Renewable energy potential and its utilization for rural electrification in Myanmar

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Abstract

Electricity plays an important role in enhancing the socio-economic development of rural and remote population. Inadequate supply of electricity in rural areas is a significant barrier to development and exacerbates poverty in developing countries where the problem is most profound. 1.4 billion people around the world virtually live in darkness during night times. Sustainable energy is a possible solution to meet the electricity demand of consumers generally, and disadvantaged rural consumers particularly.

Of more particular interest for the current study, Myanmar has the lowest level of energy access in Asia with less than 10% of the country's population having access to electricity. Myanmar, however, is richly endowed with renewable energy resources. Utilization of these renewable energy resources for rural electrification is at a very early stage of development for various reasons, including technology deficiency, high initial investment cost and, more particularly, significant physical difficulty in connecting rural communities to the national grid.

In this paper, the energy producing potential of renewable energy resources such as solar, wind, hydropower and bio-energy in rural electrification have been evaluated. Electricity generation from renewable energy resources has been found to be the most appropriate alternative energy source for the rural electrification process.

Keywords: *Renewable energy, rural electrification, policy, myanmar*

1. Introduction

The Republic of the Union of Myanmar is geographically a tropical and near tropical country with an abundance of solar radiation all year round, and the country is also heavily forested. Myanmar has a long coastal strip of over 2,008 km. Myanmar is a developing country with a population of about 60 million. The gap of the electrification level between urban and rural areas is very large. About 75% of the total population lives in remote areas and the level of rural electrification is significantly lower than urban areas [1]. Of a total of 62,218 villages in the whole country, about 45,258 villages lack electricity [2]. About 14,159 villages have off-grid power. Whilst Myanmar does have a national power grid, distributing electricity generated by use of oil, gas and coal (with which Myanmar is also well endowed) and hydroelectric power, the grid only supplies 20% to 25% of the population currently, mostly in urban areas. Nearly 90% of the country's rural population does not have access to the grid and must rely on off-grid electricity sources. That is, rural electrification is provided by the grid to only 2,765 villages. About 88% of power consumers in Myanmar rely on wood and other biomass for cooking and lighting [3]. As well, the national grid electricity capacity is unable to meet future demand especially due to 2.25% annual growth rate of population. All of this leaves the rural dwellers as the most vulnerable without power.

Most areas of the country are covered by abundant and often 'impenetrable' forest, and almost 50% of the country has mountainous and rugged terrain. Extending the current grid system to rural areas would inevitably have a negative effect on the environment. The mountainous terrain is a major barrier to development, and this would be expensive in the extreme. As well, even if the grid could be extended to rural areas, the ultimate cost to the consumer would be exorbitant. Villages are remote from each other, so it is not possible to have a sustainable consumer base in any one grid destination. For all these reasons the ultimate cost of grid-supplied electricity would be almost self-defeating for economic development for rural residents. These villages rely on locally generated power from diesel fuelled generators. Some, very few villages do have home solar power provided by the government or privately installed. About two-thirds of the country's households depend on diesel lamps, batteries or candles for their lighting, all of which are expensive and therefore unavailable to many. Traditionally, the people from rural areas have always used wood and charcoal for their household applications.

Given the paucity of power availability this has the effect of maintaining and even increasing poverty rates in rural and remote areas. The lack of electricity severely hinders communities in achieving economic development, which also hinders social development. As identified in [4], no access to electricity in rural areas seriously frustrates economic and social development of rural ethnic groups.

2. Purpose of the Research

The purpose of the current research was to investigate the viability of increasing electrification in rural areas of Myanmar by utilising renewable energy applications. Locally generated power using renewable energy seems possibly to be the answer to the supply and cost problems previously discussed. The potential of solar, wind, hydropower and biomass energy was investigated. Myanmar has a long coastal line, implying the possibility of abundant wind generation, mountainous terrain with usually reliable rainfall, implying the possibility of hydropower, abundant forests, implying the availability of sustainable bio-mass use, and also, given the rural nature of the economy, substantial availability of agricultural by-products from rice and sugar cane processing, and animal waste.

