Conference Proceedings

Solar World Congress 2015
Daegu, Korea, 08 – 12 November 2015

SWC_ Off-grid rural electrification approaches – Lesson learnt from ASEAN

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Abstract

The Association of Southeast Asian Nations (ASEAN) has a population of approximately 625 million people, of which around 50% live in rural areas. More than 20% of ASEAN Member States's (AMS) population still does not have access to reliable, affordable and sustainable sources of electricity that impede economic development and an improved standard of living. Providing their citizens with electricity access and increasing their respective electrification ratio has been a constant effort and become high priority over the last decades. The challenges to improve electricity access are diverse including institutional, governance barriers, financial and technical.

Successful examples of rural electrification based on renewable energy can be found all over ASEAN. However, less successful examples are equally widespread since renewable energy utilization often lacked a sound long term strategy or feasible business models which are crucial to ensure the sustainability. The lessons learnt from these rural electrification projects prove that the ASEAN region is still facing many challenges.

This paper presents the rural electrification situation at the regional as well as country level in ASEAN. The paper also does comparative analysis- based on the literature review, survey, interview and workshop- to explore cross learning potential and give recommendation that could serve as input for policy review, evaluation and improvement to assist future electrification efforts in the region.

The paper focuses on six aspects of off-grid rural electrification in ASEAN: (1) Policy framework; (2) Financing mechanisms and required support policies; (3) Project setup and business models; (4) Appropriate technology solutions; (5) Socio-economic aspects and community involvement; and (6) Capacity building and training. For each aspect, a number of successful approaches and lessons learnt were analysed.

Keywords: *Rural electrification, off-grid, renewable energy, ASEAN*

1. Introduction

Access to energy must be assured for development of a region, a process in which living standard (e.g. electricity, heat, mobility) of its people improves. Energy consumption in ASEAN has grown rapidly especially in megacities. However, energy (electricity) distribution to rural area remains as a challenge due to geographic and demographic characteristic of the region spread widely across southeast Asia. Rural electrification was therefore high on political agenda of the countries over the last decades and continues to be an important issue for a number of countries in the region, especially in Cambodia, Lao PDR, Indonesia and Myanmar. The reasons for low electrification rates differ from country to country: high generation costs and low income as well as adverse topographic conditions and high transportation costs are potential obstacles to successful rural electrification in those countries.

Nevertheless, the ASEAN region and its member countries are endowed with vast renewable energy resources. Hydropower, biomass, solar or wind power are feasible and often cost-efficient alternatives to conventional means of rural electrification, in particular in areas with high grid extension costs or a sparse density of population.

doi:10.18086/swc.2015.03.03 Available at http://proceedings.ises.org

There are many examples of successful and sustainable rural electrification utilizing renewable energy in the ASEAN region. Less successful examples, however, are equally existed and lead to a waste of financial resources and;/ an unnecessary high number of households without access to modern energy services. Lack of knowledge and technical skills, ineffective and unsustainable project design and the absence of financial resources undermine the long term impact of many rural electrification efforts.

This paper presents the current rural electrification trends at the regional level and at the same time review the development and lesson learnt in Cambodia, Indonesia, Lao PDR and Myanmar. These countries were selected since the electrification rate are relatively low, therefore the rural electrification activities has been significant. This work makes use of both preliminary and secondary data in presenting the current status of rural electrification in ASEAN. The data are collated from past and recent studies on rural electrification in ASEAN. A stakeholder surveys, interviews and workshop with related stakeholders and experts were also conducted for this study.

The categories studied include policy framework, financing mechanism and required support policies, project setup and business model, appropriate technology solution, socio-economic aspects and community involvement and capacity building and training.

2. Rural Electrification in ASEAN

The current level of electrification rate in the region is around 81.2% (ACE, 2015a). Wide disparity in electrification rate exists in ASEAN. Singapore, Brunei Darussalam and Malaysia has reached (almost) 100% of electrification rate, while only 33% of the population in Myanmar have access to electricity. With high priority putting by AMS to provide access to electricity, the percentage of population with electricity access has increased during the last decade. Constant effort to increase their respective electrification rate resulting the number of people without access to electricity has went down from an estimated 190 million in 2015 (IEA, 2006) to 118 million in 2013 (ASEAN Secretariat, 2015) (Table 1).

