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Independent solar photovoltaic with Energy Storage Systems (ESS) for rural electrification in Myanmar

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ABSTRACT

Myanmar's energy poverty has significantly hindered the economic and human development in the country. 66% of total population lives in rural areas, but Myanmar's national grid is concentrated in urban low-land areas, limiting the energy access amid rural populations. Although conventional rural electrification projects have largely deployed diesel generators for their low upfront cost, this study demonstrates the economic competitiveness of Energy Storage Systems (ESS) and solar energy in enhancing rural energy access. Contrary to the conventional belief that these relatively new technologies are exorbitant options for low income groups, this study provides a practical solution for the leap-frogging of developing countries by proving that enhanced energy efficiency can offset the high upfront-cost of new technology options. This study compares performance among various energy configurations using HOMER and examines economic aspects of each option. For simulation, three load scenarios are designed and used to better reflect different local energy demands in rural villages. Findings confirm that a hybrid smart grid system maintains its economic and technical competitiveness under changing load conditions, while diesel based power generation is still necessary to ensure stable power supply. Finally, cost comparison with a grid extension option which the government of Myanmar is currently pursuing under its National Electrification Plan will reaffirm that the country should consider extensive adoption of sustainable energy technologies.

1. Introduction

Energy is a prerequisite for realizing a country's economic development. In the rural context, increasing access to modern energy services, such as modern cooking fuels, improved cooking stoves, sustainable biomass production, and provision of electricity is directly associated with the lives of local residents. Their current use of firewood and kerosene contributes to indoor air pollution, often precipitating respiratory diseases and even deaths. Enhanced access to sustainable energy services will bring the local population higher living standards by enabling expanded commercial and educational activities at night.

While existing rural electrification projects have largely deployed diesel generators, fossil-fuel based power generation is not sustainable in economic nor environmental perspectives and is misaligned with the low-carbon transition of the global society. Highlighting rapid technological development, this study looks for the optimal energy system configuration for rural electrification in consideration of Energy Storage Systems (ESS) and solar energy. Various studies have examined the cost effectiveness of new technology options. Researchers have confirmed that renewable options hold economic viability in developing countries such as Iran, Columbia, Thailand, Malaysia, India, etc [6,8,15] Shahzad et al. [18] explored the feasibility of solar-biomass off grid system in Pakistan.

With an aim to establish a sustainable off-grid power system applicable to rural villages in developing countries, various energy system configurations are tested using a simulation software Hybrid Optimization of Multiple Energy Resource (HOMER). The technical parameters for hybrid solar and micro hydro options with HOMER are examined [4]. Section 2 will provide an overview of the general energy environment of Myanmar to facilitate the understanding of the country's regional energy access and renewable potentials. Section 3 introduces the data used as inputs to run simulation with HOMER. For energy system components, diesel generators are also considered to complement intermittency of solar energy and high cost of battery technologies. Considering the unavailability of the load profile, three different load scenarios are designed and used for simulation to better reflect the possible changes in local situations. Section 4 elaborates the

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Table 1
Energy production in Myanmar.
Source: Ministry of Electric Power, [13]

Item	Grid System (MW)	Isolated (MW)	Total (MW)	Percentage
Installed Capacity	4456	125	4581	100%
Hydroelectric	3011	33	3044	66.46%
Gas	1325	–	1325	28.92%
Coal	120	–	120	2.62%
Diesel	–	**87(70%)**	87	1.90%
Biomass	–	5	5	0.10%

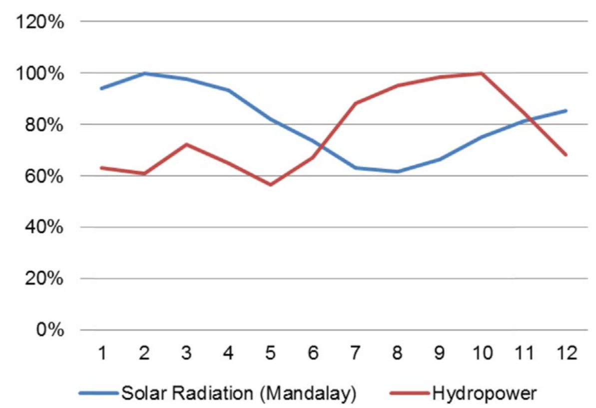

Fig. 1. Seasonal variation of solar energy and hydro power. Source: Castalia [7].

simulation results with analysis on major findings. In Section 5, the optimal energy system this research suggests will be compared to the current governmental scheme and provide policy implications.

