Optimization of the Hybrid System for Micro Hydro, Photovoltaic and Biomass Power Generation in Senamat Ulu Village Using Homer Simulation

Elsi Alfionita Syawal, Refdinal Nazir

Universitas Andalas, Kampus Limau Manis, Padang, 25163, Indonesia

ABSTRACT

Currently, the supply of electrical energy is still not fulfilled in some areas due to the depletion of conventional energy sources and fossil energy. The ideal alternative energy is renewable energy that does not have the potential to run out such as solar energy, biomass and water. Senamat Ulu is a village in Bungo Regency that has the potential for biomass power generation because it has a lot of palm oil plantations covering an area of 3,917 hectares with an average production of 6,901 tons per year. Based on the coordinates of the center of the village, simulation Homer scored solar radiation of 4.43 kWh / m2/ day for Ulu Senamat area. The purpose of this research is to obtain the amount of biomass energy potential and the optimal model for the hybrid system of power generation in Senamat Ulu Village. From the results of the study, it was found that the potential for electrical power from the biomass power plant in Senamat Ulu was 6,113.65 kW consisting of 2,189.08 kW shells and 3,924.57 kW palm fiber. The most optimal generator model is simulation I in terms of the smallest NPC and COE economies, namely NPC $ 275,091 and COE $ 0.0768/kWh where Biomass is 49,946 kWh/year at a cost of $ 0.0271/kWh, PV 26,681 kWh/year with electricity price of $ 0.107/kWh, Micro hydro 156.025 kWh/year with electricity price of $ 0.00992/kWh, Storage Li-ion 8,643 kWh/year and converter 288,331 kWh/year and the time required to payback is 5.8 years.

INTRODUCTION

Currently, the supply of electrical energy is still not fulfilled in some areas due to the depletion of conventional energy sources and fossil energy. Alternative energy can solve the problem of electrical energy. The ideal alternative energy is renewable energy, in other words the energy does not have the potential to run out such as solar energy, biomass, heat and others.

Palm oil waste has the potential as biomass energy where the waste is used as a substitute for coal which is used as fuel in Biomass Power Plants. Senamat Ulu is a village in Regency Bungo that has the potential for a biomass power plant (PLTB) because it has a lot of oil palm plantations covering an area of 3,917 hectares with an average production of 6,901 tons per year. Therefore, Senamat Ulu has a great opportunity to utilize palm oil waste as a Biomass Power Plant. In addition, Senamat Ulu also has the potential for renewable energy from sunlight sources. Based on the coordinates of the center of the village, simulation Homer scored solar radiation of 4.43 kWh / m2/ day for area Senamat Ulu data sourced from the US space agency (NASA). The use of renewable energy in the hybrid generation system will later be able to meet the electricity needs in Senamat Ulu. The electricity supply in Senamat Ulu Village is supplied by utilizing a micro hydro power plant (PLMH). However, the PLMH has not

been able to supply electricity optimally because the generating capacity is only 27 kW. Therefore, the hybrid system is a way to meet the electricity needs in Senamat Ulu village.

An efficient and reliable hybrid system design is obtained based on the correct combination of renewable energy sources, the climatic conditions of the area under study and the initial cost of the system components. To reach the optimal solution, intensive research has been carried out as in [1]-[4]. Several types of optimization methods are needed to obtain the optimal design of the hybrid system in order to achieve the optimal combination of renewable sources. Recently, various researchers have utilized algorithms in hybrid system optimization. Kalan tar et al [5], utilized a genetic algorithm (GA) to reduce the annual cost of isolated micro turbines/wind turbines with battery storage systems. Koutroulis et al [6], have also developed a genetic algorithm to achieve the optimal size of isolated hybrid systems. Singh et al [7] used antechnique artificial bee colony (ABC)to conduct a feasibility study of a photovoltaic (PV)/wind/biomass system, the results of the proposed algorithm were compared with the HOMER software and the results of the particle algorithm swarm optimization (PSO).

Paliwal et al [8] used a formal method to determine the optimal source grouping for an autonomous system. PSO has been applied to find the optimal size for each hybrid system equipment. Sharafi

& EL Mekkawy [9], have proposed a multi-objective PSO approach to optimize the size of the hybrid system depending on the emissivity constraints that have been used to reduce system costs, unmet loads and greenhouse gas emissions.