This research therefore investigated the question, simply stated as "Is the generation of electricity locally in remote and rural villages, applying renewable energy sources, viable, technically, economically and environmentally?

3. Capacity and Supply Growth

Total installed capacity of the national grid increased from 1,173 megawatts (MW) in year 2000 to 1,719 MW at the end of year 2008[5]. Electricity consumption was 104 kWh per person in 2009 and 160 kWh in 2011 [6].

Current supply is only about half of projected demand which is growing 1.5 to 2 times faster than previous with a GDP projected growth rate of 6 to 7% a year [7].

Total system installed capacity boosts up to 3,594.98 MW consisting of 2,269.34 MW (74.92%) hydropower capacity (including 33.3 MW of off-grid mini-hydropower generation), 715 MW (19.89%) gas-fire capacity, 63.02 MW(1.75%) and 3.72 MW (0.10%) of off-grid diesel generators and bio-energy in 2012[7]. In 2016, output of electricity may equal the present demand of electricity. Contemporary figures for demand indicate that it will grow at up to 12% a year [5]. National grid line losses are reported to stand at a very high level of around 25%. The country's household electricity ratio is very low because grid extensions are mainly to cover requirements of industry and urban areas [8].

4. Consumption Growth

Electricity power consumption increased to 900 GWh in year 2012 and is now at an annual growth rate of about 7%. The consumption growth rate by sector are as follows; industrial sector (6.9%), followed by commercial sector (4.9%) and transport sector (2.3%) [5].

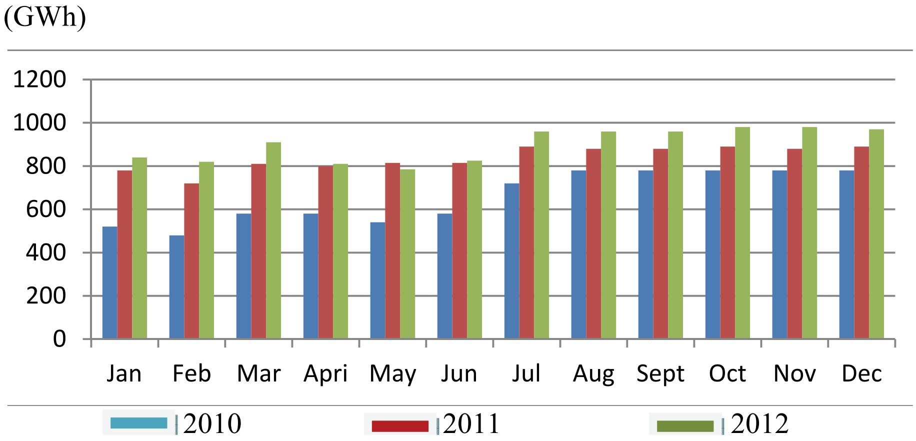


Figure 1 Monthly Growth in Electric Power Generation in 2010, 2011 and 2012

5. Renewable Energy Potential in Myanmar

5.1 Solar Energy

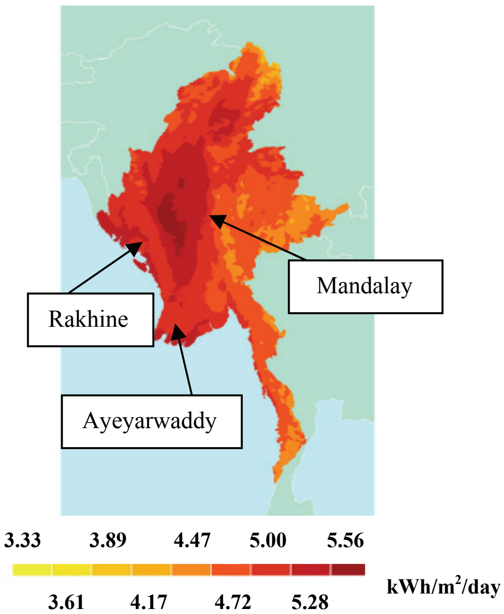


Figure 2 Yearly average of daily global radiation over Myanmar [9]

Most geographical areas of Myanmar have a high solar energy potential. The average solar radiation of Myanmar is found to be 5.08 kW/m^2/day [9, 10]. Comparison with neighbouring countries reveals that Myanmar has nearly the same solar energy potential as Thailand and Cambodia but higher than Lao PDR [11].

