to hydropower, thermal power based on coal started to gain importance. Between 1988 and 1997, electricity access was made almost universal and by 1997, 97% of the rural population had access. The efforts on rural development continued but specific programmes for access were also introduced. In 1996, the state enacted the Electric Power Law to implement preferential rural electrification in isolated or disadvantaged locations. In addition, the central government promoted rural water system development and use of renewable energies.
c) Modernisation phase: Since 1998, the effort was to modernise the rural infrastructure. In 1999, a reform of the management structure of rural electrification and introduced same tariff for rural and urban consumers. This has resulted in integration with the grid and better quality of supply. Electricity access reached in excess of 99% during this period.

3.1.2 Technology choice

The Chinese strategy for rural energy supply has focused on a number of energy sources:

a) biomass and biogas – Biomass plays an important role in rural energy supply in China but instead of traditional burning, bio-gasification has been promoted widely in the 1980s, making China the world leader in biogas production (Yisheng et al 2002). As indicated earlier, about 26.5 million biogas plants are currently being used in the country (Chen et al, 2010).

b) Mini hydro power – Rural hydropower policy was promoted in the economic reform era to empower rural population through utilisation of local resources. Small hydro served multiple purposes – produced electricity, provided irrigation water and supplied drinking water in rural areas. Incentives in terms of reduced VAT rate and state investment funds were provided to make this a success. This helped resolve the power supply problem in many areas and small hydropower accounts for more than one-half of the local generating capacity (Jiahua et al (2006).

c) Small coal mine development - Because of widespread availability of coal, China followed a policy of small, local mine development policy with an objective of reducing rural poverty. These mines were developed since 1950s but the big push came after the economic reform when the demand for coal increased. The price liberalisation of coal also gave a further boost to these mines but recently, the government has imposed a ban on these mines to reduce safety hazards and environmental degradation.

d) Development of modern renewable energies: This is a new initiative to use modern renewable energies like wind and solar power. Although these energies have been emphasised since 1990s, they have played a minor role until now but the government is providing incentives to make these energies attractive. Consequently, wind and solar energies are entering the energy system rapidly, but their share is still quite limited in the overall local generating capacity (Jiahua et al 2006).

Jiahua et al (2006) reported that rural electrification relied on three modes of delivery: local grid-based, central-grid based and a hybrid system of local and centralised grids. Local grids played an important role in areas with large hydro potential where county water bureaus or small hydropower companies are responsible for electricity supply. However, the dominant mode of supply remains the extension of central grid (about 2/3rd of the counties relied on this as per Jiahua et al (2006)) but due to high cost of transmission and high losses of this mode, rural consumers either face shortages or are unable to afford electricity from the grid. This has also prevented the development of local resources in these areas. The third mode is used in areas where hydropower is inadequately available to meet local demand. ESMAP (2000a) noted that the delegation of electricity provision to local power companies in the first instance and then integration of the local grids to the central system has allowed the Chinese system to accomplish a higher rate of access.

3.1.3 Off-grid solutions

In terms of off-grid or decentralised solutions, two modes of operation are prevalent: stand-alone systems and local-grid systems. While local grid was developed in hydro-dominated areas, the integration of local-grids to the distribution systems has now transformed the system as grid-based ones. However, the stand-alone systems are still continuing in remote areas. This is being discussed below.

Stand alone systems are mainly used in remote areas of North and Northwest China and include provinces such as Gansu, Inner Mongolia, Qinghai and Xinjiang. Photovoltaic systems are being used in these areas since mid-1990s. Three different types of supply mechanisms of PV exist in these areas:

a. Distribution companies that procure major components from manufacturers directly;
b. Small assembly shops selling directly to installers, and
c. Retailers directly selling to end users (ESMAP 2000a, p. 27).

Initially state enterprises were involved in the business and systems were sold with a large subsidy component. However, the subsidies were removed or reduced and many small companies have entered the market to sell the products on a commercial basis.

The size of the PV systems used in these areas is generally small: 10 to 20- watt systems catering to the lighting needs and powering television or a radio-cassette player. Only a few larger systems were used of 50-75 watt size. However, the consumers were not always happy with the system performance and servicing of the systems. In recent times, the average size of the modules has increased: according to World Bank (2009), between 2002 and 2007, the average size has increased from 20 Wp to 45Wp.

Brightness Programme was launched in 1996 to ensure electrification of 23 million population living in remote areas through decentralized options by 2010. Wallace and Tsuo (1997) report the PV-based electrification initiatives undertaken in co-operation with US Department of Energy in western China (see section 4.1). They report that in 1995, the PV installed capacity in China was 6.6 MWp, 65% of which was for telecommunication applications, 16% for household electrification, 11% for agricultural and industrial applications while remaining 8% was for consumer applications.

In Inner Mongolia Autonomous Region (IMAR) small wind generators (100 to 300W) have been used in more than 120,000 households for providing electricity by 1994. Similarly, more than 7000 small PV systems have been installed within that period. They report the result of the levelised cost study undertaken for the region by CEEP (University of Delaware) and indicate that the cost of small wind-based electricity was lower than PV/ Wind hybrid systems and much lower than that supplied from the gasoline generator sets.

Wang (1998) reported that remote areas of North and Northwest were the target regions for SHS installation. China imported production lines from USA, Canada and other countries since 1983 and by 1996, China had a PV manufacturing capacity of 5 MW per year. 30,000 households installed the systems. The government provided subsidies but this accounted for only 5 to 10% of the costs. Only those with a high income level could afford to own a SHS with the subsidy. Moreover, as the users are less knowledgeable and less educated, the systems were operated and maintained poorly, limiting the life of the systems and producing poor experience.

A recent report, World Bank (2009) provides further details about the renewable energy development in China. It claims that more than two million people in western China are receiving electricity through PV systems. Between 2002 and 2007, companies have reported a total sale of more than 0.5 million PV systems with an aggregate capacity of 11.5 MWp. Four provinces account for the majority of these sales: Tibet, Qinghai, Sichuan and Xinjiang. The annual sales and PV system costs are indicated in table 5.

Table 5: Annual PV sales and costs in China

Year	Sales		PV system costs	
	Annual (MWp)	Cumulative (MWp)	Per year (million US$)	Cumulative (million US$)
2002	0.80	0.80	6.6	6.6
2003	0.90	1.70	7.5	14.1
2004	1.73	3.43	14.3	28.4

2005	2.68	6.11	22.2	50.6
2006	2.45	8.57	20.3	70.9
2007	2.50	11.07	20.7	91.6

Source: World Bank (2009).

China is the world's third largest producer of PV modules with a production capacity of 2800 MWp in 2007 systems. The unit price of a 20Wp system has declined in dollar terms to $9/ Wp in 2007 from $16/ Wp before the project.

3.1.4 Organisation and financial viability of electrification

The organisational arrangement for rural electrification has changed significantly over the past fifty years[8]. Yet, the country still follows three levels of management – central government, provincial government and county or village level committees. At the Central level, traditionally a multitude of organisations have played a role but the Ministry of Agriculture and the State Planning Commission (or its new avatar National Development and Reform Commission) have always played an important role. In general, all programmes require NDRC approval. The provincial level management caters to the province level efforts but also supports the county level management in achieving the central government objectives. The county level management is responsible for the local-level decision-making about financing, resource mobilisation and operation of the systems (Catania, 1999).

In fact, in the first period of rural electrification, there was no national entity responsible for rural electricity system management or development (Pan, 2002). The role of local government was strengthened in the era of reform, when the central government transferred the responsibility of rural electrification to local governments. However, the tariff-setting power was still with the central government and in the mid-1980s, a policy of dual tariff system was introduced whereby old plants get old tariff while new plants are allowed new tariff (Pan, 2002). This was done to encourage new investment in the sector. Management through the decentralised local governments was a main driving force behind the success of rural electrification in China (Pan et al, 2006). Each country created a rural electrification leading group led by the local chief administrative officer (county governor) to take important decisions on rural electrification investments and operation. However, the distinction between the utility function and the local governance function was non-existent, which in turn led to performance-related issues subsequently.

[8] See Zhao (2001) for a detailed account of the organisational changes in the energy sector.

Due to the clash of interests and power tussles between the central government and local governments experienced towards the end of the 1980s and early 1990s which posed a great threat to the rural electrification drive of China, the central government took over some responsibilities and powers hitherto devolved to the local governments during the transition era 1980 to 1992. The period 1993 to 1998 ushered in another wave to institutional restructuring towards re-positioning the central government to effectively control the production and consumption of energy in the nation’s economy. Here, the Ministry of Energy was broken up, and in its place, the State Economic and Trade Commission (SETC) was established, while the State Planning Commission (SPC), currently the State Development Planning Commission (SDPC), and Ministry of Coal Industry and Ministry of Electric Industry (MEI) were re-established (Zhao, 2001). Though existing Ministries and Government Corporation were equally expanded and strengthened during this era, and controls over investments, consolidated by the central government, there was the challenge of effective coordination of these agencies and duplicity of policy implementation, which triggered criticisms amongst energy experts in China.

In the case of decentralized electrification, the project implementation is done through competitive bidding. State companies, private entities and former state companies as well as start-ups participate in these activities. The National Energy Administration (NEA) normally deals with the planning related to rural electrification.

The government arranged funds from the Agricultural Bank of China for rural grid construction and transformation. In addition, grants, loans, in-kind contribution are also available. In 1987, the government created a special interest-bearing loan for rural electrification which was used for large biogas plants, solar thermal and small-scale wind projects. The interest was 50% subsidized by the commercial bank. But the decentralized electrification is either fully financed by the central government or through a cost-sharing scheme where the provincial government contributes a share. The Township Electrification Programme which supported off-grid electrification in 11 provinces was a joint financing scheme where the share of central contribution was determined by the level of socio-economic development. In certain provinces, 100% central contribution was available (e.g. Tibet).

3.1.5 Lessons

The success story of China in providing such a high level of electricity access to a large rural population remains perhaps less analysed and studied. Yang (2003), and Zhang and Heller (2004) suggest that the central government policies played an important role in promoting rural electrification. Peng and Pan (2006) argue that funds for rural electrification flowed from central and local governments and even local residents participated in providing funds. Yang (2003) and Peng and Pan (2006) also suggest that the decentralised, local level management of rural electrification initiatives and the emphasis on rural development through agricultural activities, town and village enterprises and poverty reduction programmes were also responsible for the success of the country.

According to IEA (2010), the success of electrification can be attributed to the pragmatic approach which allowed local level administrative responsibility of the projects while retaining the overall programme planning at the central level. Government's commitment to the programme was crucial for its success. Technological flexibility has also allowed local resource utilization and avoided highest cost options for difficult locations. The sense of local ownership has also ensured success of projects in remote areas.

However, World Bank (1996) attributes the success to rural development initiatives that have transformed the rural economies and thereby increased rural income greatly. Dollar (2008) pointed out that with sustained economic growth China has been successful in reducing its poverty from over 60% in 1978 to 7% in 2007. He attributes this to a liberalised agricultural sector, existence of a vibrant private sector, and infrastructure pricing based on cost –recovery principles. Dollar (2008) indicates that although the state invested initially in creating the infrastructure, the pricing system ensured almost full cost recovery, which in turn allowed future sustainability of the system. He points out that increased private participation also supported this growth and in fact, cost recovery allowed domestic private sector to achieve a significantly better financial result.

China Statistical Yearbook (2008) indicates that in 2007, only 4.4% of the rural population had a per person income of less than 1000 Yuan while in 1990 the share was 82.3% in 1990. About 50% of the rural population had a yearly income between 1000 and 5000 Yuan per person in 2007 while another 31% had an income above 5000 Yuan per person per year. This shows the change in the economic conditions of the rural habitants. As a consequence, the holding pattern of durable goods has changed dramatically. For example, in 1990, air conditioner was not at all used in the rural areas but in 2007, 8.5 units of air conditioners are found in every 100 households. Similarly, the number of washing machines and refrigerators has multiplied manifolds: in 1990, only 9.1 and 1.2 units respectively of washing machines and refrigerators were found in every 100 households while in 2007, the number has increased to 45.9 and 26.1 respectively (China Statistical Yearbook (2008)).

However, rapid electrification brought problems as well. It led to tariff inconsistency, overlapping responsibilities, poor technical quality and small capacities suitable for limited level of applications. For Brightness Programme/ Township Programme, the use of inappropriate materials/ designs has resulted in a high rate of system malfunctions. For Township programme, issues like transfer of ownership, management and maintenance of systems, financial support for the long-term and tariff in the future etc. are not clear. Because some technologies were never deployed in a large scale, their long-term future is unknown (IEA, 2010). The increase in demand is putting pressure on subsidies and there is no mechanism for determining the real cost of off-grid electrification.

3.2 Experience from SE Asian countries

South East Asia provides a rich experience of successful electrification. Countries like Thailand and Malaysia have achieved complete electrification and even Vietnam has made tremendous progress despite being a relatively poor economy. Other countries such as Indonesia and the Philippines provide contrasting examples from two archipelagos who have attempted to electrify their islands in different ways. In this section, a review of four countries is presented, namely that of Indonesia, the Philippines, Thailand and Vietnam.