Based on the above conditions, the author takes a title "Optimization of Hybrid Systems for Micro-hydro,Power Plants Photovoltaic and Biomassin Senamat Ulu Village Using HOMER Simulation" which is written in this thesis. The illustrated system selects three types of energy sources: micro-hydro, photovoltaic and biomass.

PV-Wind Micro Hydro

Hybrid Generating System (PH)

The hybrid generating system is to connect various generating units with a battery storage system so as to increase the energy supply period and optimally utilize the available renewable energy resources and ensure the reliability of energy supply. To deal with unpredictable weather conditions and to put the energy supply system at load in the worst conditions, this strategy requires large energy storage capacity and costs a lot of money. However, the solution to this problem is to supply energy from the battery during cloudy weather periods and there is another backup supply (usually a diesel generator).

Introduction provides adequate background or context (problem and its significance) of the study. The subject should not be written extensively. It is expected that rationale or purpose of the study (gap analysis), the objective in general and specific, and hypothesis (if any) should be expressed clearly. Present a clear "state of the art" of the subject, which discussed literature and theoretical concepts behind it. A concise general background may be included in the article. Present at least 5 (five) recent related works to support the novelty of the research.

Biomass Power Generation Biomass

Used solely for power generation is seen as an inefficient use of biomass. Usually the overall efficiency of a biomass turbine steam power plant is 18% - 24%. Only a small part of the total energy generated from burning biomass is converted into electricity. The heat generated from the combustion of biomass is used to generate steam and turn a turbine to produce electricity.

When the steam passes through the turbine it loses only part of its heat energy. When it exits the turbine it still has a relatively high heat energy and usually this heat is released into the atmosphere through the smoke stack. The combined heat and power systems focus on capturing this heat and using it for productive purposes [6]. Higher efficiency in energy improvements can result in energy cost savings, reduced waste heat and lower CO_2 emissions. Processing plants that require large amounts of heat and electricity such as pulp and paper mills are ideal for this application. The particle size of the biomass ranges from 5 cm to several mm. The raw materials used are free due to the heat required to evaporate the water in the particles. However, the maximum moisture content is up to 30% to 50%.

Systems Photovoltaic Solar (PV)

Energy is environmentally friendly energy and is available continuously. The characteristics of solar radiation have attracted the energy sector to use this energy source on a larger scale. The solar radiation profile represents the solar resource data for the selected location. Solar radiation is highly dependent on latitude and climatic conditions [10]. The monthly average of direct solar radiation is taken by HOMER using the latitude and longitude of the selected location.

The cost of solar electricity with photovoltaic solar panels (PV) has become economically feasible in Indonesia. Solar PV generates electricity by the principle of the photovoltaic effect. Incidence of solar radiation on PV solar panels and the electricity generated. Electricity is generated in the form of Direct Current.PPV is the power output of the panel, IT is the total solar radiation on the panel, η is the efficiency of the panel. Output power is given by [11],

$$P_{PV} = I_T \ \eta \ A_{PV} \ P_{PV} \ = \ I_T \ \eta \ A_{PV} \tag{1}$$

$$\eta = \eta_{mod} \ \eta_{PC} \ P_r \ \eta \ = \ \eta_{mod} \ \eta_{pc} \ P_r \tag{2}$$

$$\eta_m = \eta_r \ (1 - \beta(T_C - T_r) \tag{3}$$

Where:
η_r = efficiency module references,
η_{PC} = efficiency power conditioning,
P_r = factor of packing,
β = temperature coefficient of efficiency array
T_r = the reference temperature for cell efficiency
T_c = monthly mean cell temperature
A_{PV} = solar array area

Micro Hydro Power Plant (MHPP)

Micro hydro power plant (MHPP) has components consisting of generator, water (hydro) and turbine. The amount of discharge and water level are the basis for measuring the work of MHP. The water rotates a turbine so that mechanical energy is obtained and is used to turn a generator and then produce electricity.