5.2 Hydro-Electricity Energy

With a favourable topography, hydro-electric power potential in Myanmar is estimated to be about 40,000 MW, however, with 34,568 MW is already achieved [6]. However, a caveat on the production of main grid hydro-electric power is that it depends on sufficient and reliable rainfall and river levels, which has been a problem in recent times.

5.3 Wind Generated Energy

With a 2,832 km long coastal strip and high elevation regions of Chin state, Shan state and the Central part of Myanmar, the potential for wind energy has been estimated at 360.1 TWh/year [10]. A study of wind resources was carried out in 1997 by the New Energy Development Organization of Japan. The study showed that three regions, namely the Chin state's hilly regions, the Southern and Western parts of coastal areas and the central parts of Myanmar are promising areas to harness wind energy.

5.4 Bio-waste from Agriculture

Myanmar is predominantly an agriculture economy, which produces about 4 million tons of rice husks per year as a waste product from the milling and processing of 21.6 million tons of rice. Sugar cane is also a major crop and the processing of this crop result in significant volumes of waste sugar sediment and other waste by-products (bagasse and molasses). Waste from livestock in the form of animal manure mainly, is also produced in great quantity. The actual volumes of these biomass components are stated in Table 1

Table 1 Yearly production of biomass [10]

Type	Quantity (Million ton/year)
Rice Husks	4.4
Lumber Wastes	1.5
Bagasse	2.1
Molasses	2.4
Livestock Waste	34.4

5.5 Geothermal Energy

Most geothermal locations throughout Myanmar have already been identified and recorded. Water at the surface, measured in 93 locations had temperatures ranging between 26.7 ^{o}C and 65 ^{o}C, and 43 locations with underground water at temperatures up to 200 ^{o}C have been found about 3000 ft (under sea level) deep and analysed for geothermal usefulness, including chemical analysis and X-ray diffraction analysis necessary to ascertain chemical corrosion possibilities of pipes and pumps and other equipment) [10, 12].

6. Current Application of Renewable Energy

6.1 Solar Energy

The potential of solar energy in central area of Myanmar is about 5.56 kWh/m^2/day. In April, Myanmar has the highest solar radiation and August has the lowest solar radiation. Except for July and August, Myanmar has above 4.17 kWh/m^2/day average solar radiation through the year [9].