Despite the efforts and important improvements in some of the countries, to date more than 18% of ASEAN's population still does not have access to affordable, reliable and sustainable sources of electricity. The absent of electricity access hampers economic development and an improved standard of living in entire regions. The region without access to electricity usually locate in isolated communities, such as islands, forests fringes and hilly settlements. These communities are generally small, consisting of low income households – with characteristic that may be economically less attractive to electricity distribution companies or even government electrification program that usually prioritizes the allocation of the scarce resources.

Tab. 1 Rural electricity access in ASEAN (as of 2013)

Country	Total Population (Thousand)[1]	Population without Electricity (Thousand, approx.)	Electrification Rate (%)[2]	GDP Per Capita at Current Market Prices in USD[1]
Brunei Darussalam	406	1	99.8	39,679
Cambodia	14,963	9,876	34	1,037
Indonesia	248,818	48,520	80.5	3,460
Lao PDR	6,644	841	87.34	1,548
Malaysia	29,948	180	99.4	10,420
Myanmar	61,568	41,251	33	888
Philippines	99,385	9,442	90.5	2,707
Singapore	3,845	0	100	55,182
Thailand	68,251	7,030	89.7	5,679
Vietnam	89,709	1,794	98	1,909
ASEAN	623,536	118,933	81.2	3,832

Sources: 1. ASEAN Secretariat, 2015. ASEAN Statistical Year Book 2014.
2. ACE, 2015a

2.1 Cambodia

Electrification rate of Cambodia is very low with only 34% of the population have access to electricity (ACE, 2015a). The Royal Government of Cambodia has set an ambitious target to reach 100% of the village with certain type of electricity by 2020 (including battery power) and 70% of household connected with grid-quality electricity by 2030. This target is further detailed in the National Strategic Development Plan Update 2009-2013 and Rural Electrification Master Plan (REMP) with Ministry of Mines and Energy as the focal point.

According to REMP, the total cost to electrify all village is about US$ 427 million or US$ 490 per household with 872,000 households to be connected. A total of 272,000 households will be electrified in the off-grid areas by decentralized mini-grids and solar battery chargings by the target year 2020. The gross investment costs will amount to about $147 million. While the remaining villages will be connected to the grid through grid extension. Electricity Authority of Cambodia or EAC (2014) reported that all the licenses issued covered 11,218 villages which was 79.716% of the number of villages in Cambodia. However, the distribution network developed until 2013 covered only 7,187 villages amounting to 51.07% of the total villages. Electricity prices in Cambodia are among the highest in the region between US$ 0.14 in urban areas to almost US$ 1 per kWh in rural areas (ACE, 2015b). It is mainly due to small diesel fuelled isolated generation system completely dependent on high-cost fuel imported from foreign countries, and not having interconnected system and high power losses in the distribution network (EAC, 2007).

The Royal Government of Cambodia has issued a Royal Decree to establish a public institution the Rural Electrification Fund (REF). The objectives of the REF are to facilitate access to electricity infrastructure and provide a secure, reliable, environmentally safe, and sustainable energy supply of various types, at reasonable and affordable price. The funding for REF shall be through donations and grants whose sources and terms shall be acceptable to the Ministry of Industry, Mines and Energy and to the Ministry of Economy and Finance and other sources from the government. The REF has received funds from Government of Cambodia through loan from World Bank and grant from Global Environment Facility Trust Fund (GEF). The funds provided grant assistance to licensees for new connections to households and for installation of mini and micro hydro projects and renewable energy projects, including solar home system. During 2012, REF, which was working as an independent organization was transferred to the control of Electricite Du Cambodge (EDC), the state own electricity company.