3.2.1 Indonesia

3.2.1.1 Status

Indonesia is an archipelago of more than 17000 islands, of which 6000 are inhabited. There are many small islands outside the main inhabited islands and accordingly, the extension of an integrated grid-based supply is a major problem. Indonesia is one of the most populous countries in South East Asia and has 18% of its population below the poverty line. Thus poverty coupled with its geographical configuration makes access to electricity a major issue.

The government has placed high priority to rural electrification and balanced development. However, Indonesia remains one of the poor performers in South East Asia in terms of electricity access. According to IEA (2010), 35.5% of the population did not have access in 2009, of which more than 50% live outside main islands. The country plans to electrify 90% of the households by 2020 and it is estimated that this requires extending 1.3 million new connections every year (Indonesian National Committee of the IEC, 2007). It is reported that an investment of $4.6 -6.4 billion is required to address the challenge but such an investment is outside the financial capability of the state utility (USAID, 2008)

The national electric utility PLN is the main provider of electricity in the country and was responsible for rural electrification. The country has electrified itself quite rapidly between 1980 and 1995, when the rate of electrification increased from 7% in 1980 to 43% in 1995 (Indonesian National Committee of the IEC, 2007). However, PLN was focusing mostly on densely populated areas of Java-Bali-Sumatra-Kalimantan-Sulawesi areas, where the rate of electrification was much higher compared to the rest of the country (see table 6 for details). The Asian financial crisis in 1997 has adversely affected the Indonesian electricity sector and left PLN financially weak. This together with its inability to recover costs of electricity supply forced PLN to focus on its existing business and to minimise losses, rather than undertaking rural electrification as a social objective. Since 2003, PLN has stopped reporting its rural electrification activities and considers that it is the responsibility of the Ministry of Energy and Mineral Resources (World Bank 2005). According to World Bank (2005), the possibility of grid extension as a solution to increase access is an unlikely solution in the present Indonesian context and the country is unlikely to achieve its electrification targets if it continues with the existing electrification policies. Even PLN estimates that grid extension is unlikely in the near future for about 6000 villages (Draeck, 2008).

Table 6: Electrification rate in major Indonesian islands in 2004

Island	Population (million)	Electrification rate (%)	People without electricity access (million)
Java	128.7	74%	33.6
Bali	3.4	86%	0.5
Sumatra	45.3	57%	19.4
Kalimantan	11.9	59%	4.9
Sulawesi	15.6	61%	6.1
Nusa Tenggara	8.2	33%	5.5
Maluku	2.1	54%	1.0
Papua	2.3	22%	1.8
Total	217.7	67%	72.7

Source: World Bank (2005) and USAID (2008).

The country has also faced uncertainties in terms of legal framework for the electricity sector. In 2004, the Constitutional Court annulled the Electricity Law 20/2002, which as a consequence disapproved all reform initiatives. This has reduced investor confidence and has rendered private investment difficult (World Bank, 2005).

3.2.1.2 Technology options

Indonesia has relied on both conventional and renewable energies for its electrification. Fossil fuels account for 80% of the electricity generation in the country while hydropower and geothermal account for the rest. The main emphasis was on extension of the electricity grid but Indonesia has also experimented with other options including mini-hydro, geothermal, solar PV and hybrid systems. PLN has generally used diesel generator sets for rural supply in dispersed areas and maintained a fleet of at least 30,000 diesel generators, with a capacity of 500 MW (USAID, 2008). However, the cost of diesel-based electricity is much higher than the revenue received from the consumers, which in turn makes the utility financially weak.

Indonesia is blessed with substantial renewable energy resources. The country has significant hydro potential (75,000 MW), geothermal potential (27,000 MW), as well as biomass, solar and wind power potential (Draeck, 2008) but only a small fraction has been developed so far due to high upfront cost, infrastructure deficiency and non-remunerative tariffs (USAID, 2008). Despite a number of initiatives solar PV has not reached the poorer section of the population. Draeck (2008) estimated that only 0.016% of the Indonesian households use PV systems, which is much lower compared to other poorer countries such as Sri Lanka and Kenya.

3.2.1.3 Off-grid solutions

Draeck (2008) and Retnanestri et al (2003) provide an overview of off-grid status in Indonesia and present the lessons from the past experience. Indonesia experimented with off-grid solutions for remote rural areas since the 1980s. By 2000, 5 MWp of power was produced from PV applications. Retnanestri et al (2003) categorized these initiatives into three phases:

a) Experimental – 1979-1986 when a number of PV systems were installed for water pumping, ice-making, telecommunication repeater and buoy lighting.
b) Pilot/ demonstration- 1988-93 when 1600 PV systems were installed in Sukatani, Lebak and West Java as pilot projects;
c) Multiple demonstration – The BANPRES project was launched in 1990 to install 3140 PV systems in 13 provinces. By 1997, 30,000 PV systems were installed by various agencies under the demonstration phase. In 1997, the government launched 50

MWp one million roof programme in which GEF, AusAid and BIG SOL projects participated.

Draeck (2008) suggested that the PV market in Indonesia can be grouped into three segments: high market regions where the consumers have a relatively high per capita income (above $1000 per year), medium market regions where the consumers have an average income between $500 and $1000 per year and low income regions (income below $500 per year). In the low income areas and with seasonal income, the issue of affordability is more acute. The off-grid initiatives can be grouped into two groups: government-driven and private-driven.

Government-driven initiatives

In 1991, BANPRES, or Presidential Assistance Project was launched and 3300 SHS were installed through this (Cabraal et al, 1996). The project received grants from the Presidential Development Budget and was implemented in 13 provinces. A government agency, BPPT (Agency for Assessment and Application of Technology) was leading the implementation of the programme. The Village Co-operatives (KUD) were the village level delivery agents and were responsible for project implementation, fee collection, maintenance and disconnection of services for non-payment. The Ministry of Co-operatives was involved in providing the link between the local KUDs and the government. A state bank, BRI (Bank Rakyat Indonesia) participated in the scheme because of its widespread presence in rural areas (Cabraal et al, 1996).

The programme identified the villages to be included in the programme using a set of criteria: affordability and willingness to pay of the consumers, grid extension possibility, location relative to the KUD, etc. Once a village is selected, villagers received the system upon becoming a full member of the KUD and agreeing to sign a lease-purchase agreement by paying the stamp duty. The KUD upon receiving the down payment then engaged a private supplier to install the system. This consisted of a 45-48 Wp PV panel, supporting structure, two fluorescent lights, an automotive battery, required wiring and control equipment and a 12V DC outlet. The system is capable of generating 145 Wh/day with 6 hours of bright sunlight and could run two lamps for 7-8 hours or 5 hours of light and 5 hours television. Consumers pay an initial payment of Rp 50,000 and a monthly fee of Rp 7500 for 10 years. The KUD retained Rp500 per month towards its costs and deposited the rest to a Revolving Fund maintained at the Bank. In contrast, commercial terms for private supply of SHS to affluent consumers were Rp 200,000 of initial payment and a monthly payment of Rp 20,000. However, the collection rate was about 60% (Cabraal et al, 1996).

The success of the programme led to semi-commercial initiatives for installation of 20,000 SHS in the country and is considered to be the predecessor of "50 MWp one million roof programme". Retnanestri et al (2003) contended that one of the pilot PV projects in Indonesia was Sukatani project in West Java which was initiated in 1988 when 102 PV lighting systems were installed. Users continued to use these systems even when grid was extended to the area after 15 years. However, Draeck (2008) indicates that the overall experience in Indonesia in terms of solar PV was disappointing. Although 300,000 to 350,000 PV systems have been installed in the country, only a small fraction of them is working, and the system components are recycled back to the second-hand market. The state utility identified about 6000 villages in remote areas where grid connection is unlikely to reach in the near future. The potential for off-grid systems in these areas remains high but the progress has been limited.

In addition, mini-grids are being used in 20 regencies, each serving 30 to 100 households with a typical capacity of 5kW (Draeck, 2008). Hybrid options using PV and diesel generators or wind-diesel generators have been tried. Under the Australian Aid programme, such a project involving an 8kWp solar PV and a 25 kVA diesel generator to electrify 200-250 households was carried out. The generator operates during the peak and inter-mediate load conditions. This solution has been experimented in five villages of Central Sulawesi and in 6 islands (Akhmad et al, 2008).

Retnanestri et al (2003) report that PV lighting systems have been used for economic activities like solar boat lighting, egg incubator and indoor/ outdoor lighting for chicken barns. In Jangari village of East Java, fishermen are using PV lights for floating fishing nets on the Cirata dam since 2000 that replaced electricity from polluting diesel engines or batteries. The users procured these systems under a semi-commercial scheme.

Private initiatives

IEA (2003) provided two examples from Indonesia where two private entities supplied solar home systems in the Indonesian market.

PT Sudimara, Indonesia: Between 1993 and 1998 this company, which was earlier known as R&S and was owned by Shell Renewables, was supplying SHS in Middle-Java, West Java, Lampung and Jambi. It stopped operation after the financial crisis of 1998. They offered both cash sales and a hire-purchase option. The company carried out the installation at the consumer premises and undertook the collection of monthly payments for hire purchase sales. They offered a 40 Wp SHS and produced the BOS locally. The price was about $400 and charged a down payment of 20%, with the rest spread over a maximum of 3 years carrying an interest of 20%. The system ownership was transferred to the consumers upon full payment.

The company operated about 65 branches and each branch covered an area of 45 km radius. The company faced credit management problems as it grew and overheads increased. Raising loans or credit from banks was difficult in absence of collaterals.

PT Mambruk Energy International, Indonesia: Mambruk started its operation in 1998 and has achieved a significant level of sales. It operates a cash sale and a hire-purchase sale through Sales and Service Centres (S&SC) and their appointed agents or outlets. S&SC places a batch order for units and arranges for their sales through its agents or outlets. The consumer upon entering into an agreement and upon payment of required charges receives the unit which is installed by the technician of S&SC. The company has experimented with alternative payment collection schemes - collection through debt collectors and payment with a trusted person in the locality who received a commission. A system in 2001 cost USD 320 and required a down-payment of 25% which can be spread over a three month period and a monthly fee spread over a maximum of 30 months.

Draeck (2008) reported that PT Mambruk and Shell Solar participated with BRI in the village credit scheme and supplied 1000 SHS units each in the plantation area where farmers have regular income streams.

3.2.1.4 Organisation and financial viability of electrification

As indicated above, the state utility is the main agency used in the electrification process. The funding for rural electrification was provided by the state, which was utilised through the PLN. In the off-grid projects, both state and private entities operated, and the donor agencies have played an active role in providing support and conducting pilot projects. The government provides subsidy for SHS based on the level of income and location but this has put a subsidy burden on the state. Also, the financial difficulties of the state affected its commitment towards financing.

Retnanestri et al (2003) reported that Indonesia classifies the consumers into three categories – under developed, more developed and developed economic standing. According to them, demonstration projects are important for the first two categories whereas semi-commercial projects are useful for the third category. In a demonstration project, government or donor agencies support the revolving fund used to finance the project whereas in a semi-commercial project, consumers contribute significantly to the cost recovery. In a demonstration project, rural cooperatives provide the support service whereas in a semi-commercial operation, consumers deal directly with the dealer.

3.21.5 Lessons

Although Indonesia has shown commitment to rural electrification and use of renewable energies, it remains one of the weak performers in the region. Even the Philippines, having very similar geographic conditions (island state), has been more successful in providing electricity access. Based on Retnanestri et al (2003), Draeck (2008), USAID (2008) and World Bank (2005), the following lessons can be highlighted:

- Limited growth despite huge potential: Indonesia offers huge potential for off-grid solutions because of its geographical location and its configuration (island country). Although Indonesia has experimented with the PV technology and other options, the country did not make a substantial progress in its rural electrification compared to its neighbours or countries in similar positions. Lack of government commitment due to financial and political difficulties faced by the country, reliance on the state initiatives mainly through the national power company and lack of local participation in the programmes have affected the success.
- Tariff and subsidy issues: Indonesia offers fuel subsidy and other supports for conventional fuels and its electricity tariff does not ensure cost recovery for the electric utility. Poor financial condition, lack of access to private funds and dwindling state support for social projects have affected the electrification efforts of the national electric utility.
- Regulatory confusion: The annulment of the reform-oriented electricity act and the subsequent regulatory confusion has also slowed down the electrification process. This has affected the private investment climate and consequently, governance issue has emerged as a major concern.
- Second-hand PV market – A second hand PV market is active in Lampung. Local entrepreneurs are buying or collecting used sets from places where such systems have become redundant due to extension of grid connections. They sell these used items upon repair and replacement of components where necessary. This is reported to be a profitable business and is thriving in this area but raises the issue of theft, corruption, ability to repair parts and availability of suitable components.
- BoS manufacturer – Indonesia has been successful in creating a vibrant balance of system (BoS) manufacturers who provide the components and assemble imported parts. This has led to an export market for these components as well.

3.2.2 The case of the Philippines

3.2.2.1 Status

According to IEA (2010), the overall electrification rate in the Philippines was 89.7% in 2009, with only 9.5 million without access to electricity. IEA (2009) indicated that 97% of the urban population and 67% of the rural population have access to electricity. However, according to the National Electrification Administration, the country achieved 100% electrification of urban areas and 99% electrification of other areas, although 77% of the households have access to electricity (NEA (2010)). Clearly, despite the differences in the coverage of the above two definitions[9], the Philippines has recorded an impressive rural electrification performance. This is even more impressive considering the fact that the country is composed of more than 7000 islands, some of which are far-fetched from the main area of inhabitation. The present target is to achieve 90% household electrification by 2017 and a four-year revolving development plan is being used to achieve this target.