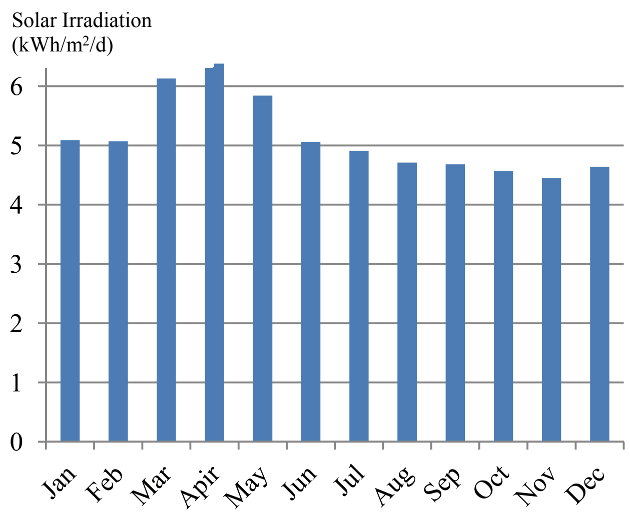


Figure 3 Average daily solar radiation in Mandalay region

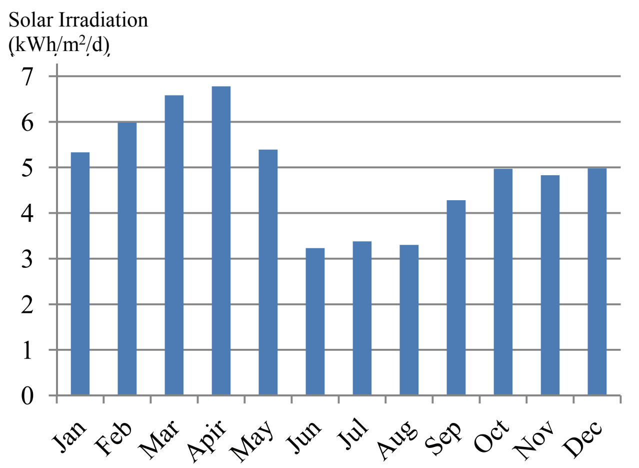


Figure 4 Average Daily solar radiation in Rakhine region

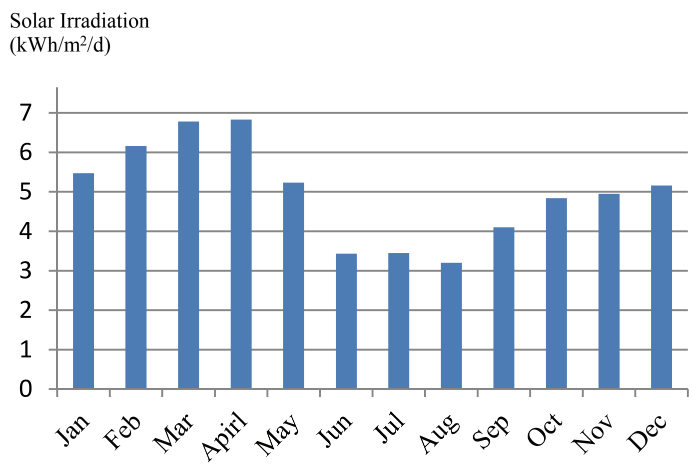


Figure 5 Average daily solar radiation in Ayeyarwaddy region

According to the figure 3, 4 and 5 the average solar radiation (based on NASA data) for the selected region is calculated. Since the peak solar radiation is 1 $kW/m^2/d$, the number of peak sun hour is numerically equal to the daily solar radiation in kWh/m^2. For instance, the daily output of solar array can be approximately estimated to be 491.3 Wh, if we assume that a 100 Wp solar array is installed in Rakhine region with average solar radiation of 4.91 $kWh/m^2/d$. Practically, energy output from solar array has about 80% in Wp. The annual energy can also be calculated based on the CEI-IEC 61724 methodology for monitoring the photovoltaic system performance by using the following equation [23]:

$$\text{Annual Energy Output (kWh/kWp)} = \text{Global in plane irradiation} \times \text{Performance ratio} = ((kWh/m^2)\ \text{year}) \times 0.5\ (\text{Solar Home System})$$

Table 2 Potential of Solar Energy in selected regions in Myanmar

Regions	Solar Radiation ($kWh/m^2/d$)	Daily energy output (Wh)	Annual Energy output (kWh/kWp)
Mandalay	5.12	512.45	1410.18
Rakhine	4.94	494.36	1293.27
Ayeyarwaddy	4.96	496.61	1279.36

Table 2 illustrates the potential of using solar energy in certain selected regions in Myanmar, such as the Rakhine region, which has the lowest level of rural electrification in Myanmar [2]. It shows that the potential for applying solar energy for electrification is high. For instance, Mandalay and Ayeyarwaddy regions have potential of daily energy output of 494.3 Wh and 496.6 Wh respectively. The Department of Engineering Physics and the Electrical & Electronic Research Centre of Mandalay Technology University implemented and installed 3 kW PV systems in remote areas which cannot access the national grid system. In order to reduce the difference of education facilities between rural areas and urban areas and to have access to the Internet (now seen as essential), the Ministry of Science and Technology has laid down a plan to provide electricity to schools and institutes by using solar energy in those areas. With a conversion efficiency of 14 to 16 % ,160W capacity solar modules were used to supply ten computers; one overhead projector , IP star internet equipment and ten fluorescent lamps in each school. The 24 V systems were installed in order to save valuable energy [13]. A properly designed system stores the solar energy in the battery bank and an off grid inverter is used to convert the stored DC energy into useable 220 V AC for common rural household usage.