Over the years, a number of REF programs (such as Power to the Poor (P2P) Program, Program for Providing Assistance to Develop Electricity Infrastructure in Rural Areas, and Expansion of Grid Networks) attempted to enhance electricity access either as part of overall rural development or specifically targeting rural electrification. At present around 12,000 Solar Home System and about 60 Rural Electricity Enterprises (REE) that run biomass gasifier and numerous small mini hydro sites have been implemented under REF (Sovanna, 2012). P2P program provided interest free loan for: (i) costs for the connection fees of the electricity supplier, (ii) costs for deposit to be deposited with the electricity supplier, (iii) costs for purchase of materials and labour for the installation of wires from the connection point to its house, and (iv) costs for purchase of materials and labour for the installation of in-house wiring. The loan was disbursed through the licensee who is responsible to pay back to REF by collecting from the Borrower in easy monthly instalments within a specific period (EAC, 2014).

2.2 Indonesia

Rural electrification has been one of the development program priorities set by the Government of Indonesia since mid-1980s given that electrification and village electrification ratio was low at that time. In spite of difficult geographical and financial barriers, Indonesia continues to make measured progress towards providing access to electricity to the majority of its rural population. According to Indonesia Central Bureau of Statistic (BPS, 2014), in 2013, number of village in Indonesia was 74,093 that covered around 59 million households. The number of village with electricity has reached 62,682 or 80.5% percent of total village (Ministry of Energy and Mineral Resources, 2014).

On a regional basis, the electrification rate varies from below 30% in very isolated areas (e.g. Papua and East Nusa Tenggara) to over 99% in the urban centers of Java (e.g. Jakarta, Bandung and Surabaya). The successful

electrification program has increased both electrification and village electrification ratio tremendously in the last 20 years. The lack of a unified land, low population densities particularly in the eastern part of Indonesia and low average consumption per capita makes economies of scale difficult to achieve. In this case, utilization of local energy resources that predominantly renewable energy are the best option to cope with this situation.

The government categorizes rural electrification in two stages, namely pre-electrification and rural electrification (Ministry of Energy and Mineral Resources, 2010). The pre-electrification was program that provide minimum electricity supply for lightning and other minimum use of appliances (such as radio) for the household with power limited up to 100 W, powered by photovoltaic (typically Solar Home System) and micro-hydro power plant. The rural electrification was considered as full electrification program where household is connected to 220 VA or 450 VA. The electricity could be generated by diesel generator and/or hybrid power plant that combining diesel generator and renewable energy technologies such as centralized photovoltaic and wind turbine.

As rural development and its energy service provision are one of key development priorities, there are various government agencies and ministries that involve in rural electrification, i.e. Ministry of Finance, National Planning Agencies, Ministry of Home Affairs, Ministry of Rural Area and Development of Disadvantage Region, Ministry of Cooperative and Small Medium Enterprise, Ministry of Public Work and Housing, and State Electricity Company. Most of these ministries implementing renewable-based rural electrification projects through different model of delivery: directly carry out project procurement, channeling special allocation fund through provincial government, or by carrying research and development project in the beginning, followed by handing over the system to local government and State Electricity Company after the research project completed. Funding for rural electrification project comes from various sources: annual national budget, annual regional budget, multilateral and bilateral grant/technical assistance, international donor organization/NGOs, CSR and others.

2.3 Lao PDR

In 2006, electrification rate of Lao was only 47 percent (Malaykham, 2006), significantly improve to 87 percent in 2013 (ACE, 2015). Rural electrification was set as power sector priority with clear target of 70% by 2010 and 90% by 2020, as stated in Rural Electrification Master Plan (REMP) (Institute of Renewable Energy Promotion, Ministry of Energy and Mines, 2013). According to Ministry of Energy and Mines (MEM, 2004), the electrification rate expansion are conducted in two methods: (i) to expand the grid to comparatively easily accessible areas and (ii) provide off-grid supplies to remote areas where it is difficult to expand the present grid due to environment or cost reasons. Development of off-grid renewable energy sources such as SHP, solar, wind, biomass increases the energy self-sufficiency and security as well as sustainability. Currently, more than 20,000 households have been connected to solar home systems and Small Hydropower (SHP) have been providing electricity to people living in rural and remote area (MEM, 2011).

