Techno-economic investigation of a grid-connected photovoltaic-biomass hybrid system for shaping the sustainable electrification in Ayeyarwady delta of Myanmar

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Abstract. This article presents the techno-economic investigation of the Grid-connected Hybrid system by harnessing the abundant potentials of Renewables in Ayeyarwady Delta of Myanmar. The focused village in this study, Ma Yan Chaung, is geographically situated at latitude 16° 35' 7"N and longitude 94° 54' 7"E. Its annual average Solar GHI (Global Horizontal Irradiation) is 5.08 kWh per m² per day. It is included in the electrified (Grid arrived) village tract of Moke Soe Kwin and located in the Myaungmya Township. Site survey to that village was conducted in May, 2019. According to the collected data, the available Biomass is 480 tonnes per day and the estimated demand of the focused village is 2296 kWh per day with 361.7 kW peak. The thousands of different models are simulated in the powerful Microgrid tool, HOMER (Hybrid Optimization of Multiple Energy Resources) Pro (version 3.13.3). Then, the feasible Grid-connected system is proposed with 100 kW PV; 1,800 kW Biomass; 45 kW Converter; total NPC (Net Present Cost) 4,255,082 $; levelized COE (Cost of Energy) 0.01575 $ per kWh; Initial Capital 524,000 $, and Operating Cost 219,337 $. Annual Energy Sold to Grid is 15,045,299 kWh and Average Monthly Energy Sold is 1253775 kWh. The simulated results significantly demonstrate the good performance and the available benefits of the proposed system. Moreover, this system can shape the Sustainable Electrification to tackle the Climate Crisis in Ayeyarwady Delta Region of Myanmar.

Keywords: Myanmar, Ayeyarwady Delta, village Ma Yan Chaung, Grid-connected PV-Biomass Hybrid system, HOMER Pro

1. Introduction
Myanmar is in dire need to meet the Energy demands of the rapid developments in Myanmar in recent years. The electrification rate is about 50 % of the country. Hence, the more Electrical generation stations, transmission lines, and distribution facilities are required to implement.

Fortunately, Myanmar is blessed with the abundant Renewables resources. Therefore, Renewables generation systems can be the feasible options to fulfil the needs and to accelerate the momentum of the socio-economic development of the country.

1.1. Background
In Myanmar, about 65.35% of the population is living in the rural areas [6]. To terminate the rural poverty, the country prioritises Off-grid rural electrification. Then, the Pre-electrification with SHS (Solar Home Systems) and Mini-grid, is the key task of Myanmar’s National Electrification Planning...
(NEP). Solar Mini-grid is more favourable in many villages due to the abundant Solar potential. In order to implement the successful Mini-girds, the feasibility analysis is the essential work [3]. Off-grid component of the NEP is implementing by the Department of Rural Development (DRD) under the Ministry of Agriculture, Livestock, and Irrigation.

Myanmar is the ideal place to cultivate the rice which requires abundant water resources, and rice is the main agricultural crop, exported globally, and its output steadily increasing for domestic demand and foreign exchange. Once paddy is harvested, rice husk forms 20 % of the crop’s volume that is both bulky. As output increases, the byproducts of this produce also increase, may be requiring environmentally friendly ways of disposal that neither occupies space or cost too much to transport, nor pollute to the air. Myanmar produces over 13 million tons of rice per annum. According to the agriculture statistics, Ayeyarwady region covers about 28 % of the total paddy (rice) production [5]. Ayeyarwady Delta is famous as the “Rice Bowl of Myanmar” which blessed with rich alluvial soil and occupies the vast paddy farms. Due to the major rice seed production, many villages possess the tremendous Rice Husk, the raw materials for the Biomass power generation system.

1.2. Gap of the Research

The large amount of the current implementation of Mini-grid projects are Off-grid PV Mini-grid and Off-grid PV-Diesel Hybrid Mini-grid. Also, there is no research study for Grid-connected Solar PV-Biomass Hybrid system in Myanmar until now.