6.2 Hydropower

Hydropower is more cost-effective and predictable than other renewable energy technologies that can be considered for rural electrification. Myanmar's average annual rainfall is estimated as being 2,341 mm compared with the world's average annual rainfall which is 750 mm. Consequently, hydropower potential is very high in Myanmar and one of the most commercially viable and least environmentally instructive among other kinds of renewable energy. Flood control, water supply and electric power generation can be done by using multipurpose hydropower technology. Myanmar has significant amount of hydro-power resources, and hydropower potential is estimated at 49,212 MW [7]. Based on plant size off –grid hydropower technology applied for rural electrification can be classified as Mini-hydro, Micro-hydro and Pico-hydro. The micro-hydro generation potential is estimated to be 4,450 kW in the Mandalay region whilst the total estimated Micro-hydro potential for Myanmar is 33,002 kW [5]. The total development capacity of the hydroelectric sector is about (327 MW in the national grid system). As for the long-term fulfilment of the country's electricity requirements priority has been given to the development of hydropower resources as one of the vital sources of energy.

In order to fulfil the rapidly growing demand of electricity in Myanmar, about 32 mini and micro hydropower projects have been developed over the last decade throughout the country [7].

6.3 Wind Energy

Monthly average wind velocity in selected regions such as Rakhine is 3.1 m/s based on readings from the Sittwe Meteorological station, the Mandalay region has 2.5 m/s based on Mandalay Meteorological station readings and the Ayeyarwaddy region has 2.9 m/s based on the Myaungmya Meteorological station readings. Most other regions also have average wind speed of about 2 m/s.

Through the analysis of data, it can be seen that small wind turbines could be used to provide electricity on the coastal areas, hilly regions and the middle parts of the country, which do not have access to the national grid system.

In 2005, in Chaung Thar village near Pathein township, the first hybrid power generation system was constructed. In this system, the wind turbine generates 40 kW and PV system generation is 80 kW. This system can support 1,307 households, one high school, two monasteries and one small centre with a 16 bed hospital, a police station and a post office [13].

Evaluation of wind power provides important information in the assessment of wind power projects. For this purpose the wind speed data at 10 m above ground level relating to the selected regions were taken from the Meteorological Department of Myanmar for the period 2009 to 2012. The average monthly wind speed at the reference height was changed from 10 m to 50 m, which is appropriate for the height of wind turbines in rural areas.

The power available in the wind can be calculated by [23]:

$$P=1/2\overline{\rho}V^3C_p$$

Where V is the monthly wind speed (m/s). C_p is the coefficient by Betz limit, which can achieve the maximum value of 59% for all types of wind turbines, is the corrected monthly air density (kg/m^3) and can be estimated by the following equation:

$$\overline{\rho} = 1.225 - (1.149\times104) \times z$$

where z	=	the location's elevation above sea level in meters)
u_x	=	$u_r\,(z_x/z_r)$
u_x	=	wind speed in different level (m/s)
u_r	=	wind speed in reference level
z_x	=	different height (m)
z_r	=	reference height (m)
α	=	shear exponent

By applying these equations, the potential of wind in specific regions can be estimated. Table 3 shows the estimated power output of selected regions. From that data, it can be concluded that it is important to choose a suitable wind turbine for low wind speeds as well as wind energy potential of the region, to increase the performance of wind energy power in remote areas.