Vongsay and Bounsou (2014) mentioned that electric power system of Lao PDR is separated into three parts by regions (Northern, Central and Southern region) because there is no national grid connected from north to south. The extensions of electric power grids to remote households are either prohibitively expensive or economically unjustified. The main problems to implement off-grid renewable energy technology for rural electrification are: high initial investment cost with low rate of return and unavailability of tools for management and technical standards.

The Law on Electricity, first published in 1997 and revised in 2009 then later in 2011, appointed Ministry of Energy and Mines (MEM) for framing policies and strategies for the energy sector including developing Laws and Regulation on electricity business. The responsibility of MEM included supervision of electricity companies and assisting the government in deciding the tariff. The Institute of Renewable Energy Promotion (IREP) under MEM oversees the implementation of renewable energy, energy efficiency and rural electrification programs in Lao PDR. The Law on Electricity has recommended the utilization of RE-based power plants for rural electrification, either in grid tied or off-grid mode. The law also has provision for generating funds for rural electrification.

The Lao government has successfully implemented few off-grid renewable energy-based rural electrification

Programs with the help of international funding (World Bank, JICA). The public-private partnership models like those of Provincial Energy Service Companies (PESCOs) and Sunlabob (100% Lao owned company engaged in selling hardware and providing commercially viable energy services for remote areas), have been successfully implemented. However, these programs have not resulted in large scale deployment of off-grid renewable energy technologies for rural electrification due to dependence on subsidy.

2.4 Myanmar

Myanmar has one of the lowest electrification rate in ASEAN. According to Ministry of Livestock, Fisheries and Rural Development (2014), there are 63,899 villages in Myanmar, of which only 36% of the villages having access to electricity. The remaining of 40,865 villages need to be electrified. The disparity of electricity access between rural and urban area is huge. Yangon and Mandalay, the biggest cities in Myanmar, have the electrification rate of 75%; while the rural areas have electrification rate as low as 16 percent. In fact, most of rural communities in border areas have no access to the grid-based electricity at all, while some regions and states with a high share of rural population (e.g. Ayeyarwady and Magway Regions and Rakhine State) have access to grid-based electricity below 10 percent (World Bank, 2014).

The main mode of electrification has been the utilization of diesel generator followed by the extension of national grid. The utilization of renewable energy has been constantly promoted, such as single house solar system (SHS), solar lamp charging system, small scale hydropower and biogas system. Government of Myanmar has appointed several ministries to boost the electrification rate. Ministry of Livestock, Fisheries and Rural Development (MoLFRD) is the main implementer for rural electrification, both off-grid and on-grid; Ministry of Electrical Power (MoEP) is responsible for national grid, which mainly electrifies urban areas; Ministry of Industry is helping and encouraging small and medium enterprises to invest on electricity supply; Ministry of Science and Technology undertakes researches for rural electrification especially on biomass and biogas in cooperation with Ministry of Agriculture and Irrigation.

In order to escalate the rural development and poverty reduction activities, on August 2013, Ministry of Livestock and Fisheries was reorganized as the MoFLRD, and assigned as the Focal Ministry for rural development. Under MoFLRD, Department of Rural Development (DRD) is responsible for all rural infrastructures, including electricity access. To promote the off-grid rural electrification, DRD has organized rural development and electrification committee in village and township, surveyed the community needs, allocated budget according to parliament's decision and cooperate with private sectors, UN agencies, and NGO to achieve the electrification target.

Myanmar National Electrification Plan (NEP) 2015 – 2030 is being formulised by MoEP and MoLFRD with the help from the global Sustainable Energy for All (SE4All) initiatives, led by the World Bank and the United Nations. The NEP is envision to be a comprehensive action plan for developing, financing, and implementing electricity access scale-up program in the whole country, with the target of achieving universal access by 2030. Its aims to align support from different stakeholders with the implementation program for achieving national access targets and syndicates financing on a timely, ongoing and programmatic basis. NEP also proposed institutional reforms required to ensure alignment of funding sources and accountabilities for effective and timely implementation of the electrification program.

3. Off-grid Rural Electrification Approaches

The success (or failure) of off-grid rural electrification approaches with Renewable Energy Technology (RET) depends not only on a broad range of influencing factors: geography, availability of natural resources, reliability of technical solutions, financial feasibility; but also human capacity and dedication of individuals to name only few of them. These factors vary greatly from country to country and framework conditions are comparable only to a limited extent.