1.3. Motivation

It is required to highlight the benefits of the Hybrid deployment of Renewables in Myanmar. Recently, the Grid is arrived at the targeted village in this study, Ma Yan Chaung, which is included in the village tract of Moke Soe Kwin in Myaungmya Township of Ayeyarwady Delta. It has tremendous potential of Rice Husk and abundant Solar Photovoltaic (PV). The electrification rate of the whole country is 50 % in December 2019. The current electrification rate in this region is about 18 %. The feasibility investigation of Grid-connected Solar PV-Biomass Hybrid system is needed to supply the electricity demands of the local area, and sell back the excess electricity to the Grid.

1.4. State-of-the-Art

The State-of-the-Art is obviously shown in Figure 1. Actually, it is the strategic process of combined four different works. The site visit is the most important work to understand the real situation and the problems to solve. From its experience, the reasonable solutions and load profiles are evaluated. Moreover, the potential of the resources are studied. Then, the appropriate Energy, the technology, design, and the main components are selected. The parameters and costs are validated. As the crucial work, the feasible models are simulated in HOMER Pro environment. Finally, the Optimum Model will be selected [1].
2. Integration of the Grid-connected PV-Biomass Hybrid model in HOMER Pro

2.1. Site location in the mapbox of HOMER Pro

Before modeling, the focused village is placed [1, 2, and 3]. Similarly, for this research work, village Ma Yan Chaung, located at latitude 16°35′7″N and longitude 94°54′7″E, is inputted into HOMER Pro mapbox as shown in Figure 2. It is situated in the Ayeyarwady Delta Region of Myanmar as mentioned in Figure 3.

![Figure 2. Location of village in HOMER Pro](image)

![Figure 3. Village in the Ayeyarwady Delta](image)

2.2. Solar and Biomass inputs

The main parameter for designing PV power generation system is GHI (Global Horizon Irradiation). Then, GHI is downloaded from NREL (National Renewable Energy Lab) database in HOMER Pro as mentioned in Figure 4. The scaled annual average GHI is 5.08 kWh per m² per day, which is appropriate with the map data in [12, 13]. The output power of PV system can be varied according to the rating of the temperature. Therefore, the effect of the temperature is considered with the PV Advanced Properties module in HOMER Pro. Then, the temperature data is needed to input and downloaded from NREL. Its scaled annual average is 26°C. The collected Biomass data is set up in HOMER Pro as reflected in Figure 5.

![Figure 4. Solar GHI input of the village](image)

![Figure 5. Biomass input of the village](image)
2.3. Project parameters
For strategic Energy planning, the Economics and the Constraints are the key parameters [2]. Based on the data in [14], the discount rate and the inflation rate determined. The annual capacity shortage is put as 0 %. by considering 24 hours supply for each day. The project lifetime is taken as 25 years.

2.4. Load profile
Load profile of the village Ma Yan Chaung is evaluated as 2296 kWh per day and 248.78 kW peak. It covers the total power of 100 households, public utility loads, and public end users of this village. Then, this load profile is set up in HOMER Pro model as described in Figure 6.

2.5. Main Components
The proposed Grid-connected PV-Biomass Hybrid model is mentioned in Figure 7. PV inputs for 1 kW are: Capital cost is 1080 $; Replacement cost is 0 $; Operation and maintenance cost is 0 $ per year, and the lifetime is 25 years. The advanced input is the ground reflectance 20 %, and the array (panel) slope is 16°. Temperature inputs also set with PV Array temperature coefficient -0.38 % per °C, and PV Array operating cell temperatures 47°C; and efficiency of the standard test condition is 19.1%. The converter inputs for 1 kW are: Capital cost is 400 $; Replacement cost is 380 $; Operation and maintenance cost is 0 $ per year and lifetime is 15 years. The available raw material, Rice Husk, is sufficient to feed 1800 kW Biomass generation system. Then, it is set up with the capital cost 210,000 $, the replacement cost 150,000 $, and the operation and maintenance cost 1.5 $ per operating hour. Based on the electricity prices of the country, Grid inputs are set up as: Grid power price 0.10 and 0.11 $ per kWh and Grid sellback price 0.03 and 0.05 $ per kWh.