3.2.2.2 Technology choice

The main mode of electrification is the extension of the electricity grid. The Electricity Co-operatives (EC), created in the 1960s, generally manage the local grid and distribute electricity in their areas. A specific group called Small Power Utilities group (SPUG) of the National Power Corporation produces most of the power for small and isolated islands. Other generators include independent power producers, new power producers, local government units, qualified third parties and community-based generators (DOE, 2008). SPUG operated 304 generating units in 78 small islands with a generating capacity of about 130 MW. Most of this capacity comes from diesel generators – either land-based or barge mounted. It also operates a micro-hydro plant and a hybrid renewable energy farm (DOE, 2008). Co-operatives generally buy power from SPUG and distribute it through their distribution systems.

However, for remote rural areas where extending the grid is not cost effective or is not likely to materialise in the near future, off-grid solutions have been used. Mini-grid system has been used in such areas. Mini/ micro-hydro power was the preferred energy source where hydro potential exists. Similarly, geothermal power has also been exploited where available. Otherwise, new renewable energies such as solar power, wind and biomass have been used, although the development in these areas remains slow compared to other technologies. SPUG operated 8 isolated grids in 2008 (DOE, 2008).

[9] The NEA considers an area electrified based on the concept of accessibility. If it is possible to supply a customer upon request even if it is not electrified, the area is considered as electrified. Thus in an electrified area there can be households without actual connection to the grid or supply.

Heavy reliance on diesel for small-scale power generation imposes cost burden on the utilities of an oil importing country. The price fluctuations in the international market affect the overall cost of production and the viability of the business. This imposes in turn a heavy subsidy burden on the government.

The Philippines is however endowed with significant renewable energy resources. It has the largest potential for wind power in South East Asia and can support about 700 MW of capacity. It has large small hydropower (~1800 MW) and geothermal power (1200 MW) potential. It is also the largest solar manufacturing hub in South East Asia. But the progress in renewable power development has been slow.

3.2.2.3 Off-grid options

The country has a long experience with PV technology but often as a pre-electrification strategy rather than a permanent solution. A few examples are given below:

a) In 1982, a collaborative programme with German assistance installed a 13 kWp plant under Philippine-German Solar Energy Project (PGSEP). However, the plant was uneconomical due to its high capital cost and the demand grew faster than the plant could supply.
b) The above programme however led to the next phase of development under Special Energy Program (SEP) in 1987 (Cabraal et al, 1996). SEP relied on the SHS-based electrification and developed a village selection criteria based on the following (Cabraal et al, 1996):
    a. Area not included in the near-term electrification plan;
    b. Existence of an approved rural electrification cooperative for program implementation and fee collection;
    c. At least 20 users in a cluster within a day’s travel time;
    d. Ability and willingness to pay the fee;
    e. Existence of a local association or NGO to take responsibility of collection, maintenance, monitoring and access to the areas at all conditions.

The SEP procured the SHS and supplied to RECs who sold to the consumers upon payment of charges for BOS (balance of systems) and on agreeing to pay monthly charges. A typical system consisted of 53Wp panel, associated controllers and converters, a lead-acid battery, and five lamps. The system could generate 130 to 206 Wh per day that was sufficient to light one or two lamps for few hours and operate a radio (Cabraal et al, 1996).

The entire system except the panel is locally produced but the quality was a major problem. The REC technicians are responsible for installation and maintenance or trouble shooting while the NGO or local association collected the fees and monitored the performance of the systems.

The price of the system was 23,000 pesos (USD 900) in 1995. The imported components were exempt from duties and taxes. The SEP created a revolving fund to fund procurement of new units. Only 10% of the households could procure the SHS in cash terms but another 20 to 60% could afford with an appropriate financing mechanism while the rest could not afford the SHS but could buy a battery.

c) In 1991, with GTZ support, NEA initiated a “pre-electrification project” by installing SHS in remote households through the electricity co-operatives. This project installed about 2000 systems but was a one-off exercise (ESMAP, 2001a).
d) An Australian aid-funded project supported installation of 1000 packaged PV systems in 390 villages for community infrastructure development (ESMAP, 2001a).
e) The Renewable Energy Power Program (REPP) was the most important government initiative in promoting renewable energies in the country. This was initiated in 1993 and aimed to support small renewable energy power projects up to 25 MW by providing finance up to 750million pesos. A task force under the Department of Energy was created and the department guaranteed the purchase of electricity produced from the renewable projects under the programme. Although this generated a significant amount of interest, the project faced difficulties and delays, and was never successfully launched (ESMAP, 2001a).

However, most of the initial experiments did not produce promising results either due to their limited scope or one-off nature of the intervention. In 2008, the Renewable Energy Act was enacted and this provided support for renewable energy development in the country through feed-in tariffs, renewable portfolio obligations and Renewable Energy Market creation. Additionally, market incentives are being provided to support on-grid and off-grid use of renewable energies.

To achieve the target of 90% household electrification by 2017, the Department of Energy has planned to provide 200,000 SHS in remote areas under its SWITCH programme which supports a transition from kerosene to a renewable energy for lighting. The Department will provide P8000 per SHS and P1500 per lantern (DOE, 2008).

3.2.2.4 Organisation and financial viability of rural electrification

The government initiatives for rural electrification in the Philippines started in 1960 when the Electrification Agency was set up. The electrification process started with government support and low-cost financing available at the time. Initially, the country established small systems (each of less than 500 kW capacity) and by 1969, there were 217 such small systems (ESMAP, 2002). But due to financial and technical problems, most of these systems failed and were closed down. Consequently, only 18% of the population had access to electricity by early 1970 (ESMAP, 2002).

The second phase started in 1969 when the National Electrification Act was passed and the Electrification Agency was reorganised to create the National Electrification Administration (NEA). The private utilities played an important role in the electricity sector of the country but they mostly focused on the urban areas, which created a significant urban-rural gap. NEA decided to promote the Rural Electrification Co-operatives to enhance electricity access in rural areas. This gave impetus to the electrification process and during the next two decades, the country recorded significant progress (ESMAP, 2002). By early 1990, the country reached 100% electrification in the municipal areas. But the electric co-operatives faced financial difficulties in pursuing the electrification goals due to drying up of low-cost funds. The cooperatives were designed along the US model of rural electric cooperatives but the Philippine co-operatives cannot request members to contribute funds beyond their initial subscription payments. Accordingly, they were totally dependent on NEA funding for their operations. Subsequent to reform of the sector in 2002, the government did not allow NEA to borrow additional funds for lending to co-operatives, which in turn affected their access to capital.

Prior to the reform of the electricity sector in 2002, the country was served by 139 distributors, of which 20 were investor owned and 119 were electricity co-operatives, each covering a specific area franchised to them (ESMAP, 2004). Upon reform in 2002, the country has adopted a competitive electricity market model but the reform progress has been slow. In 2003, the government launched the Expanded Rural Electrification Programme to achieve 100% electrification by 2008 (extended to 2010 afterwards) and 90% household electrification by 2017. The programme focuses on a combination of approaches including extension of distribution network, setting up of micro/ mini grids and the use of off-grid systems. The programme has allowed participation of non-government and non-utility agencies in electricity provision and resource generation by involving qualified third parties (QTP). Where a co-operative or a franchisee finds it unviable to provide electricity, the Missionary Electrification project is undertaken, which receives a continuous flow of subsidy from a fund created by levying a universal charge, set by the electricity regulator, on electricity users. For off-grid electrification, innovative delivery mechanisms are being used to reach the dispersed population (DOE, 2008).

3.2.2.5 Lessons

The experience of the Philippines 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. However, ESMAP (2004) indicates that the performance of ECs is not uniform and the difference in the performance cannot be explained by common driver variables such as differences in the consumer density, area or per capita income of consumers. The report suggests that the governance and management of the cooperatives is responsible for such variations. The performance has been impressive where the local participation was high.

The reliance of grid extension as the electrification method has resulted in a high cost solution and poor financial viability of the co-operative system. In addition, the experience with private investors in the rural areas has not been long enough to come to any conclusion. It is also surprising that despite having the geographical advantage and huge renewable energy potential, the off-grid options have not been attempted beyond the donor-government sponsored schemes. However, ESMAP (2002) indicated that the benefits derived from electrification outweighed the costs incurred in the process.

Another important lesson is that the country has relied on both state support and market-based mechanisms to enhance electricity access. Similarly, it is relying on market-based mechanisms to a large extent to promote renewable energies. There is need for a more detailed study to appreciate the developments in this country.

3.2.3 Other South East Asian countries

3.2.3.1 Thailand

Thailand's rural electrification is considered a success story. Its grid-based rural electrification programme, which began in 1974, has increased the number of electrified villages from 20% to 99% by 2004 [Harnboonyanon, 2005]. Three distinct development phases in Thai rural electrification can be identified:

a) Initial stage between 1964 and 1975 – This phase relied essentially on diesel generators on a limited scale and by 1975 only 20% villages had access to electricity.
b) Accelerated rural electrification programme between 1975 and 1996 – This period saw an expansion of the grid and resulted in a rapid growth in electricity access. As a consequence, 44% of the villages were electrified by 1981 and by 1986, 75% of the villages received electricity (Harnboonyanon, 2005). By the end

of the programme by 1996, 98% of the villages were electrified. The success of this programme has been mainly due to the integrated and systematic planning process set in accordance with the National Plan with emphasis on expansion of electrified villages all over the country as soon as possible. To complete the task, PEA took some initiatives like reducing capital investment cost by actively minimizing the losses (especially theft), high bill collection through village leaders, cross subsidy from urban to rural, bulk tariff subsidy, community involvement, and reducing construction and operating cost.

c) Household electrification programme – Since 1997, the focus has changed to electrifying households and more than 550,000 households were provided electricity access in two phases. Only less than 1% of the households lacked electricity by 2004 and most of these households are located in national parks, forests, islands, etc. These were to be electrified using solar home systems.

Rural electrification in Thailand was carried out by the Provincial Electricity Authority (PEA). PEA used a pragmatic approach towards electrification. It used a ranking scheme to decide the village electrification decision. This was based on the following seven components: 1) proximity of the grid, 2) accessibility by road, 3) village size, 4) number of expected customer in the first five years, 5) potential agriculture and industrial loads, 6) number of commercial establishments, and 7) extent of public facilities (ESMAP, 1997). PEA accelerated a village selection if that village was willing to make a larger contribution to the construction cost. 17,681 villages out of 70,726 contributed 30% but only 707 villages contributed the full amount (ESMAP, 1997). However, there are some evidences that most of these contributions were paid by a few individuals and by politicians securing local development funds (World Bank, 2000).

Harnboonyanon (2005) identified the following key success factors behind the Thai success:

a) Standardised technical design: PEA used a standard technical design for all rural areas that was easy to use and replicate.
b) Simple construction standard: The delivery was based on a simple standard and involved private contractors to provide the supply.
c) Financial support – The electrification programme received generous financial support from the government, local people, donor agencies and international funding agencies. This support ensured a rapid development of the system.

d) Cross-subsidy - The development was supported by a tariff policy that ensured cost reduction for the rural consumers. The cross-subsidy was provided at the wholesale level for rural consumers from the urban consumers.
e) Dedicated organisation – PEA was a dedicated agency for the provision of electricity in the rural areas. This separation of responsibilities and organisational arrangement ensured a concerted effort on rural electrification.

Yet, Thailand also faced a number of constraints. The financial viability of rural electrification programme was an issue, given the heavy investment in developing rural electricity infrastructure and poor revenue potential due to low demand. The non-availability of adequate infrastructure for transportation of equipment and materials was another issue. The cost of revenue collection and regular meter reading was high for PEA and this affects the financial viability of rural system operations. Finally, the reliability and quality of supply was also a problem (Harnboonyanon, 2005).

However, Thailand essentially relied on grid extension and has used off-grid options only in a limited scale. Two technologies were used for off-grid electrification – micro-hydro systems and more recently solar home systems. The micro-hydro systems were initiated in early 1980s and used in the northern areas of Thailand. Only in the third phase of Rural Household Electrification in 2004-05 the solar home systems were introduced to electrify the remaining households. The experience with these systems has been mixed at best, with poor quality and poor performance affecting the overall benefits.