However, there are certain factors which are considered to be indispensable for successful rural electrification approaches which shall be carefully considered for planning and implementation of such projects. These factors comprise: (i) a stable and predictable policy framework; (ii) reliable support policies and a feasible

financing mechanism; (iii) a sustainable project setup and business models; (iv) the application of appropriate technology; (v) the due consideration of socio-economic aspects and community involvement; and (vi) continuous training and capacity building.

3.1 Policy Framework for Off-grid Rural Electrification

Most of the countries in the region have established rural electrification bodies or formulated schemes with supportive legislation to extend the rural electrification. However, there has been no separate policy framework for off-grid rural electrification. Provisions regarding off-grid electrification are usually included in the policies and plans for rural electrification in general, which most often focus on grid extension as the least-cost solution for many rural areas.

The REF in Cambodia started a pilot project in Kampong Speu with the first US$ 10,000 repaid from the 12,000 SHS rent-to-own programme. The target of this pilot project was 1,000 households. REFs were identifying the families and managing the loans with customers. The similar project has been very successful in Lao PDR. The REMP in Lao PDR set a National Electrification Target of 94.7% on household basis by 2020, which will be achieved by on-grid system, i.e. grid extension (90.9%) and by off-grid system using mini/micro hydropower and SHS (3.8%) (MEM, 2010). REMP considered affordability as the most important criterion. At initial stage, the project developers were required to visit the village with a sample of SHS kit and explains its technical features and application as well as the payment schemes to the villagers in detail prior to list potential customers. If the percentage of candidates that was able to pay less than 50% of total households, this village would not be selected for SHS-based electrification.

While in Indonesia, the enactment of Law No.30/2007 on Energy affirmed the right of citizen to the access to energy. The law made improving access of energy for the poor and community lives in remote area as one of the key objectives of national energy management. Energy access could be achieved through providing assistance/support to the poor to improve access to energy and developed energy infrastructure in the underdeveloped region to reduce regional disparities (Government of Indonesia, 2007).

Table 2 presents common key policies to promote off-grid rural electrification prevalent in the ASEAN region.

Tab. 2 Key policies for promoting off-grid rural electrification in the ASEAN

Key Policies	Main content of the policy
Strategies	- Long term objectives and strategic goals; - Transparent overall rules and guidance regarding development plans and financial; - Roles and responsibilities among the relevant institutions and stakeholders.
Development plans	- Review of energy access in the country (i.e. detailed electrification rates in different areas); - Criteria for the selection of target areas/communities; - Resource mapping for target areas/communities (i.e. water course, biomass, wind, solar, etc.); - Action plans including prioritization of areas/communities to be electrified; - Data collection on location, socio-economic conditions, electricity demand, etc. for the targeted villages.
Financial incentives	- Specification on types and amounts of financial incentives for off-grid electrification projects (e.g. investment subsidies, VAT exemption, import duty exemption, income tax holidays, etc.); - Criteria for the entities eligible for financial incentives (e.g. power producers, project owners, end-user, community, etc.); - General pricing principles for off-grid electrification (i.e. tariff structure for off-grid applications).
Financing mobilization	Mechanism for mobilizing funds for off-grid rural electrification (including domestic as well as international sources).

3.2 Financing Mechanism and Required Support Policies

There are several possibilities that can be applied to finance off-grid rural electrification projects. The option most commonly applied in the ASEAN are private financing, financing through the public power utility, government financing, and Public Private Partnerships (PPP)[1]. Table 3 summarizes the financing mechanism and required support policies in ASEAN.