Table 3 Annual available power from wind energy in selected region

Regions	Wind speed range at height 50 m (m/s)	Corrected air density(kg/m^3)	Annual available power(kW/m^2)
Mandalay	3.02	1.2	19.76
Rakhine	3.9	1.244	42.84
Ayeyarwaddy	3.65	1.223	17.54

Under the Ministry of Science and Technology (MOST), 1.2 kW wind turbine project was implemented in the technical high school, Amar township in Ayeyarwaddy Division and Dattaw Mountain, Kyaukse Township in Mandalay Division for rural electrification development and lighting purpose. A 15 ft wind turbine (3 kW) of axial type was constructed for rural electrification [13].

Table 4 Wind energy utilization projects

Location	Turbine type	Capacity(kW)	Application
Dattaw Mt. Mandalay Division	Radial Flux Magnet Generator, 3 blades, system	1.2	Electrification
Technical High School Mandalay Division	Direct Driven Horizontal Type & 3 blade system Using Axial-flux Permanent magnet Generator	1.8	Electrification
Shwe Thar Laung Mt. Mandalay Division	Direct Driven Horizontal Type & 3 blade system Using Axial-flux Permanent magnet Generator	3	Electrification

6.4 Biomass thermo-chemical energy

Since 2002, 151 community size biogas digesters for village electrification have been constructed and utilized in central region such as Mandalay, Sagaing, Magway and Nothern Shan state. These are 25, 50 and 100 cubic meter in size, fixed dome type electricity producing biogas plants with installed capacity of 5 to 25 kW, serving 175 villages with 4 hours per day of electricity. They involve anaerobic fermentation process in which cow dung is used as raw material sufficient to drive a 25 HP gas engine and 15 kVA generation [13].

In 2008, 100 cubic meters in size, fixed dome type biogas plant was constructed at dairy cow breeding farm in Mandalay Division. It can produce biogas for cooking and generate electricity to provide light to whole farm.

7. Barriers in using renewable energy for rural areas Myanmar

Despite efforts in remote areas, electrification progress and success rate is slow. There are some barriers which affect the performance of renewable energy systems in rural areas.

As an example, the performance of PV panels is significantly impacted due to build up of dust, moss, bird dropping and water spots fouling the panels. As well, given their location, fast growing trees in the vicinity also quickly shade the panels. These problems require continual and constant maintenance attention.

The initial investment cost of wind turbines is high, and the wind speeds necessary for wind turbines to be effective are not found nation-wide. Lightning strikes are also a problem given the amount of thunder storms producing lightning as a characteristic of Myanmar weather. This is also a major disincentive to using wind turbines.

Given this, wind turbines have been installed by the Ministry of Science and Technology for research purposes in connection with the development of rural electrification.

Although micro-hydropower potential is the most significant renewable energy resource in Myanmar, there are some barriers to this as well. Hydropower requires expensive control systems and extensive piping. Micro-hydropower turbines require 10 m or more of statics head of water. This is not always available in targeted rural areas where electrification is needed.

Although the capital cost is a common barrier in the implementation of mini and micro-hydro projects, using locally manufactured components, with appropriate sizing and design, costs can be contained.

8. Issues related to rural area electrification applying renewable energy

Lack of subsidies and high initial capital costs are economic issues for rural area electrification.

Also legal and regulatory rules and an adequate legal frame work within which private power producers can operate is needed. Lack of access to credit financing for both consumers and investors to undertake projects is a difficulty and there is also ack of sufficient technical awareness in rural population [14].

Since Myanmar is a developing country, progress of rural electrification has been very slow. The main reasons for this are high upfront equipment and assets costs and decentralized electricity supply grids that are gradually but slowly being extended [15, 16]. Furthermore, the high cost of transmission and distribution and over dependence on donors make it difficult to extend renewable energy into rural areas.