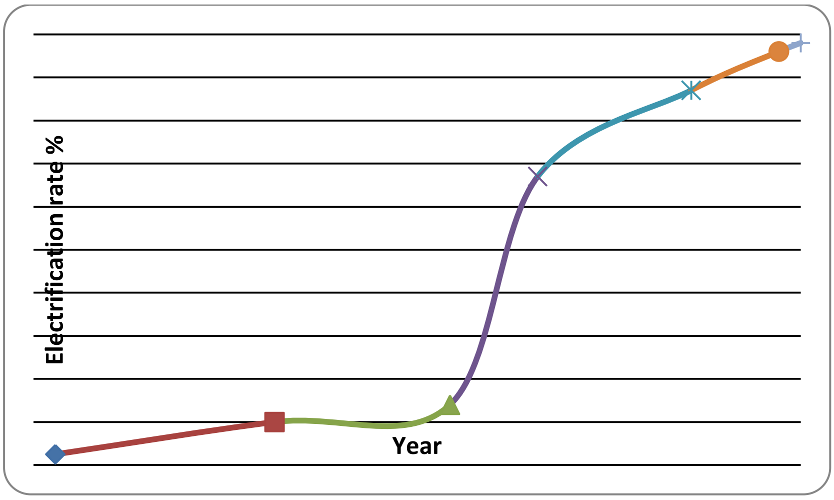
3.2.3.2 Vietnam

Vietnam provides another example where rapid progress has been made in terms of rural electrification. Vietnam is a populous country (90 million in 2011) with a high share of the population living in rural areas (about 70% of its population). According to Shrestha et al (2004), only 2.5% of the poor had electricity access in 1975 but the rate of access accelerated in the 1990s and according to IEA (2010), the country has achieved close to 98% electrification. As a result, from a mere 1.2 million population with electricity access in 1976 the country managed to provide electricity to 82 million population by 2009 (World Bank, 2011a). According to Nguyen (2007), about 2 million households living in remote areas lack access to electricity grids, where off-grid electrification methods are being used. World Bank (2011a) provides a detailed review of the Vietnamese rural electrification experience. In the following paragraphs, we briefly present the salient features and essential points.

Vietnam started its electrification in the mid-1970s during the post-war recovery period but the focus was on developing required infrastructure, particularly in the urban areas. Therefore, rural electrification was not the priority during this period and consequently, and the progress was relatively modest. The country initiated market-oriented economic reform initiatives in the mid-1980s following the example of China and wide-ranging changes to the economic system were initiated (ADB, 2006). This period paved the way for rapid economic growth, and some crucial electricity infrastructure was created during this period. Rapid progress in electrification was made during since mid-1990 (see Fig. 1) when the electricity generating capacities and transmission networks were available, and when the Electricity of Vietnam (EVN) was established to ensure integrated development of the electricity supply industry. At this time the government also set the national electrification targets. After a short period of rapid electrification, the progress continued at a slower pace due to reduced access to favourable funding and emergence of institutional and organisational issues related to electrification. While EVN was ensuring village level connections, taking the grid to the households was done using diverse operational and administrative arrangements. The emphasis then shifted to better regulation of the industry and better quality of supply. The ad-hoc operational arrangements were initially converted to local distribution utilities and then consolidated to create viable local distribution business. A uniform distribution tariff system and the distribution code were established in 2009 and 2010 respectively, to provide a structured distribution system in the country.

As noted in the previous cases, Vietnam also relied on grid extension as the main mode of electrification. The state played an important role in the entire electrification process – policy making, strategy development and delivery. Vietnam followed a logical approach in building the capacity and infrastructure first and then expansion of the system to rural areas. It also prioritised the process by putting emphasis on productive use of energy, which helped create demand for electricity. The creation of EVN and its effective support in promoting rural electrification contributed to the success of the programme as well. Finally, the involvement of various stakeholders and the focus on cost sharing and cost-recovery were also important features of the system.

Fig. 1: Progress in electrification in Vietnam



Source: World Bank (2011a).

Some studies report the progress in electrification in Cambodia and Laos but very limited information is available on Myanmar. For example, Maunsell Ltd (2004) provides a detailed study of the electrification status in Lao PDR and proposed a framework for rural electrification. Bambawale et al (2011) explain the quadrupling of electrification rate between 1995 and 2009 in Laos. Similarly, Arriaga (2010) and Smits and Bush (2010) discuss the pico-hydro alternative for electrification in Lao PDR. Zeriffi (2011) presents the efforts being made in using distributed generation in Cambodia to provide electricity access. All these record the progress being made in this region and the alternative options being attempted to provide electricity access.

3.3 Experience from Africa

In this section, a brief review of literature relating to the African continent is presented. We start with South Africa and then consider other examples from the region in an aggregated manner.

3.3.1 The South African case

3.3.1.1 Status

In 1993, South Africa had an electrification rate of 30%. Since the end of the Apartheid regime in 1994, South Africa has been active in promoting changes to its policies. In 2000, it declared the access to basic services, including electricity, as a social right. By 2009, the country has achieved a 75% electrification rate, with 88% urban and 55% rural population having access to electricity (IEA, 2010).

In 2009, 3.4 million households lack access to electricity, of which almost 50% live in informal settlements. The government plans to achieve universal electrification by 2014 (IEA, 2010).

3.3.1.2 Technology option

South Africa has relied on grid extension as the principal means of electrification. Before 1993, the focus was only on urban electrification but during the Apartheid regime there was systematic discrimination of supply in areas inhabited by non-white population. Since 1994, the country has adopted an Integrated National Electrification Programme (INEP) which allows for both grid extension and non-grid supplies. But off-grid supply has not been widely used and is used only when grid cannot be extended. Coal remains the main fuel for electricity generation in the country. Where grid is not extended, solar home systems are used for electrification.

3.3.1.3 Off-grid solutions

In rural areas where grid has not reached, SHS is used as the means of electrification. The suppliers are selected through an open-bidding process and they have the obligation of providing cooking fuel (paraffin or LPG) alongside providing SHS. The suppliers receive a subsidy from the Department of Energy (DoE). The service provider has a monopoly in its area of service. DoE has selected 6 private consortia in the first phase of the programme (IEA, 2010). However, the progress in this respect has not been impressive – only 50,000 SHS have been installed to date. Lack of political will, non-payment of fees by consumers, and the perception of a temporary solution or inferior solution are among the factors affecting the success of off-grid supply. Renewable energy is publicly called "rural energy" and this has created a negative image. Technology innovation for rural electrification has not succeeded. The South African example also supports the claim that rural electrification as such does not lead to economic growth or job creation or business development. DoE surveys have confirmed this view.

3.3.1.4 Organisation and financial viability of rural electrification

In South Africa, the electricity business was traditionally carried out by two types of organisations – the state utility Escom and the local authorities (Bekker et al, 2008). Escom generates, transmits and distributed electricity while local authorities distribute in their areas. The responsibility of rural electrification was with the local authorities in their distribution areas but Escom took over some crisis-ridden areas and increased its market share in the overall distribution business (Bekker et al, 2008). By 2008, Escom distributed 55% of electricity to end-users while the local authorities served the rest (IEA, 2010).

The electrification under the INEP was financed by the state budget and since 2003, has cost about $160 million per year. The financial support is expected to increase to $280 million by 2012. Bekker et al (2008) indicated that Escom initially thought the electrification programme could be self-financing but by late 1990s, it became apparent that this is unlikely and the state took the responsibility for funding the infrastructure development and subsidising supply. From this perspective, the financial sustainability of the rural electrification programme is not ensured.

3.3.1.5 Lessons

The South African approach to electrification provides a number of lessons as follows:

- the achievement was largely due to a strong government commitment and financial support. The subsidy provided by the government in creating the infrastructure has been substantial. However, maintaining the large subsidy for energy consumption remains a debatable issue.
- The focus on grid extension as opposed to attempting alternative solutions is another feature of South African experience. The idea of avoiding "low grade" solutions perhaps creates a forward loading of capital investment but avoids a phased infrastructure development for rural areas. Whether this is a replicable model or not needs to be analysed further.
- The idea of bundling cooking fuels with SHS is another innovative idea used in South Africa. This could help reduce the dependence on traditional energies by the poor.
- IEA (2010) suggests that South African case confirms that rural electrification does not necessarily lead to economic development.

3.3.2 Other country experiences[10]

We provide a brief review of some countries cases below – covering a range of countries in Africa.

3.3.2.1 Botswana

Only 45% of Botswana's population enjoys connectivity to electricity grid (IEA, 2010) and about one million lacked access in 2009. The electrification rate in urban areas is 68% but the level of electricity access to national grid in isolated communities and rural areas is just 12% (IEA, 2009). Ketlogetswe et al (2007) and Ketolgetswe and Mothudi (2009) provide reviews of electrification policy and the use of solar home systems in the country respectively. Botswana has implemented a wide range of energy sector reform aimed to increase access to modern energy resources in rural communities. The reforms focus on a strategy to increase the level of access to electricity for isolated communities and to build capacity for sustainable socio-economic development.

[10] I gratefully acknowledge assistance provided by Dr. Suad Bardi who spent six months at the Centre as an exchange researcher from Sudan and Mr. Nikhil Rodriguez, a student assistant, for reviewing the literature for this section. However, they did not receive any financial support from the project. I am only responsible for any errors.

The government introduced the first rural electrification program in 1975, concentrating on major villages. Financial assistance for early phases of development was sourced from International Organizations including the Swedish International Development Agency (SIDA). 1990 saw the introduction of a new scheme called Rural Electrification Collective Scheme (RECS). During 1997/1998, the number of villages enjoying electricity infrastructure increased from 7 to 14 per year, the government introduced the RECS to complement the indirect subsidy for national electricity grid infrastructure network.

RECS, as a new scheme required house owners to contribute 40% upfront payment for first time connection with the remaining balance of 60% payable over a 10-year period at 15.25% interest. Despite these terms aimed to reduce cost of first-time connection, the off-take for the scheme was considered relatively low. In April 2000, the scheme was again reviewed and consequently required potential consumers to form syndicates of at least four members within the same vicinity of the village. Reasons for forming such groups included easing the costs of electricity distribution through shared responsibilities among members. Later, the scheme required that each syndicate contribute 5% of the total first-time payment for connectivity whilst the remaining 95%, was contributed by government, refundable by the consumer over 18, 60 or 180 months dependent on an individual's chosen option. The repayment process attracts a lower interest rate than the normal prime interest.

Non-grid photovoltaic system in Botswana was mainly restricted to applications in institutional facilities, such as, police stations, public schools, clinics, and wildlife posts where conventional electricity was not provided. As part of government's commitment to increasing access to electricity particularly in isolated communities, the strategy to develop renewable energy practices extended to include centralized photovoltaic power systems. As a direct result of this, 1995 marked the first construction of centralized photovoltaic power plant at Motshegaletau, a small village located 50 km from the national electricity grid.

Emphasis on the use of photovoltaic systems has been reflected in a number of government policy documents. For example, The Vision 2016 which is the country’s blue-print for future national aspirations spells out that the country must be developed as a centre of excellence for solar energy technology.

Botswana, which is considered in the academic and policy circle as a successful case that avoided the “resource curse”, does not provide a role model for other African countries in respect of rural electrification. While it is striving for a better electricity access and wants to provide access to all by 2016 (UNDP-WHO, 2009), it is not yet evident that this target will be reached.

3.3.2.2 Kenya

Kenya, located on the east coast of Africa, with a population of 38 million in 2008 is an important East African economy (Kiplagat et al, 2011). Recent IEA data (IEA, 2010) indicates that only 16% of the Kenya's population has access to electricity and 33 million people lack access in the country. While 55% of the urban population has access, only 1.5% of the rural population is connected to the grid (IEA, 2009). The electricity system with an installed capacity of 1345 MW in 2008 is relatively small. Hydropower and geothermal energy contribute about 80% of the electricity generation, making the country highly renewable energy dependent for its electricity production (Kiplagat et al, 2011). But Kenya continues to experience a marked shortfall in its electricity supply, caused partly by system losses (estimated at 20%), and partly by the country's over-dependence on hydropower, which is frequently affected by the perennial droughts causing reduction in water levels in the national systems of dams (Rabah, 2005).

The country has a long history of pursuing with rural electrification. The Rural Electrification Program (REP) was initiated in 1973 and lasted for 15 years. Although the number of household connections increased during this period, the progress was relatively limited. In 1997, the Electric Power Act was enacted and the Rural Electrification Authority (REA) was established which developed the first master plan and included the formulation of a rolling Rural Electrification Program Master Plan to present least-cost electrification options for target areas. The 1997 master plan prioritized a list of projects for implementation based on economic and social factors, regularly updated to show what has been done and to come up with new load centres. A new master plan is being developed to take stock of the present situation.

However, the Electric Power Act provided limited incentives for private sector participation and the creation of the REA did not result in an accelerated development. A new Energy Act came into existence in 2006 and the Rural Electrification Authority was created under this act to implement rural electrification programme and to accelerate implementation of rural electrification projects (Kiplagat et al, 2011). To support rural electrification the Rural Electrification Programme Fund was established under the provisions of the Energy Act 2006, which is supported through the electricity sales levy (charged at 5% at present) and other fees and charges levied by the Energy Regulatory Commission, and other grants, donations, and contributions made available from the government budget or elsewhere. The Rural Electrification Authority is also required under the act to secure additional funds from other sources, including through participation of the private sector in the form of Public Private Partnerships. It can also enter into agreements with other international donor agencies. Kenya has also introduced the feed-in tariff system for grid-connected renewable electricity generation and hopes to attract private investors in this area.

REA is mandated to explore, promote and develop the use of sources of energy, including renewable energies. Kenya is endowed with substantial renewable energy resources but the attention so far has been on hydropower and geothermal energy. The country has a potential of 3 GW of micro-hydro power (less than 10 MW capacity) but only a small number of schemes have been installed so far. So far only 32 MW of small-hydro power capacity has been installed by the Kenya Electricity Generating Company, and less than 1 MW for schemes owned by community and private enterprises (Kiplagat et al, 2011). Kiplagat et al (2011) also indicate that 55 sites have been identified with capacities between 50 and 700 kW in rural areas which can provide cost-effective supply to small communities. Maher et al (2003) suggest that pico-hydro systems (less than 5kW size) can play an important role in Kenya as a source of off-grid electricity supply in remote areas. Williams and Simpson (2009) suggest that such systems can become cost effective through local manufacturing and careful technical system design. Similarly, Kirubi et al (2009), using a detailed case study of a Kenyan small-hydro power system, suggest that community-based small hydro systems can contribute to productive use of electricity thereby generating income opportunities. These systems can also support better business and social services which can improve the quality of life.