Tab. 3 Financing mechanisms and required support policies

Financing mechanisms	Financing sources	Key support policies required
Private financing	• Equity • Commercial and/or soft loans	• Market-based electricity pricing policy in target areas; • Clear legal framework on private financing in off-grid rural electrification; • Indirect subsidies (e.g. technical assistance, free land use, VAT and import duty exemption, income tax holidays, etc.); • Soft loan policy for RET-based rural electrification projects.
Public power utility financing	• Equity • Commercial and/or soft loans	• Inclusion of off-grid electrification into the utility's work program (e.g. through regulation); • Policy on cross-subsidized tariffs; • Indirect subsidies (e.g. technical assistance, free land use, VAT and import duty exemption, income tax holidays, etc.); • Soft loan policy for RET-based rural electrification projects.
Government financing	• Government budget • International/local grant (ODA) • Local/international long-term soft loans	• Policy on off-grid rural electrification; • Institutional setup to implement off-grid rural electrification programs; • Financial incentives including direct and indirect subsidies.
Public Private Partnership (PPP) financing	• Private financing • Government budget • Grants and loans	• Grants (e.g. project preparation, seed investment, etc.); • Soft loans policy for RE-based rural electrification projects; • Financial incentives including direct and indirect subsidies.

The public power utilities (e.g. PLN in Indonesia and EDL in Lao PDR) are investing in off-grid rural electrification projects using their equity capital and (soft) loans from local and/or international financing institutions, thereby cross-subsidizing rural electrification activities and – in some cases – creating business cases for private developers. Subsidies are regularly provided by the government or international partners in order to ensure financial viability for the project developers/investors and affordability for the customers at the same time. In a SHS project in Cambodia with 12,000 planned installations, US$ 100 were granted for each supplied household. The subsidy made the rental fee payment to the developer affordable for the customers at US$ 4.86 per month for a 50-Wp SHS and US$ 3.35 per month for a 30-Wp SHS over a 4-year period without interest (ACE, 2012).

3.3 Project Setup and Business Models

One of the big hurdles for off-grid rural electrification is the fact that private investments are not economically viable or the return on investment is comparably low. Thus, a sound project setup including a feasible business model indispensably ensures effectiveness and sustainability of rural electrification projects

[1] The term "PPP" is widely used in different contexts. Within this paper, PPP refers to a project where the public and the private sector cooperate and both parties provide investments.

The lack of organizational structures, high levels of initial capital investments, and lack of ability or willingness to pay by rural customers are some of the major issues that make it challenging to develop a business model for off-grid rural electrification.

A large variety of business models for off-grid rural electrification exist in the ASEAN region, depending largely on local conditions and political objectives. Table 4 summarizes the successful business model applied in AMS. In reality, however, a hybrid types of these models are often applied, combining the advantages of different approaches.

Tab. 4 Project types and business models

Business model	Key features
	Market-based models
Fee-for-service model	A project investor/developer invests in and owns the off-grid power generating system and supplies electricity to rural customers. The investor/developer ensures operation, maintenance and replacement of the power system. The customers pay for the electricity they use either based on metering (kW/h) or a fixed (monthly) charge. The electricity tariffs are usually set at a financially viable level (cost covering) and are relatively high compared to other approaches.
Dealer model	Customers/end-users purchase the power system either with own cash and/or loans. The customer is normally a household or a facility owner (e.g. rice miller). Beyond warranty service, the customer assumes responsibility for all operational and replacement costs. There is no payment for consumed electricity, only consumables and spare parts required for the operation and maintenance of the power system have to be purchased.
Lease model	In contrast to the dealer model, the equipment is owned by the lessor (e.g. ESCO) and transferred to the customer only at the end of the leasing period. The lessor remains responsible for maintenance and repair, while the customer pays a (monthly) rental fee during the leasing period.
	Government induced community-based business models
Fully grant-based model or Partially grant-based model	An off-grid power system is 100% grant-financed, usually by government or international partners, while the projects implemented under the partially grant-based business model will be financed by a mix of grant and long-term soft loans and/or local contributions (e.g. from the government budget or the community). The power system is usually owned, operated and maintained by a community- based entity such as village committee, community cooperative, etc.
	Public Private Partnership (PPP) models
Operation-Maintenance PPP model	The Operation-Maintenance model is a partnership, in which a public partner invests in an off-grid power generating system and contracts a private partner to operate and maintain the system. The public partner retains ownership and overall management of the power system.
Operation-Maintenance-Management PPP model	Under the Operation-Maintenance-Management model, a public partner enters a contract with a private partner to operate, maintain and manage the off-grid power system. The public partner remains the owner of the system, but the private partner may invest own capital in the system.