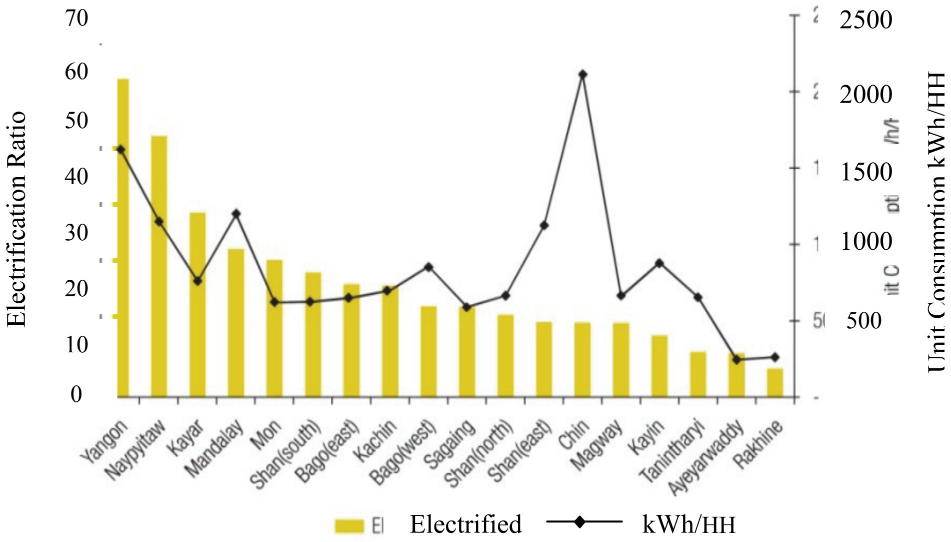
Renewable energy is one of the best ways to provide electricity for those living in rural communities. It is a key factor to make the right to development a right for all. Since Myanmar is a developing country, it needs to develop rural electrification plans and policies for those remote areas where there is no access to national grid electricity supply. Extending grid connections would be costly and impractical. The advantages of off-grid renewable energy in these areas are taken into account by the policies and rural development programmes. Due to high initial investment costs of renewable energy systems, the rural electrification utilising renewable energy sources must be supported financially by government subsidies.

In addition, the Ministry of Livestock, Fishery and Rural Development and the Ministry of Industry as the coordinator and planner of rural electrification must develop programmes which implement a renewable power plan for rural areas [17].

9. Discussion

For rural development, rural electrification is a key factor and can bring tangible social and economic benefits such as household lighting, refrigeration & cold-storage of food and improved health care for rural population. Most rural people cannot invest up front in an autonomous power supply system because of their low incomes and savings [18]. Levels of rural electrification are closely related to the cost of national grid extension combined with inadequate energy sources [19]. Since lighting is a daily basic requirement for remote areas, the villages which have an electricity supply therefore have a greater opportunity for lighting for homes, school, street lighting and health care for residents. As most rural people in remote areas, rely on agriculture, especially in the growing and supply of food crops, provision of electricity can result in better food storage and preservation, thereby enhancing food quality, as well as providing irrigation ability. In general, electrification in rural areas is an imperative for lessening social exclusion, overcoming remoteness, and lessening the vulnerability often felt by remote inhabitants.

However, two major obstacles stand in the way. First, the unavailability of electricity supplied from the national grid (only 10% of population lives in rural areas with access to electricity from national electric grid [10]), or the too high cost of that, and second the cost of conventional energy such as petroleum fuels, gas, coal, candles, paraffin for the generating of electricity, or non-electric lighting, is also greater in rural areas than in urban areas because of the remoteness of retailers.



kWh/HH = kilowatt-hour per household

Figure 6 Electrification and unit consumption [5]

The difference of electrification levels is substantial between urban and rural areas. In rural areas only 37% of the households can use electricity, 24% use battery. However, 72% have electricity and 10% use battery in urban areas. Different levels of natural status and economic development are served by different power supply enterprises, the power supply enterprise in poverty stricken areas have a high responsibility and accordingly confront more difficulties in providing universal electricity access and universal service in operation [20]. Figure 6 shows the electrification and unit consumption in each State and Division of Myanmar.

In brief, Myanmar has a profuse potential for renewable energy resources, including hydro, solar, wind and biomass. Given the amount of solar radiation access throughout the year, solar home systems (SHS) are widely used in rural areas. Solar systems can play an important role in solving the energy problem in rural areas. These energy resources have been applied at an initial stage in rural electrification and research and development programmes are still under way for the development and application of renewable energy. Although the government takes part in the development in sectors of renewable energy utilization, some rural areas still have the barrier of technology knowledge in operating and maintaining the equipment. Low level of systematic community participation is still evident.