2. Overview of energy situation of Myanmar

While Myanmar's electrification rate is at the lowest level (31%) in the Southeast Asia region (ADB, 2013) [1]), its national grid is highly concentrated in low-land urban areas. According to the same source, Yangon City has the highest electrification rate (78%), followed by Kayar (46%), and Mandalay (40%), and Nay Phi Taw (39%) in 2013. Rural areas are poorly electrified, with an average rural electrification rate of 16%. Although electricity consumption in Myanmar has doubled over the last 10 years, the national average per capita consumption of electricity is only about 110 kW-h (kWh) per annum, which is the lowest among the 10 Association of Southeast Asian Nations (ASEAN) countries. As in many developing nations, power supply for unelectrified regions in Myanmar is also largely dependent on carbon intensive sources. 70% of electricity generated from isolated grid systems in Myanmar is fueled by diesel (Table 1).

To achieve stable power supply and close regional gaps in energy access, the government of Myanmar established the National Electrification Plan (NEP) with assistance from the World Bank and the government of Japan. Aimed at electrifying 100% of households in the country by 2030, the plan addresses the least cost roll-out to the grid. According to the plan, it is estimated that about 98% of the total new connections will be grid-based, while households at the end of the roll out plan will be provided with temporary mini-grid or off grid options [7].

However, fundamental problems that are intrinsic to Myanmar's current energy environment substantially threatens the efficiency of grid-based electrification. First, Myanmar's transmission loss is the highest in the Southeast Asia region. About 24% of electricity produced from the national grid is lost in the process of transmission and distribution [22]. The country has about 250 transmission lines, extending 10,057 km (kms), and 70% them are 66 kV systems mostly originating from Yangon [4]. Low voltage is poorly suited for transmission over long distances and leads to high electricity loss. According to ADB's assessment, the majority of the existing 66 kV lines, mostly in urban areas, are already outdated and need to be phased out and replaced with those capable of handling higher voltage to enhance energy efficiency [4]. With current infrastructure conditions, transmission to peripheral areas in mountainous terrain only increases the loss and substantial funding needs to be mobilized for improvements.

Another challenge is the large dependence on hydro-power in their energy generation mix. The country has substantial hydro potential of 39,720 MW, of which about 6% has been developed [23]. The Irrawaddy and the Salween River are the two biggest rivers that provide crop lands and hydropower capacity [12]. Due to the significance of water resources to neighboring regions, large-scale hydro dams along the rivers has been developed in cooperation with neighbors such as China and India [12]. While the country's abundant water resources attract significant foreign capital investment, it is uncertain whether the

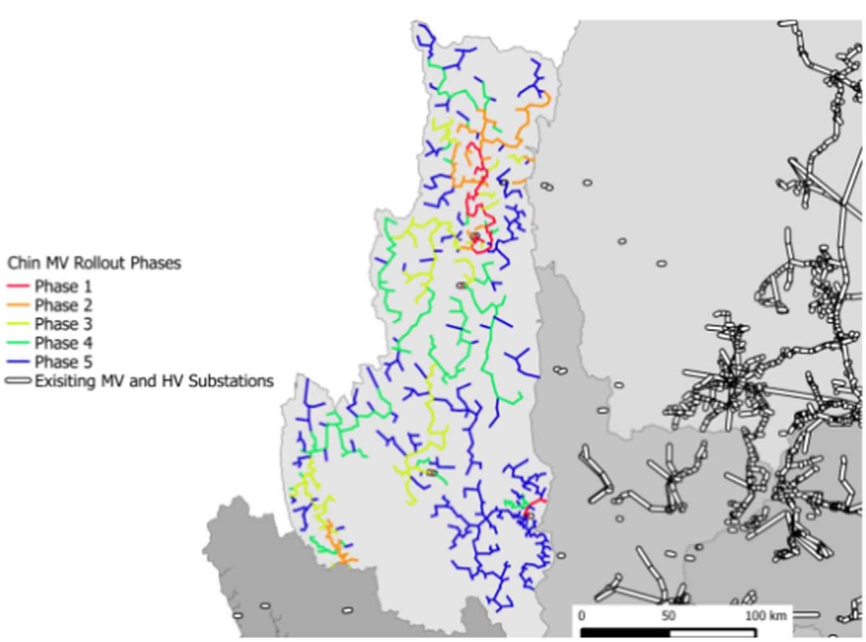

Fig. 2. National grid rollout plan. Source: Earth Institute [10].