Fee-for-service business models helped attract the private sector to invest in off-grid rural electrification. This model applied in Shwe Hlay Chaung village in Myanmar which was implemented in 2008 to replace diesel-based battery charging system by a rice husk gasification power using a dual-fuel engine. The system included a rice husk gasifier, a 30 HP dual gas engine, a 20 kV electric generator, power distribution to supply electricity

to 50 households and a battery charging system and also free of charge electricity supply to a pagoda and monastery. The project was owned by a private developer who operated and maintained the system. Total investment was around US$ 6,100 financed by a commercial loan with 7% interest rate per annum. The total income was around US$ 500. Taking into account the cost of equipment maintenance, the investment was paid back in 2 years (ACE, 2012).

3.4 Appropriate Technology Solutions

Technology choice is one of the most critical factors that affect the success and sustainability of an off-grid rural electrification project. There are several types of technologies that can be utilized for off-grid rural electrification: diesel generators, hydro power (mini, micro or pico system), biomass gasification power system, biogas-based power system, wind power (home-scale system), solar PV (mini, home-scale or pico systems), hybrid power system. However, the most common technologies used are solar photovoltaic (PV) – both SNS as well as mini grids- and mini/micro hydro systems.

Typical SHS includes a 10 to 130 Wp PV array, a rechargeable battery for energy storage, one or more high efficiency lamps and an outlet for television or radio. The mini/mico/pico-grids are typically in the range of 5 to 1,000 kW and provide water pumping and in-house appliances. Almost all the countries reviewed have used SHS as a means for extending lighting to areas that could not be reached by the grid. A key factor of the success of the solar PV programme in different countries is due to quality standards ensured for PV panels, batteries and other components as approved by the technical standards committees in respective countries.

Two steps should be carried out in order to select an appropriate technology for an off-grid rural electrification project:

- A technical analysis to preliminarily identify the appropriate technologies; and
- Economic and financial analysis of different possible technologies.

The technical analysis includes the collection and assessment of the main input data such as local renewable energy resources, population, dispersion of customers, energy consumption, income level, willingness to pay, requirement on reliability of electricity supply, productive use of energy, etc. The technical analysis should also take into account the efficiency, reliability and expected lifetime.

The economic and financial analysis includes the capital costs, O&M costs, and other related costs (e.g. O&M training cost, environmental protection cost) of each technology, the tariff system proposed and the subsidies offered. These assessments are usually conducted technology neutral and are not pre-determined by choosing a particular technology.

3.5 Socio-Economic Aspects and Community Involvement

Socio-economic and environmental aspects as well as potential impacts on the community need to be taken into consideration in off-grid project planning and implementation. It is observed from the rural electrification efforts in all the study countries, the benefits of electricity increased standard of living, productive activities and social institutions. Environmental benefits include positive impacts on soil, water and air pollution.

In addition, local community involvement is an essential aspect in rural electrification projects. If a project is not well explained, accepted or appreciated by the community beneficiaries, sustainability can be hampered. Community involvement is therefore important at all stages of the project cycle, from planning and project development to project implementation and long- term operation. It is crucial to understand the community's needs and potential before starting with the actual planning of a project. For example the chosen project design (e.g. business model) will only work, if gain acceptance from the villagers. The communities and their representatives play furthermore a crucial role in supporting the construction works (especially for hydropower projects) as well as in operating and maintaining the power system in case this task is not carried out by a private entity.

A close monitoring and evaluation of the socio- economic and environmental impacts of off- grid rural electrification are particular interest in order to asses and understand the long-term impacts and benefits of

the measure. Since rural electrification programs most often have a political and development objective, the monitoring of economic progress, social and welfare impacts as well as environmental consequences of a particular off-grid electrification program is essential.