In some areas of townships and villages remote from the national grid system, where electricity is supplied, this supply capacity is about 55,380kW. In some areas, rural electrification is provided by hybrid (mixing biomass and diesel) power generators [3]. Average electrification rates grew from about 16% in 2006 to 26% in 2011[5]. To develop long term performance of renewable energy all direct and indirect subsidies for conventional energy should be identified and gradually eliminated towards renewable energy application [21].

Electricity is a vital requirement for economic development in rural area. Electrification ratio differences between rural and urban areas are about double. Taninthary, Ayeyarwaddy and Rakhine regions located in coastal areas can access less than 10% of electrification. Myanmar's electrification rate is the lowest among ASEAN countries as represented in Fig.7 [22].

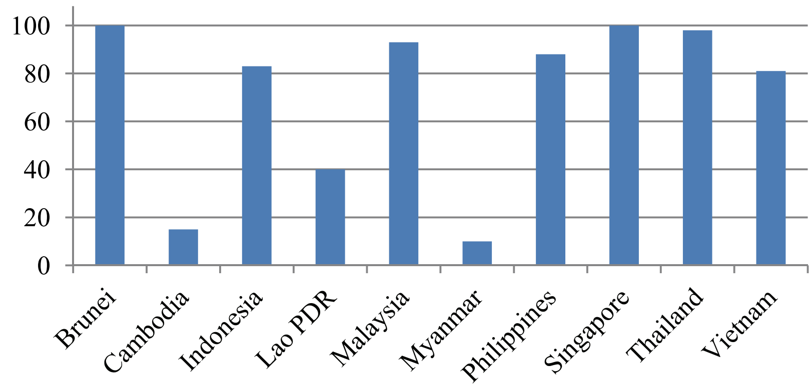


Figure 7 Electrification rate in ASEAN countries

10. Conclusion

To investigate the potential for decreasing the energy poverty of the rural areas of Myanmar with the aid of off-grid electrification, the current status of energy and electrification in rural areas was investigated. The potential renewable energy sources of three selected regions are summarized in the following table:

Table 5 Potential of renewable energy sources of selected regions

Regions	Daily solar energy Available(Wh)	Annual power available by wind (kW/m2)	Annual power available by micro-power(kW)
Mandalay	512.4	19.76	4,450
Rakhine	494.3	42.84	-
Ayeyarwaddy	496.6	17.54	-

The Rakhine region has the highest in wind power potential. Among the renewable energy sources, hydro power and solar energy are predominant. Although the average overall wind speed may be slow in Myanmar, it can still provide an alternative source for generating energy, especially in the coastal areas of Myanmar. The potential for utilizing renewable sources is high in Myanmar, given the hot and humid climate of the country. There are downsides to this climatic situation which causes some problems and barriers in implementing the rural electrification projects. To achieve the benefits of such systems in rural areas, different social, institutional and economic issues must be considered and local population's cooperation should be sought, otherwise it would be ineffective.

The current application of renewable energy for rural electrification is at a very initial stage in Myanmar. The present national grid system provides coverage in urban areas and a small number of rural areas which mainly depend on conventional energy for their lighting. Among the renewable energy sources, the most favourable belongs to biomass, solar and hydropower.

Average annual wind speed in coastal areas and some highland areas can be a good alternate energy source for rural electrification in those areas. Lack of systematic analysis and case studies and feasibility studies of community development are barriers to rural electrification development. Rural electrification processes focus on conventional methods such as grid extension technology which is not viable due to the damaging environmental effects and are not economical enough for remote dwellers that live in widely dispersed communities in those areas. So, the government encourages the development of electrification by renewable energy in rural areas with the participation of private sector. Renewable energy application is not only the most proper option for rural electrification, but it is the one suitable for Myanmar.

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