The country was the first Sub-Saharan African country to introduce geothermal power in a significant amount and by 2008 has an installed capacity of 163 MW. This has been identified as a low cost power source in Kenya and the government is putting an effort in harnessing this source.

Similarly, Kenya has the world's highest ownership rate of solar systems with 30,000 systems sold per year (Kiplagat et al, 2011). Jacobson (2005) asserted that Kenya has emerged as the global leader, in per capita terms, of solar energy use. The solar market in the country has emerged with limited government support and donor interventions and the market has been sustained without significant subsidies. Hankins (2000) provided a detailed report of the solar market development in Kenya and asserted that between 1982 and 1999 the market grew into a USD 6 million per year industry. The market has developed in stages – in the first stage in the early 1980s the upper-middle class households (tea/ coffee farmer, businessmen, etc.) started to procure the systems and the market was creamed off by early 1990s. The next phase of the development was driven by the television boom when cheap Chinese televisions became widespread in the countryside. The demand for smaller solar home systems soared to cater to this need and the market thus expanded to rural masses. In the third phase, hire-purchase arrangements were introduced for consumers (Hankins, 2000).

Over-the-counter cash sales represent the most common form of solar system transactions. Jacobson (2007) argues that the market has benefitted the middle class who could afford the system and that the solar systems have hardly provided direct income generation opportunities. It has however influenced the social interactions and has become a tool for communication and social connection. The government is now promoting solar system installation in public institutions and with the feed-in tariff in place more solar systems are likely to be integrated into the grid system. Yet, the overall contribution of solar energy in the country's electricity is just below 1% (Kiplagat et al, 2011). The demand for solar PV systems in the Kenya market is driven by small business owners, rural professionals such as school teachers, civil servants, and pastors, as well as the better off among the small holder cash cropping farmers. Solar PV plays a more substantial role in supporting the use of electric light for key social activities, and household applications such as television, radio, and cellular telephone charging that help increase interconnectedness between the rural people, and markets. Abdullah and Jeanty (2011) presented a contingent valuation study to identify the willingness to pay for renewable energies. They found that rural households are willing to pay more for grid-based electricity than PV electricity and that they prefer to pay monthly connection payments as opposed to lump-sum payments. They also suggest that the poorest section of the population cannot afford the renewable energies and therefore the renewable energy through solar systems did not really benefit them.

Kenya can be considered as a rural electrification paradox. The country has set up organizations and created dedicated funds for providing energy in deprived areas. It has received sustained international donor attention and has experimented with a variety of technologies and options. Yet, the country remains poorly served in terms of electricity and energy access. While there have been cases of limited success in some areas or pilot projects, their replication and sustenance has not been ensured. This shows that it is not sufficient to have the legal framework or organizational arrangement for a successful electrification programme. It requires a strong government commitment and financial support, a strong strategy and a systematic plan to bring success.

3.3.2.3 Nigeria

Nigeria, with a population of 154.7 million, is undoubtedly the most populous country in Africa and accounts for close to half of the population of West Africa. Although Nigeria is blessed with abundant energy resources, the country has not been successful in harnessing them effectively and according to IEA (2010), only about 50% of the population had access to electricity in 2009 and more than 70 million population lacked access to electricity. Only a quarter of the rural population has access to electricity while less than 70% of the urban population has electricity access (IEA, 2008). Consequently, Nigeria accounts for the largest number of people in Africa without access to electricity. According to ESMAP (2005), only about 30,000 connections are provided every year in Nigeria and given the high rate of population growth, it is expected the number of people without access will grow unless effective interventions are made. According to UNDP-WHO (2009) study, the health effect of lack of access to clean energies is significant in terms of premature deaths and chronic diseases as well as loss of productive manpower.

The rural electrification programme started in 1981 and was implemented by the electric utility with the federal government providing the support. Its aim was to connect the local government headquarters and important towns to the grid. While local government headquarters have mostly been connected to the grid, the expansion of the network for general rural electrification did not happen. ESMAP (2005) identified a number of challenges and barriers facing the rural electrification programme in Nigeria. These include poor organizational arrangement, weak financial position of the utility, supply-driven approach without considering the demand generation aspect, lack of local capacity to manage such activities, etc.

Recently the country has initiated a number of initiatives to address the above problems. The government has approved an energy policy in 2003 that aims for a coordinated development of the energy sector using both fossil fuels and renewable energies. The Electric Power Reform Act of 2005 paved the way for restructuring of the electricity industry and a national regulatory commission was created to regulate the electricity industry. The Act also led to the creation of the Rural Electrification Agency in 2006 to rapidly expand rural and peri-urban access to electricity in the country in a cost-effective manner, employing the grid and off-grid options. The Act also provides for a Rural Electrification Fund to support rural electrification projects. But the progress in respect of implementation has not been impressive so far.

Nigeria is blessed with abundant resources of fossil fuels as well as renewable energy resources. But the country faces a serious electricity supply shortage due to inadequate generation capacity. The transmission and distribution network is weak and requires a significant strengthening before any major expansion into rural areas can be aimed. Although the renewable energy potential remains high, the level of exploitation is limited. Nigeria produced a Renewable Energy Master Plan in 2006 that aimed at a transition from the fossil-fuel based economy to a more sustainable energy system. It also set short, medium and long-term targets for renewable electricity generation that varied from 13% for the short term to 36% for the long-term. Although the country has experimented with solar PV, solar thermal, wind and bio-mass technologies, no significant success has been achieved in harnessing the vast potential. For example, Ohunakin et al (2011) indicated that only 5% of the small hydro power potential has been tapped so far. The rural electrification authority does not seem to be working effectively and the slow progress of sector reform has not helped in reducing the energy access problem.

The Nigerian example clearly shows that lack of strong government commitment and support acts as a major barrier to rural electrification. While organizations have been created to promote rural electrification, they remained ineffective and lacked capacity and financial strength. A clear road map, a well-monitored implementation plan and proper demarcation of responsibilities would be required to make progress in rural electrification.

3.3.2.4 Tanzania

Tanzania has a relatively low electricity access – about 14% in 2009 (IEA, 2010) and only 2% of the rural population has access to electricity. The electricity system in the country is very small – the installed generating capacity was about 1000 MW in 2010 and about 60% of this comes from hydropower generating stations. In order to improve energy access in rural areas, a dedicated Rural Energy Agency was created in 2005, which started its operation in 2007. The agency is overseen by the Rural Energy Board which also oversees the Rural Energy Fund. The Rural Energy Agency provides financial support to project developers and promotes rural energy projects. The Fund is supported through an electricity levy (charged at 3% and to go up to 5%) as well as grants from international agencies, government budgetary support and other sources. The Agency is mostly working with private investors who identify the projects, submit their business plan and get agency's approval. Most of the projects are renewable energy-based and often off-grid type, while the national transmission utility Tanesco is mainly responsible for grid extension.

Several studies have reported the Tanzanian case. Kainkwa (1999) analysed whether wind energy can be used in the dry season to supplement electricity generation in the country. Based on wind data from two sites, he found that a hybrid hydro-wind system can serve the dry season better and improve reliability of electricity supply. Similarly, Sheya and Mushi (2000) describe the status of renewable energy use in the country. However, these studies did not focus on rural electrification as such.

Ilskog et al (2005) analysed the co-operative model for successful electrification in a Tanzanian village. The authors evaluate the performance of a rural electrification co-operative pilot project, and found that the co-operative, which was formed in 1993 (with regular operations commencing in 1994 with 67 consumers) had a tariff that was more than 15 times higher than in the nearby town served by TANESCO – the electric utility. Even with the higher tariff, the cooperative has been growing and reached 241 consumers in October 2002. Most of the energy produced was consumed by households for lighting purposes with the remaining being consumed in businesses, 12% in institutions and public buildings and approximately 3% for street lighting. The reliability of the supply has improved from 80% in 1994, to 97% during 200 with one major episode occurring in 2001 where the operations were shut down completely due to lack of funds for purchase of spare parts.

Several key conclusions can be taken away from this study.

a) First, the pilot project demonstrates that the villages can manage their own electricity supply system if given adequate technical, management and financial support.
b) Second, the co-operative pilot study shows that even in rural villages, it is possible to find a fraction of the population that has the ability and willingness to pay the fairly high price of almost 0.5 USD/kWh for electricity.
c) Third, if power is generated using fossil fuels that are subject to price volatility, the need to increase tariffs at the same rate as fuel prices increase is a must, otherwise funds run out and operations must come to a halt. Additionally, the tariff must be sufficient for the build up of an adequate budget for maintenance and reinvestment. The above co-operative strove to aim for at least 30% capital recovery during its operations even though most of the equipment and grid were supplied by TANESCO and other aid agencies.
d) Finally, non-metered supply should be avoided in preference for metered consumption.

Gullberg et al (2005) presented a related study where they analysed the effect of introducing solar PV and compact fluorescent lamps in a Tanzanian village where the co-operative model discussed above was operating. Their study found that the PV system with incandescent lamp can compete with diesel generation and offers a reliable system but the subsidized cost of diesel makes diesel generation cheaper for the consumers.

Marandu (2002) investigated whether local investors in Tanzania are capable of establishing and managing power sector enterprises in Tanzania and examined the extent to which this capability could be harnessed to enhance rural electrification- especially of the poor. The data used in his report was acquired from interviews of power sector stakeholders. He concluded that

a) substantial local ownership is possible in small power enterprises but is limited in the larger ones. It is interesting to note that the small firms are located in rural areas and most of those were established to support an economic activity rather than selling of power as a core activity.
b) Second, he reports that available evidence suggests that the terms and conditions of local financial institutions are major constraining factors on the ability of local investors to mobilize finance locally. With regard to the terms and conditions for the loans, Marandu (2002), reveals four things. The level of interest rate charged can be

as high as 24% for funds. As far as the level of collateral is concerned some require the borrower to cover 100-150% of the loan. The repayment period varies between 8 to 10 years.

c) Third, it appears that, on the overall, technical, managerial and professional capabilities needed to set up, operate and manage Independent Power Production (IPP) and Independent Power Distribution (IPD) enterprises exist locally. The results from a survey conducted and reported suggests that that electrical technicians, managers, accountants and artisans take a long time to get employment, while engineers and lawyers take a short time. Therefore, he contends that that a new power sector investor may find it relatively easy to secure most of the required skills from the market except engineers and lawyers.

What is interesting in his report is that he points to rural electricity cooperatives and suggests that with the appropriate incentives, legal and regulatory framework in place, there is the possibility that local private investors may be capable and willing to invest in rural electrification. However, what he fails to represent is that such co-operatives could not have been started and would not have survived without external financial support, in particular from Sida and TANESCO (for financing of rehabilitation of generator sets, purchase of a new generator set and expansion of the distribution network). The initial difference between revenues and operating costs was covered by working capital provided by SEI.

Barry et al (2011) have identified factors that should be considered for promotion of renewable energies to address energy access problems in Africa and used eight case studies in Rwanda, Tanzania and Malawi to confirm these factors. They then suggested a list of 13 factors that could be used to ensure sustainable renewable energy technology choices.

3.3.2.5 Zambia

Haanyika (2008) analysed the policy, legal and institutional measures implemented in Zambia and assessed their potential or effectiveness to tackle some of the challenges facing rural electrification in the country so as to increase access and affordability. The overall level of access to electricity in rural areas in the early 1990s was 0.8% of the rural population; mostly for cooking. 1.5% used electricity in 2000. However, the population growth of 2.9% in effect hides the level of success achieved. Rural electrification in Zambia was for a long time viewed as grid extensions to replace diesel generators in isolated towns. The use of decentralized systems and renewable energies were introduced through the broadening of the National Energy Policy (NEP) in 1994. It broadened rural electrification to include alternative technologies such as solar PV and mini-hydropower. It is interesting to note that this helped to facilitate the increased application of decentralized technologies, thus enabling social institutions and residences in remote towns and villages with low population densities to be supplied with electricity from solar PV. However, the author does point out that the application of alternative technologies has a number of constraints such as lack of awareness, high initial costs, limited acceptability and lack of skills.

Establishment of the Rural Electrification Fund has contributed to increased financial resources for rural electrification. The key rural electrification strategy of the government of Zambia was to set up a Rural Electrification Fund (REF) whereby all electricity consumers would contribute 3% of the billed electricity to help promote the electrification of non-electrified areas. A lifeline tariff for small consumers was put in place to maintain affordability. The REF remained the main source of funding for RE. What is interesting to note however is that Zambia undertook liberalization hoping that it would bring about private investments in the sector. However, Haanyika (2008) points out that that rural electrification is unlikely to attract private finances in the absence of a supportive framework. He found no such framework in place that was structured for attracting private sector participation in RE except by way of prioritizing RE projects whose promoters were prepared to contribute towards the network costs. He warns against using the REF to fully fund financially sustainable projects.