3.6 Capacity Building and Training

Capacity Building and Training (CB&T) is fundamental for all involved stakeholders to ensure that they can fulfil their roles and responsibilities in an off-grid rural electrification project. The Mini Hydro Power Project for Capacity Development (MHPP) in Indonesia promotes the dissemination and exchange of know-how on mini hydropower, as well as the sharing of best practices in the building of sustainable facilities (MHPP, 2011). Typically, the following stakeholders are eligible for targeted CB&T measures:

- Policy makers and government officials (central and local level);
- Project developers;
- Financial institutions and private investors;
- Equipment manufacturers and construction companies;
- Power plant operators and managers;
- Local communities/end-users

General information on aspects such as policy, technology, financing, project impacts and benefits, etc. are to be provided to most of the stakeholders in order to raise awareness and general knowledge on off-grid rural electrification. Various formats of CB&T measures such as seminars, workshops, study tours, site visits, classroom and on-site training were applied in ASEAN region. The selection of an appropriate type of CB&T depends on the target stakeholders as well as the topics presented.

4. Conclusion and recommendations

Rural electrification is one of the keys to rural development and gaining high priority in ASEAN region to meet the economic and social development goals, as well as political priority. Though all countries reviewed here have developed policy frameworks and envisage bringing more areas under electrification, some countries have no specific policy framework for off-grid rural electrification and have not shown specific initiatives to improve the overall household connection level.

Further, source of funding for rural electrification programs were in the form of private financing, government financing and PPP. Private financing is used for commercially viable projects. Government financing can offer low, affordable electricity tariffs to rural villagers, however the investment are hardly paid back while PPP combines the advantages of the private and the government financing mechanism. Subsidy component either to improve the infrastructure or through cross subsidization of tariffs for poor customers are observed in all rural electrification program in the region.

The off-grid technologies prioritized seem to fit to a large extent with the geographical characteristics of the demand, resources potential and distribution system. The distribution system and technological performance are relatively better placed for solar PV than for micro hydro and biomass gasifier.

This paper shared the rural electrification experiences and lesson learnt from four selected countries of ASEAN for cross learning potential across the region as well as other developing countries. This review presents a number of recommendations for the planning and implementation of off-grid rural electrification:

- Policy makers shall develop the key policies for promoting off-grid rural electrification which shall include a development strategy and concrete action plans, a suitable electricity pricing policy, financial incentives and a framework on funding mobilization;
- A clear legal framework for private investment in off-grid rural electrification needs to be established in order to mobilize the private sector to become actively involved in this market;
- A central institution/agency shall be created to coordinate the planning and implementation of all off-grid rural electrification activities in a country;
- The public sector should use its resources to finance off-grid projects in poor rural areas where business

models can hardly be established and projects are less or not profitable. Wherever possible and economically viable, priority should be given to the private sector to get engaged for investment and project development;

- The business model selected for an off- grid rural electrification project shall have some degree of flexibility and fit the specific conditions of the community implementing the project. The business model may have to be modified along the way in order to cater to the actual developments and changes in the project structure during project implementation;
- Whatever is the selected business model, maintenance should be taken to ensure that end-users have access to quality electricity services at affordable prices;
- The project design must not be technology driven. Technology choices are to be based on practical considerations. A cost-benefit analysis of different technology options (including grid extension) should be carried out to determine the least-cost solution;
- Productive and institutional applications of electricity not only help to improve standards of living (e.g. job creation, better health care) but also increase the economic attractiveness of the off-grid power project. The project developers therefore must consider initiating or enhancing productive activities as they significantly increase the sustainability of the project;
- Maximizing the awareness and involvement of the benefitting community in the early stages of the project cycle, especially during the project assessment phase, is vital to the success of off-grid project implementation. Key activities include public awareness campaign, regular meetings with community leaders and focus-group meetings;
- Capacity building and training to develop local capacities in design, implementation, management and O&M is essential for the success of off-grid rural electrification projects. Therefore, adequate resources should be devoted to developing local capacities.

5. Acknowledgements

The article is based on a review of the off-grid rural electrification approach in ASEAN, conducted as part of Renewable Energy Support Programme in ASEAN (ASEAN-RESP) Phase I, from 2010 – 2013. The ASEAN-RESP Phase I was a joint programme between Deutsche Gesellschaft für Internationale Zusammenarbeit, GmbH (GIZ) and ASEAN Centre for Energy (ACE).

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