3. Simulation Results and Analysis

3.1. Tabular results
In HOMER Pro, the thousands of various Mini-Grid models are investigated with the mix-analysis of Techno- Economic performances based on the inputs set up of the previous section. The simulation table results are arranged for the models of the most optimal to the least cost-effective options [2]. The optimization tabular results are shown in Figure 8.
The optimum Grid-connected model is evaluated as: 100 kW PV; 1,800 kW Biomass; Converter 45 kW; Dispatch LF (Load Following); NPC (Net Present Cost) 4,255,082 $; levelized COE (Cost of Energy) 0.01575 $ per kWh; Operating Cost 219,337 $; and Initial Capital 524,000 $.

3.2. Electrical and Renewables results

Figure 9 reveals the electrical results of the proposed Grid-connected Solar PV-Biomass Hybrid system. PV system shares 0.85% (136,646 kWh per year) and Biomass shares 99.1% (15,768,000 kWh per year) of the electricity production. AC primary load consumes 838,040 kWh per year and 5.28% of the total generation. The proposed model can sell 15,045,531 kWh per year, 94.7% of the total generation, to the Grid. Excess electricity shares only 0.0943%. There is no unmet electric load.

Figure 9. Electrical Results of the Proposed System

Figure 10. Biomass generator power output

Figure 11. PV power output

Figure 10 and Figure 11 are the Renewables results dealt with the power output. It can be seen that the Biomass generator can be generated the constant power for the whole year whereas the PV power generation is fluctuated throughout the whole year.
3.3. Grid results

Grid results are presented in Figure 12. It is obvious that the energy purchased is zero and the energy is sold in every month. It is more than 1,200,000 kWh energy sold in most of the month, except February.

![Figure 12. Grid results](image)

4. Conclusions

In order to perform the real implementation of the Sustainable Hybrid project, the Techno-Economic investigation is very important. The feasibility studies of all of the Mini-grid in Myanmar are evaluated by applying the HOMER Pro software tool. Therefore, this research work is very useful as the trusted reference to fulfil this fact.

The proposed model is the Grid-connected system. Therefore, the project life time is considered as 25 years. The evaluated COE (Cost of Energy) of the proposed system, 0.01575 $ per kWh and the other economic results are the reasonable value. In every month, the proposed system can sell the generated power to the Grid. The proposed Distributed Generation system can enhance the Grid reliability as well as promote the electrification rate. Moreover, the other electrical results are excellent and therefore, this work can be shaped as Sustainable Electrification with 100 % Renewable fraction by installing the Grid-connected PV-Biomass Hybrid System in the Ayeyarwady Delta Region. The endless welfare towards the local inhabitants can be achieved by implementing the proposed system.

5. Recommendations

The recommendations from this research study are highlighted as follows:

- Rice Husk could be taken from the neighbouring villages either to meet the minimum limit of the storage capacity or reduction of the water pollution in the rivers and the streams of Ayeyarwady Delta Region.
The harnessing the potential of abundant Rice Husk can save the annual oil expenditure as well as the foreign currency of Myanmar.

The proposed system significantly contributes to achieve Goal No. 7 of the World’s SDGs.

The current Diesel Mini-Grids of Myanmar’s villages can be substituted by the Solar PV-Biomass Hybrid Mini-Grids.

6. Future works
The future works are mentioned as the following:

- Future studies could be more details of the technical designs.
- Integration of Wind power generation system could be considered.
- It should be scheduled for the operation and maintenance of the Biomass generator.

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