In an effort to bring the cost down of rural electrification, Zambian policy promotes the adoption of low-cost methods of power distribution and home wiring. This included the use of local materials such as wooden poles and locally manufactured copper conductors, ceramic insulators, etc. The main findings lead to the conclusion that the policy and associated strategies coupled with the institutional framework have so far contributed to some achievements in RE. Haanyika (2008) brings up a great need to establish an effective mechanism for monitoring rural electrification achievements. He suggests that such a monitoring mechanism could reside with the created RE authority in place in Zambia which was given authorithy through the 2003 enactment of the Rural Electrification Act.

Lemaire (2009) analysed the case of energy service companies that were established in Eastern Zambia to supply solar home systems. He studied three such companies which manage 100-150 solar home systems and found that despite initial government subsidies, only the rich section of the population could afford the systems who could pay for the monthly rentals. However, ESCOs faced difficulties due to high inflation rate and irregularities in income of consumers. Also technical difficulties due to overuse of the systems and constant discharge of batteries were encountered. He suggested that while ESCOs are complementing the traditional utilities, more long-term government support is required to sustain the private-public initiative.

Gustavson (2007) also reported a case study of an ESCO in Zambia where he noticed that once users have acquired knowledge about the operation of the SHS, they started to put higher loads on the system and over time, the load started to increase. Despite these efforts, rural electricity access remains very limited in Tanzania.

3.3.2.6 Namibia

Namibia has an electrification of 18% with a relatively high urban electrification (70%) but a low rural access level of 13%. About 1 million people in the country does not have access to electricity (IEA, 2009).

Wamuknoya and Davis (2001) report on a study conducted in Namibia where the government has promoted both options in its rural electrification programme. Their report suggests that a key benefit from access to electricity in rural areas is better lighting. Better lighting translates to improved security, ability to study at night and extended evenings. Other benefits include elevated social status and improvements in quality of life of households are electrified. Cooking or the use of electric cooking stoves is not seen as a significant benefit brought through access for electricity. However, their study indicates that electricity for cooking remains low though in grid-electrified households 30% do own and make occasional use of an electric stove, which indicates that a transition to electricity is occurring slowly. Interestingly, their report suggests that electricity access was not significantly linked to the growth or diversification of income generating activities or migration to or from rural areas to cities. Weighing the benefits between grid and solar households, their results suggest that once the grid has been extended to rural service centers there is litle in terms of benefits generated to recommend grid over solar technologies: The cost of supply seems to be the determining factor. However, they find that due to government subsidies involved in expanding grid- based rural electrificiation it distorts the potentially favourable deployment of the solar option even if it is a lower economic-cost solution.

In their paper Moner-Girona et al (2006) provide an overview of the status of solar home system installation in Africa and highlight the opportunities for cost reductions via local manufacturing. According to the authors solar home system costs have dropped significantly over the past few decades due to technical advances, manufacturing innovations, and economies of scale in production. Sub-Saharan Africa has benefited from these steadily decreasing international prices for PV equipment over the last few decades. However, PV system prices are higher in Africa than in other parts of the world due to taxes and transaction costs in the process of delivering the system.

The authors suggest that the local production of photovoltaic modules and systems can have a significant effect on the sustainability of the local market. Local manufacturing has the potential to expand existing markets as well as to create jobs, service, training and financing, to reduce solar module costs, economically manufacture special order modules in low volumes; be well positioned to offer parts, and create opportunities to tailor solar technology to specific in-country African requirements.

However, the authors believe that cost reduction should not be the overriding reason to introduce local manufacturing. They believe that other reasons should be taken into account, such as the need to transfer technology, improve manufacturing, and strengthen the country's human resources in research and development. The local manufacture of PV systems would not solve things alone, according to them, but would go a long way to make PV a source of economic strength, and not a net drain on the economies of African nations.

3.3.2.7 Senegal

Senegal has an overall electrification rate of 42% with a relatively high urban electrification rate at 75% but a relatively low rural access rate at 18% (IEA, 2009). More than 7 million people in the country lack access to electricity.

Camblong et al (2009) sought to present the results of a micro-grid project with a high installed content of renewable energies with an aim of promoting electrification of rural regions of Senegal using these technologies. Before they were able to match the technologies to the needs of the villages, the authors conducted a survey of three regions in Senegal to study the electrical energy needs of non-electrified villages' households. The authors were then able to examine these estimated needs with potential renewable energies to meet them.

The methodology by which the surveys were undertaken was thoroughly covered in this paper and well thought out. The authors of this paper provided detailed information on how they defined different village categories, determined the number of villages per region, the criteria to select the villages where the surveys would be carried out, the choice of survey questions and finally sampling the household surveys.

The survey has provided insightful information on socioeconomic and housing statistics that may be useful to keep in mind for off-grid planning. In terms of socioeconomic information: The authors found that the main activity carried out in most villages was agriculture. More interestingly the second activity conducted was in livestock farming and the third activity being commerce. The authors also point out that emigration too plays an important role in households and villages. There was at least one emigrant per family in the three regions' villages and the number of emigrants increases with the proximity of the capital of Senegal, Dakar. This is particularly important because the emigrants are often the most important financing source of the families. Thus, the number of emigrants is normally linked to the purchasing power of families.

Housing statistics provided some interesting information about approximity of houses to one another and building materials used to build them. The survey indicates that nearly every family in the sampled villages had at least a secondary building close to the main building. The authors point out that this is important because it provides useful information to estimate the length of the electrical cable which would have to be installed if the village were to be electrified with a micro-grid. Additionally, housing statistics of the survey showed that nearly 80% of the buildings were built with cement and more than 72% of the main buildings had tin roofing. The importance of this information provides insight into the possibility of deploying heavy equipment such as PV panels could be installed on the main building.

The authors concluded that solar energy potential is excellent for the country whilst wind energy potential could be interesting in some specific sites and that biomass could also be an efficient source if livestock farming was properly managed in the future. They further believe that the electrical energy needs could be met through the deployment kit based micro-grids.

3.3.2.8 Mozambique

Mozambique has an electrification rate of 12% and had about 20 million people without electricity access in 2009 (IEA, 2010). The rate of electrification is poor both in urban and rural areas – only 21% of the urban population and 6% of the rural population has access to electricity (IEA, 2009).

Mulder and Tembe (2008) analyze the dynamics of the relationship between electricity and socio-economic development by means of a cost–benefit analysis of a typical rural electrification project in Mozambique, assessing the impact of electricity on households, education, agro-business, commerce, and the public sector.

The authors' simple cost–benefit analysis of a typical rural electrification project in a developing country, Mozambique, showed that in spite of the high costs (about US$2100 per realized customer in 2005) the project has led to positive cumulative net benefits within 4 years. These results lead to the conclusion that rural electrification projects in principle can be commercially viable on the condition that they include at least one key customer which could generate a considerable return.

The African experience shows that efforts are being made in the continent but they remain less effective compared to the other regions of the world. It appears that a strong government commitment towards rural electricity access is lacking and the efforts of donors or non-governmental organisations are not sufficient to bring a wholesome change in the region.

3.4 Experience from South America

3.4.1 The Brazilian experience

3.4.1.1 Status

According to IEA (2010), Brazil reached an overall electrification rate of 97.8% by 2009- with 99.5% urban areas electrified and 88% of rural areas. This has been achieved through grid expansion to a large extent and the 1988 constitution has considered distribution of electricity as a public service.

The country has made a significant progress in its electricity access provision. Until 1990s, most of the electrification was undertaken at the state level using government funds. Some decentralised activities were supported by donor agencies. In 1994, a major electrification programme, PRODEEM was launched with state funding. Electrobras was co-ordinating agency. Another programme, LnC (or Light in the Countryside) was launched in 2000, which received funds from RGR (or Global Reversal Reserve). This was coordinated directly by MME (Ministry of Mines and Energy). However, these programmes did not have a clear universal electrification target and the concessionaires, especially the private ones, were not interested in reaching out the remote areas with little demand.

Consequently, in 2003, a specific universal electricity access programme, LpT (Light for All) was launched with an objective of electrifying the country by 2010. The programme laid emphasis on productive use of energy and integrated local development, and accorded higher priority to less developed, poorer areas of north and north-east. Although the programme allows for grid extension, decentralized options and individual systems, Brazil has relied mostly on grid expansion. Very limited use of decentralised and off-grid solutions has been made so far. Only 3100 SHS have been installed until end of 2006 and diesel generators are predominantly used in the Amazon region. The non-electrified areas of the Amazon region have less than 30 households in an area and because of distance from the grid, it is uneconomical to extend the grid in these areas. Under the MME Guidelines, Electrobras are evaluating 23 special stand-alone or decentralized projects in 2009 but it is expected that diesel generators will continue to play an important role in this area.

According to Andrade (2009), the rural communities in Brazil have special characteristics, as follows:

- they are highly dispersed, with very low population density, sometimes as low as less than 1 person/km2;
- not integrated with the formal economy;
- lacks disposable income or monetary strength;
- poor HDI;

- low levels of consumption.

Accordingly, the problem for the remaining non-electrified villages is more complex. IEA (2010) reports that Brazil has achieved poverty reduction in the past few years and achieved its MDG target in this respect but it still suffers from extreme poverty in some rural areas of north-east.

3.4.1.2 Technology options

Brazil has relied on grid extension as the main mode of electrification. The main difference with South Africa is that a large share of electricity in Brazil comes from hydro sources, making it less environmentally damaging. Diesel generator based mini-grid systems have been widely used in rural areas, especially in the Amazon region. According to Goldemberg et al (2004), more than 1000 diesel generator sets are used in the region, of which more than 700 sets have a capacity of less than 500 kW. Brazil has also used other forms of renewable energies such as solar PV for electrification purposes.

3.4.1.3 Off-grid solutions

Andrade (2009) indicates that isolated systems provide electricity to 3% of the Brazilian population (1.6 million consumers) spread over 45% of the territory. Thermo-electric plants running on diesel are generally used in most of the cases but this entails fuel waste as one litre of fuel used in the plant may require spending two litres of fuel for transportation to the region. The quality of power is not high and the supply is often not available for 24 hours.

Zerriffi (2008) indicates that Brazil has a considerable experience in the decentralised electrification programme. CEMIG, the utility of Minas Gerais, undertook a PV-based electrification in the 1990s for electrification of schools, community buildings and households. However, the programme could not achieve its target and only 450 SHS were installed out of a target of 4700 between 1995 and 2001.

According to Andrade (2009), three main programmes have been used in Brazil for universal electrfication:

a) PRODEEM (The State and Municipal Power Development Programme) – This was launched in 1994 to provide decentralized renewable energy options to schools, health centres and other community facilities. Between 1996 and 2002, more than 8700 systems were distributed leading to an installed capacity of 5.2 kWp. The programme faced operation and management problems and the performance was not high due to poor operating results of the installed systems (50% not working) and other institutional issues (Zerriffi, 2008).

b) LnC (Rural Power supply National Programme) – This was initiated in 1999 and extended grid connection to rural areas. Between 2000 and 2003, 630,000 connections were made.
c) LpT (Light for all) – Initiated in 2003 to connect more than 2 million rural households by 2010 with a budgeted expenditure of R$12.7 billion.

Two types of efforts are found in Brazil:

a) efforts by centralised utilities to provide access in their service areas – this is the dominant mode of operation and has often promoted diesel mini-grid, solar home systems in remote areas and providing supply to community structures (schools, etc.) through PRODEEM programme (Zerriffi, 2008).
b) There are a few examples where non-centralised agencies have also participated in decentralised energy supply. An NGO, IDEAAS, has developed a fee-based SHS where consumers pay an installation fee and a monthly charge. The NGO used a mix of loans and grants for funding but requires the installation of 4000 units to break-even. This has not been ensured but if the costs can be controlled, the model could be replicated and sustained (Zerriffi, 2008).

The diesel mini-grid is used in the rural areas of Amazonia and is provided by government-owned utilities like CAEM, who use grants for “Lights for all” programme and diesel fuel subsidy for rural areas. Even then, the services are not economically viable and the companies run into deficits. On the other hand, private companies like COELBA have relied on SHS to provide electricity to the remote areas. While they can access funds for “Lights for all” programme, being private utilities cannot operate under financial losses, although they also try to use cross-subsidies from rich consumers to make up for some losses.

3.4.1.4 Organisation and financial viability of rural electrification

Until 1990s, the rural electrification programmes were implemented at the state level through franchisees selected by the state. PRODEEM followed a top-down approach and was a centralised project and implemented through utilities (Goldemberg et al, 2004). This was funded by donor agencies and the federal government. The LnC programme was implemented by Electrobras and coordinated by the Ministry of Mines and Energy. For the LpT programme, a new organisational structure has emerged (IEA 2010). The regulatory agency, ANEEL plays a key role here for setting the annual targets and approving the concessionaires while Electrobras, the national utility, holds the secretariat for the programme. The Ministry of Mines and Energy coordinates the programme. The funding is essentially provided by the federal government although the states contribute about 10% to the cost.

3.4.1.5 Lessons

The Brazilian experience also supports the case for state support in rural electrification infrastructure. Like South Africa, Brazil has also relied mainly on grid expansion and only used off-grid solutions where grid cannot be extended. Its reliance on diesel generators for off-grid solutions as opposed to renewable sources is another important feature of the electrification strategy. In all programmes, the state took an active role in setting the targets, creating the organisational arrangements and monitoring of the programme. Although Brazil has reduced its poverty and developed economically, the viability and sustainability of its subsidised electrification programmes is not ensured.

3.4.2 Examples from other South American countries

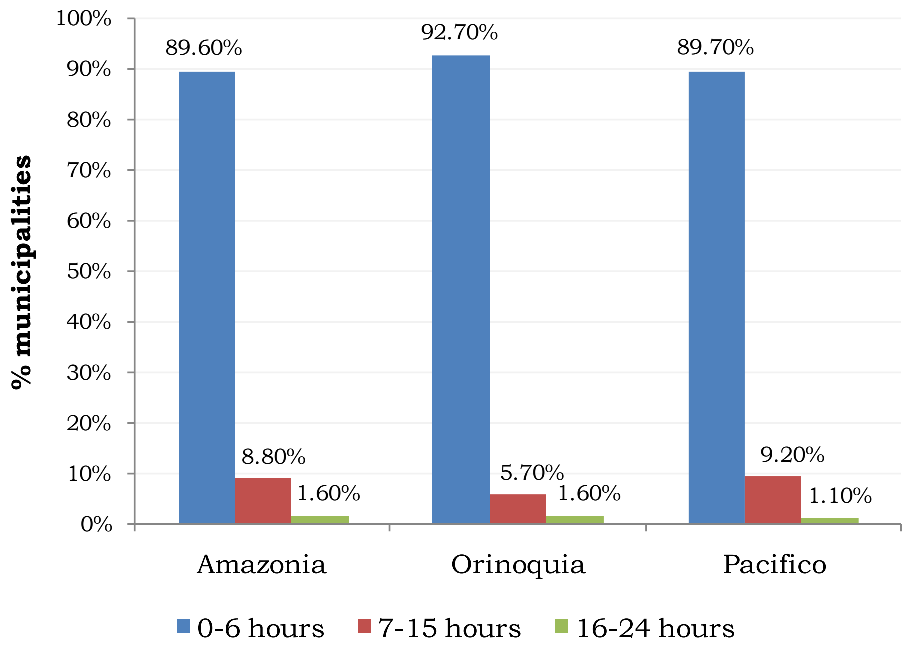
Colombia

Electricity in Colombia is supplied by the National Interconnected System (NIS) and by local systems in the Non-Interconnected Zones (NIZ). The grid-based access covers 96% of its 45 million population, whereas the zones which are not connected to the national grid cover a population of 1.5 millons spreading over nearly 66% of the country's territorial surface (Silva and Nakata, 2009). Around 88% of this population is living in rural areas and the population density can be as low as 2 persons/km2. The installed generation capacity in the NIZ zone was 90MW[11] in 2007. Diesel plants contribute 92% of the total installed capacity and come with varied characteristics depending on where they are located. On the other hand, the small hydroelectric plants constitute almost 8% of the total capacity.

One of the characteristics of the electricity system in NIZ´s is its intermittent supply. Figure 2 depicts the average number of hours of electricity per day in the main NIZ´s areas. The graph shows that the 90% of municipalities have 6 hours of electricity per day. While a number of government agencies are involved in the policy and planning of electrification in the NIZ area, the supply is undertaken by 93 public service enterprises.

[11] PIES-MME. December 2007

Fig.2: Duration of electricity supply



Data source: IPSE (http://www.ipse.gov.co)

The General State Budget and the National Royalties Fund support the new infrastructure creation in the NIZ area and provide subsidies for power supply. Between 2003 and 2007, a total of about 307 Million USD was provided to the NIZ as support towards electrification. Yet, the level of access in many areas is quite poor and the remoteness implies that the cost of supply is higher when the supply comes from diesel. Silva and Nakata (2009) report that diesel costs 60% more in the NIZ area compared to that prevailing in the capital and consequently, the average price of electricity is twice that of grid-connected areas and the service duration is limited.

Although renewable energies can become cost effective in certain areas and could displace some fossil-fuel use in rural Colombia, the progress has been rather limited. Hernandez et al (2011) report that the telephone company (TELECOM) first used solar PV systems for rural telecommunication systems in 1979 and this still continues to provide electricity for rural telecommunication. In recent times, some solar PV systems for individual household use are being used with the financial support from the general budget and special funds. Also a 125 kW mini-grid pilot project is under development (Hernandez et al, 2011).

Chile

Jardesic (2000) reported the Chilean programme that was introduced after the restructuring of the power sector in the country. In the early 1990s, almost 50% of the rural population had no access to electricity and an innovative rural electrification was introduced (called PER in Spanish) in 1994 to address the problem. It aimed at providing electricity to 100% of electrifiable rural dwellings within 10 years and reach 75% coverage by 2000. The programme was deeply rooted in: i) decentralised decision-making; ii) community participation; iii) competence promotion in the energy supply; and iv) use of appropriate technologies. A special fund was created to provide one-time direct subsidy on a competitive basis to cover the investment costs while the tariff charges set by the regulators were to cover the operating costs. The subsidy fund is allocated based on the progress made in the past year and the number of households still lacking access. Jardesic (2000) reported that the programme produced demonstrable results, achieving the 75% target set for 2000 by 1999. The state invested $112 million between 1995 and 1999 and the private sector also brought another $60 million.

Peru

According to IEA (2010), Peru has an overall electrification of 86% with 4.2 million without access to electricity. But this overall picture hides the stark urban-rural divide: only 28% of the rural population had access in 2008 as against 96.5% of the urban population (IEA, 2009). This is one of the lowest rural electrification rates in South America and it is a reflection of the fact that Peru is one of the most unequal societies in the world and that poverty in rural areas is widespread (Cherni and Preston, 2007). The country relied on grid extension as the main mode of electrification and significant progress was made in the 1990s when the country reformed the electricity industry. The level of electrification increased from 45% in 1972 to 75% in 2002 (Cherni and Preston, 2007) and then to 86% in 2009. But the process remained an urban phenomenon and the rural areas did not see significant improvements in this respect. In fact, rural electrification was not within the purview of the sector reform and the responsibility rested with the Department of Electricity Projects of the Ministry of Energy and Mining. The Department prepared the Rural Electrification Plan and carried out projects under the plan. These were essentially grid extension projects and did not yield results due to a number of factors: inappropriate project selection, shortage and uncertainty of funds and the possibility of corruption (Cherni and Preston, 2007).

A Rural Electrification Law was introduced in 2002 to ensure rapid rural electrification using appropriate resources and technologies. It provided for a Rural Electrification Fund and left the electrification responsibility with the state. The Fund is guaranteed to receive no less than 0.85% of the annual national budget, which according to

Cherni and Preston (2007) represented an increase of about $14 million in funding per year that could electrify additional 11-13000 families per year. However, this is clearly insufficient to address the rural electrification problem.

Off-grid electrification can be a viable option in rural Peru, although grid extension received the emphasis. Some isolated investments and experiments were carried out in the 1990s. Martinot and Reiche (2000) reported that in Peru a GEF funded project aimed at creating a model concession arrangement for the development of PV-based rural electrification in Peru through the involvement of local communities. The users will pay a monthly fee and the government will provide a subsidy and contribute equity to the project. It aimed to provide 12000 SHS within 4 years.

ESMAP (2001b) reported evaluations of several small-scale projects through post-investment investigations and found that micro-hydro plants and diesel generators faced a number of problems including frequent shutdowns, high subsidy requirements, and lack of management skills. It is reported that there are 300,000 isolated households in the country where grid extension is not feasible and off-grid systems will be used to provide electricity access (ESMAP, 2001b). As part of a World Bank project that started in 2006, 39,000 people are targeted to be provided access with solar PV systems (ESMAP, 2011).

A recent study suggested that Peru has a significant small hydropower potential and a conservative estimate puts it at 1600 MW. But as small hydropower has to compete with cheap gas-based electricity, investors did not find it attractive to invest in Greenfield projects, which prevented the country from realizing its small hydro potential (World Bank, 2011b).

In 2008, the Renewable Energy Decree was introduced to promote renewable energy and renewable electricity in the country. But the focus again was on grid-connected supply. The country still needs strategic thinking to address the rural electricity access issue.

These experiences from South America show that while the urban electrification has been very successful, there are areas of low rural electrification in the continent. Although the grid-based approach has been favoured and countries have tried private investor-led developments, the rate of success varied. While countries have created funds and special legal arrangements for rural electrification, they were not always quite effective. Therefore, no univocal lesson emerges from these experiences that can be used in other countries.

4.0 Off-grid case examples

4.1 Gansu Pilot project experience (China)

Gansu project case: With US DOE support, a project of providing SHS was undertaken by SELF (Solar Electric Light Fund) with the aim of providing 600 households and schools with electricity. The project also aimed to create a distribution network for sales and service, provide training and experiment with alternative financing mechanisms (credit and cash sales). The project was initiated in Gansu province where a typical SHS had the following configuration: 20Wp crystalline silicon PV panel, a charge controller, a 38 AH sealed lead-acid battery, two 8-W compact fluorescent lamps, and associated wiring. The retail price was 2400 RMB (290 USD in 1995). DOE provided 50% of the costs while the Chinese agencies provided the remaining 50%.

Three local companies assembled the components and installed at the consumer premises – one was a private company, one was a subsidiary of a state-owned research institute while the third was a state-owned electric component manufacturing unit. The main components were initially supplied from the US and subsequently made in China in collaboration with US companies. However, quality was an issue and strict quality control was introduced. The project laid emphasis on capacity building and a two-week technician training programme was organised.

Based on the success of this project, the Chinese Ministry of Agriculture planned to extend similar programmes to other western provinces to provide SHS to 10,000 consumers. It also decided to create a testing and monitoring centre.

Source: Wallace and Tsuo (1997).

4.2 The Zambian ESCO experience

Lemaire (2009) reported the Zambian experience with the ESCO model. Zambia took the inspiration from the Pacific Islands model and has implemented it since 1999 with the financial support of the Swedish International Development Agency (SIDA). Three ESCOs have been created in three regions: one in Nyimba called NESCO, one in Lundazi, called LESCO and one in Chipata, called CHESCO. The first two started their operation in 2001 and CHESCO started in 2002. A fourth company was also considered initially but it went bankrupt. LESCO has installed 150 systems by 2005 (about 50% of them are not working), CHESCO has installed 150 systems (138 working) while NESCO has installed 100 systems (98 working). This shows that the system has not grown significantly beyond their initial operations. The investment cost was about one million dollars for 400 systems. The installation costs are broken down as follows:

- for NESCO, 100 installations cost 104,000 USD;

- for LESCO, 150 units cost 134,000 USD, while

- for CHESCO, 150 units cost 178,000 USD.

The break-down of costs is as follows: 40% for panel, 30% for battery and 30% for installation.

The government procures PV systems, which are then lent to the ESCOs, who install and maintain the systems for a fee paid by the users. The ESCOs repay the loan to the government over a 20 year period. Since 2005, the government has transferred the ownership of the assets to the ESCOs but the companies have to repay the loan within 10 years, with a capital subsidy of 50% for old systems and 25% for new systems.

A technician from the ESCO visits the installation each month to collect the fee and get the feed-back. In general, the payment record is reported to be high in NESCO (95% of the customers paying regularly) while the record is somewhat different in other areas. CHESCO, for example, faced financial problems due to default of Zambia National Service Camp.

ESCOs faced a number of technical difficulties: in CHESCO, the pre-paid tokens did not work, resulting in loss for the company and poor service to consumers. The battery packs also were a source of trouble. However, the main problem was the financial viability of the ESCOs as the monthly fee was recovering only 15% of the cost of the system. ESCOs are required to repay the loan taken from the government but with such a low cost recovery, they cannot ensure repayment. Although the companies have increased the monthly charges in recent times, the cost recovery is not ensured and the high fee makes the systems less attractive to rural users.

Conditions for replication

Lemaire (2009) also identified a few conditions for replication of the Zambian example. These are as follows:

a) locations - until costs decline, PV technology is more appropriate for wealthier areas.

The service area of an ESCO has to be such that its technicians can maintain the installations regularly and collect fees using a light mode of transport. The possibility of any connection to the grid can modify customers' expectations and can affect the financial condition of the ESCO.

b) flexible systems

Initially a standard system was made available [a 50Wp panel with a 90-105 Ah battery to light up to 4 lights and a connection for a TV/ radio]. Now ESCOs offer a number of alternative schemes to suit the customers' needs. The payment method can be made flexible as well as farmers tend to have an irregular flow of income. CHESCO accepts payments during harvest with interest.

Energizing public institutions like schools, hospitals etc. may have a social goal but from an ESCO perspective, the risk of non-payment increases from such organizations that can ruin the financial viability of the ESCO.

c) Training and awareness

The users need to be made aware of the limits and good practices of using PV systems. This could reduce the over-use of batteries and malfunctioning of systems. Establishing a local network of component and system suppliers is essential for a successful business. Excluding the local suppliers from the bidding process makes things worse.

d) financial design

Because the systems are unaffordable by the local consumers, subsidy systems are required. A study indicated that a subsidy of 50-70% of the capital costs would be required. This is an area of concern.

Rural Fund – The electricity act provides for a 3% levy on electricity consumers to create a rural fund. However, this was never created.

e) Issues

Lemaire (2009) raises a number of issues including the following:

1) ESCO for PV or for other energies: a successful business model can cater to PV and other energies for cooking/ heating. The viability of the business can be better for such a wider remit of the business.
2) Size of the ESCO: In Zambia, small companies have been created. While this provides the benefit of providing a local service, some advantages may be

obtained by expanding the size of the companies – in terms of scale of operation, cost advantage in procurement, etc. But in such a case, the company has to establish a system of managing the business internally.

4.3 Sunlight Power Maroc (SPM)

Morocco launched its General Rural Electrification Programme (PERG) in 1996. At the time Morocco had 35% of its population without electricity. PREG aimed at achieving electrification of all villages and their integration to the system by 2006. It had recorded a very impressive progress and by 2008, only about 3% of its population lacks access to electricity.

Sunlight Power Maroc (SPM) was established in 1988 and sells SHS to cater to lighting, TV and radio needs. It also supplies other related equipment such as television, water pumping systems, solar hot water systems and cell phone charging systems. It operates through wholly owned branch offices in mid-sized towns and rural areas.

The core business is conducted through a fee-for –service system used by 80% of its clients. It also offers a cash sale and hire-purchase sales. SPM supplies, installs and maintains the systems. In the fee-for-service system, the client pays two monthly instalments at the time of connection (one as deposit and the other towards first month's charge) and pays a monthly charge of 9 to 24 USD. They can cancel the contract on a month's notice and upon paying a removal charge of $25. For cash sale, the price varies between $450 and $1200 depending on the size. For hire purchase, a down payment of 30% is required and the rest is spread over 36 monthly instalments.

The approach taken by SPM is capital intensive and is difficult to raise funds from the capital market. It has sold 2000 units until 2003.

4.4 The Dominican Republic experience

ADESOL, an NGO which started as a credit business in 1984, is active in the PV market in the country. ADESOL promotes PV systems, operates a revolving credit fund, and provides training to technicians. In addition, there are other NGOs like ADEPE, SSID and ADESJO. ADEPE started as a credit agency for solar PV in 1991 and has established a large rural promoter network. SSID, a church based NGO for community development, promoted PV systems since 1992. ADESJO began its operation in PV credits since 1985. All these agencies receive funds from donor agencies or other funding agencies and provide loans to consumers.

A typical SHS consists of the following: PV module of 25-48 Wp, associated wiring and controllers, a lead-acid battery and associated converter, lights and fixtures. A typical system can support a few lights, a 14-W television and a small radio/ cassette player. Most of the components are imported but the BOS was procured locally. The cost is USD 700 and consumers purchased and owned them. They paid a monthly fee of 30 USD. But the devaluation of local currency affected the cost considerably.

Source: Reiche et al (2000).

4.5 Solar Energy Supplies in Zimbabwe

63% of the population lives in rural areas but 5% of rural households have access to clean water or energy. Until 1992, only private companies with an interest in renewable energies were involved in supplying PV systems. GEF started a PV pilot project in 1992 that provided support to rural households and applied PV for income generating activities such as small-scale irrigation.

Solar Energy Systems supplies standard kits for 3 to 6 lamps for cash or credit through a network of credit stores and other retailers. Products can also be purchased directly from the company. For credit systems, a down payment of 25% is required and the rest is payable over two years in monthly payments. An interest on the credit amount is charged at the prevailing bank rate. Only civil servants whose monthly instalments are directly credited by the government Salary Service Bureau do not pay a down payment. Majority of the systems (70%) are sold through on credit terms.

The company assembles and manufactures the kits upon receiving an order for a standard lot of kits from the credit stores or retailers. Shops receive the delivery in 3 to 6 weeks time. They demonstrate the kit to the consumers but it is the responsibility of the consumers to install the system and maintain them. Consumers can complain about malfunctioning kits and normally do not pay for them. The supplier then has to solve the problem or face legal actions. The supplier trains the staff of credit stores on the use of the systems.

The business is carried out on commercial terms. A network of 120 stores has developed in the country but the stores have their own infrastructure – not related to the supply company. They cover an area of 100 km.

Source: IEA (2003)

4.6 Experience of the Alliance for Rural Electrification

ARE (undated) provides a number of rural electrification examples using renewable energies supported by the Alliance. The examples are provided in a standard format that covers the challenge, opportunities for renewable energies, the company, project financing and project outcome. A few examples are summarized below:

a) ACRA providing hydroelectricity in rural Tanzania – ACRA, an Italian NGO working in Africa and Latin America, set up in 1968 has set up a mini-hydro project on the Kisongo river in Tanzania. The project involved two turbines of 150kW capacity and associated transmission and distribution systems. Then project was financed by a grant from the Italian government and upon commissioning the project was transferred to a multi-village utility. Domestic consumers will be charged a flat rate while the commercial consumers will pay by meter. The project will connect 200 users initially but on completion of the second turbine 1000 consumers will be serviced.
b) Conergy Sabah school electrification project – Conergy Singapore for the Asia Pacific region, a subsidiary of Conergy Hamburg, has electrified 63 schools in Sabah Malaysia using a hybrid PV-diesel system. The area did not have grid electricity and local supply from diesel generator sets was erratic. Conergy installed the systems in 63 sites. The projects were financed by the Ministry of Education, Government of Malaysia.
c) Fortis Wind Turbines in 7 Mauritanian villages – Mauritania is one of the poorest countries in the world where access to electricity is a problem. Car batteries are used to provide electricity but its recharging required a long distance traveling. Fortis installed a wind turbine of 1400 Watts that generated power to charge the batteries and excess power is used pump water. The project was financed by the Dutch Ministry of Development and the operating costs are paid revenues from battery charging service.
d) Solar and hydropower in Laos by IED: IED is an independent French company active in this area since 1988. A pilot study installed 6000 SHS and an expansion of the system to 15000 consumers through SHS and an additional 1000 consumers through

hydropower was agreed by the World Bank and GEF in 500 villages. This was managed by IED for the first 4 years. Local PESCos are responsible for technical and financial sustainability over 10 years. GEF and World Bank provided a soft loan and consumers pay a hire-purchase payment and a monthly repayment fee regulated by the government.

e) SHS in Eritrea – Phaesun GmbH, a German company is involved in Eritrea in supplying SHS to 350 households. A 12 Wp PV SHS was installed in each household and was financed by grants and soft loans. Each household pays a monthly fee of 4.5 USD.

4.7 The AMORE Story in the Philippines

The Alliance for Mindanao Off-grid Renewable Energy (AMORE) programme is a successful off-grid electrification programme run by Winrock International with support from the USAID and the Department of Energy, Philippines. This programme is electrifying the remote, rural areas of Mindanao island where one fourth of the national population resides. The quality of life in Mindanao has been much below the national average and the electricity access was low.

The programme started in 2002 and at present the third phase is being implemented. The programme is relying on renewable energy technologies, namely PV battery charging stations, solar home systems and micro-hydro systems, to provide clean energy to the deprived communities. At the end of the second phase 13,000 households have been electrified in 400 barangays in 12 provinces of the island. The community members organise their own association and register it with the appropriate government agency. The programme provides training to the associations to transfer required knowledge and skills to the members. The association raises funds, maintains the system and decides about the expansion of the system.

The first two phases of the programme received grants to subsidise the electrification systems. But to recover the operating costs a membership fee and a one-time charge are payable by the association members. In the third phase commercialisation attempts are being made to ensure long-term sustainability of the electrification process. The project has exceeded its targets and is successfully running, bringing lights to the poor rural communities and improving their lives.

Source: http://amore.org.ph and Winrock International (2005)

5.0 Concluding remarks

This review brings out a number of interesting findings and lessons from the rural electrification and off-grid experience around the world outside South Asia. These can be summarised below as follows:

a) Many countries considered in this review have made a significant progress in terms of electrification. However, the rate of success has depended on the level of government commitment, will and financial support to the process. In all cases, the electrification process has heavily relied on state subsidies for infrastructure development and in many cases for system operation. This leads to the issue of long-term viability and sustainability of such programmes.

b) Grid extension has been used as the preferred mode of electrification in most of the cases. In some cases, it is noticed that the alternative off-grid solutions are offered as a “temporary” solution, until grid extension becomes feasible. This is especially true in the case of South African approach but is evident in Brazil, Philippines and elsewhere. Promoting off-grid solutions as “inferior” or “temporary” solutions creates concerns regarding the acceptability of these options and reduces their attractiveness. This also creates a sense of “discrimination” or “isolation” in the minds of the users and can adversely affect the success of programmes for access to electricity.

c) The Chinese experience provides an alternative approach where rural development is integrated with the rural electrification programme. The decentralised decision-making process, reliance on local energies, development of local grid and supply network initially, followed by its upgrading and linkage to the national grid, and strong state commitment have produced a successful example of rural electrification and access. The phased network and supply development, reliance on local content, linkage with agriculture and local economic activity development, and high local participation in the process have created wider benefits that have sustained the programmes and made electricity accessible to all. However, the need for modernisation arises once the system reaches maturity and through a strong state support, China has ensured such a transformation of the system. It requires further analysis to determine whether the Chinese model can offer a replicable model for South Asia or Sub-Saharan Africa.

d) Where off-grid solutions are used, they appear to cater to limited needs of the consumers for lighting and some entertainment through radio/ TV connections. However, very limited efforts have been found where these solutions have promoted productive use of energy for income generation. Similarly, very limited effort has so far gone into hybrid off-grid solutions to provide a reliable and affordable solution. This feeds into the debate whether rural electrification is a pre-requisite for rural development or vice versa.

e) The South African example of bundling lighting and cooking solutions through the same service provider offers an interesting solution. This addresses the main energy needs of the rural communities but finding a viable, economic solution remained a challenge.

f) While some private partners are participating in some off-grid supply activities, it is the general experience that the donor-assistance or state-support has been the catalyst for off-grid solutions. Better results have been achieved where the entire programme is well co-ordinated with adequate support services and clear assignment of responsibilities. The development of a local supply chain has also played a major role in the successful delivery of the systems.

g) Some countries have created an electrification fund and/or a specific electrification organisation but the rate of electrification has not improved much. This shows that it is not sufficient to have a dedicated organisation or a specific funding mechanism. It is important to create adequate organisational capacity and sufficient funding for rural electrification. It is also important to have proper strategies, prioritisation and planning for electrification. These aspects have not been adequately considered in many countries.

This review raises a number of questions for further work. These are indicated below:

a) As indicated earlier, the possibility of replication of the Chinese model needs further investigation. Can South Asia and SS Africa learn from the Chinese example? How can this experience be reproduced in other contexts? Is the phased development of the system (local grid followed by integration) using local resources and local technology a desirable approach? Is the small-scale local resource development an economically efficient approach? Does it lead to technological lock-ins?

b) Given that the long-term viability of solutions requires consumers' ability to pay for the services, the issue of income generation and economic development of the rural users cannot be ignored in the off-grid solution design. Apart from the Chinese example, this linkage appears to have received limited attention, especially in the case of off-grid solutions. How can this integration be achieved and implemented? Further research attention on this is required.

c) Moreover, as many of the off-grid solutions are based on new technologies whose long-term reliability and implications are unknown yet, the issue of appropriate mix of technologies for a secure, reliable and viable solution needs greater consideration. The present experience does not appear to focus on such a wider consideration. Are the present experiments with off-grid solutions making the poor more vulnerable for the future? Is it limiting their future options or locking them to inferior solutions?

d) Can an electrification fund and/or a dedicated organisation form a way out for enhancing rural electricity access in developing countries? Although the experience has not been so promising so far, do they hold any promise? Can this mechanism deliver and if so, what needs to be done to make it work?

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I am only responsible for any remaining errors.

Disclaimer

The views expressed in this report are those of the authors and do not necessarily represent the views of the institutions they are affiliated to or that of the funding agencies.

OASYS South Asia project

The Off-grid Access Systems for South Asia (or OASYS South Asia) is a research project funded by the Engineering and Physical Sciences Research Council of UK and the Department for International Development, UK. This research is investigating off-grid electrification in South Asia from a multi-dimensional perspective, considering techno-economic, governance, socio-political and environmental dimensions. A consortium of universities and research institutes led by De Montfort University (originally by University of Dundee until end of August 2012) is carrying out this research. The partner teams include Edinburgh Napier University, University of Manchester, the Energy and Resources Institute (TERI) and TERI University (India).

The project has carried out a detailed review of status of off-grid electrification in the region and around the world. It has also considered the financial challenges, participatory models and governance issues. Based on these, an edited book titled "Rural Electrification through Decentralised Off-grid Systems in Developing Countries" was published in 2013 (Springer-Verlag, UK). As opposed to individual systems for off-grid electrification, such as solar home systems, the research under this project is focusing on enabling income generating activities through electrification and accordingly, investing decentralised mini-grids as a solution. Various local level solutions for the region have been looked into, including husk-based power, micro-hydro, solar PV-based mini-grids and hybrid systems. The project is also carrying out demonstration projects using alternative business models (community-based, private led and local government led) and technologies to develop a better understanding of the challenges. It is also looking at replication and scale-up challenges and options and will provide policy recommendations based on the research.

More details about the project and its outputs can be obtained from www.oasyssouthasia.dmu.ac.uk or by contacting the principal investigator Prof. Subhes Bhattacharyya (subhesb@dmu.ac.uk).

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