To obtain the amount of power generated at the MHP, in general, use the following equation [13]:

$$P = \rho \ x \ Q \ x \ H \ x \ \eta \ x \ g \tag{4}$$

Description:
η = turbine efficiency
P = turbine power(Watts)
H = effective head(m)
Q = the water flow (m^3/ s)
G = force of gravity (m / s)
ρ = density of water (kg/m)

HOMER

Homer used to assist in the design of power system optimizations and to facilitate comparison of power generation technologies in various applications. Homer models the physical behavior of a

power system and its lifecycle cost, which is the total cost of installing and operating the system over its lifetime. Homer enables modeling by comparing many different design options based on their technical and economic benefits. In addition, Homer can choose a hybrid model that is optimized to serve the supplied electrical load. In a power plant, COE depends on the selection of various renewable energy technologies and their resources [14]. Homer contains a number of energy component models and evaluates appropriate technology options based on cost and resource availability. Analysis with Homer requires information about resources, data on component types, total load, cost, efficiency and long operating life of the plant as well as comparing various equipment to optimize the design system [15].
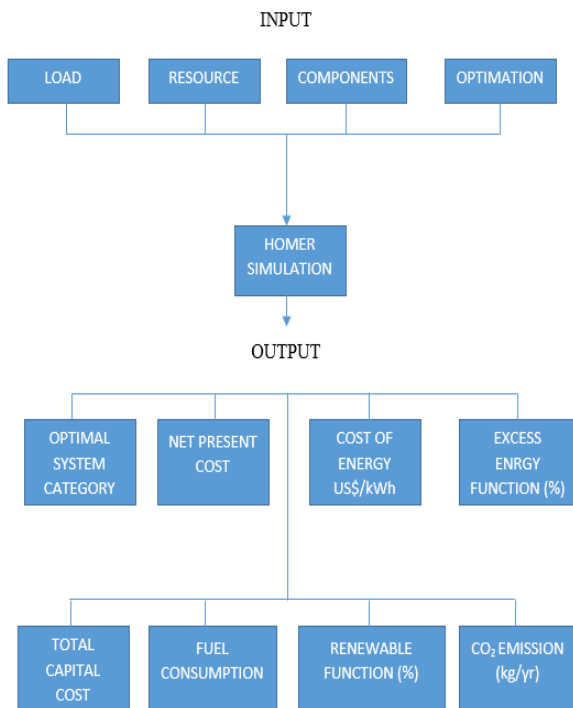
Picture. 1 Schematic from HOMER. [7]

Economical Model

The main results of the HOMER simulation are the total net current cost (NPC) and energy cost (COE) of examining the system configuration(s). NPC analysis is an appropriate measure or scale for economic purposes of comparison of classification and configuration of different energy systems, the reason being that NPC balances widely different cost characteristics of renewable and non-renewable sources. In addition, it explores and summarizes all relevant related costs incurred in the term of a renewable energy project. The economic performance parameters of the photovoltaic-biomass hybrid power system with storage and converter were calculated through system modeling. For the economic aspect, (NPC) and (COE) of the system were investigated. HOMER uses the total current net cost (NPC) to represent the system's life cycle costs. The NPC is calculated by (5) [18]:

$$NPC \ (\$) = \frac{TAC}{CRF} \tag{5}$$

$$NPC \ (\$) = \frac{TAC}{CRF}$$

Where, TAC is the total annual cost; CRF is the capital recovery factor which can be calculated by the following equation (6):

$$CRF \ (\$) = \frac{i \ (1+i)^N}{(1+i)^N - 1} \tag{6}$$

Where, N is the number of years and I is the annual real interest rate (%).

The energy cost (COE), which is the average cost per kilowatt-hour ($/KWh) of electricity generated by the system in question is estimated as in (7):

$$COE \ (\$) = \frac{C_{ann,tot}}{E} \tag{7}$$

Where, $C_{ann, tot}$ is the total annual cost, $. E$ is total electricity production, KWh/Year.

To calculate the payback time for a project (*simple payback*) as follows:

$$Simple \ Payback \ (yr) = \frac{Initial \ Investment}{Annual \ Payback} \tag{8}$$

The following in Figure 1. will explain the various input parameters that HOMER needs to model the system: the demand for energy loads that the system must serve, the energy components selected to generate electricity, the various energy resources associated with the selected components, and how these hybrid combinations are combined. operate to a service load [16].

Research Methods

In simple terms the research process for optimizingpower plant capacity *hybrid* using *software is* Homerexplained through the flow chart in Figure 2.
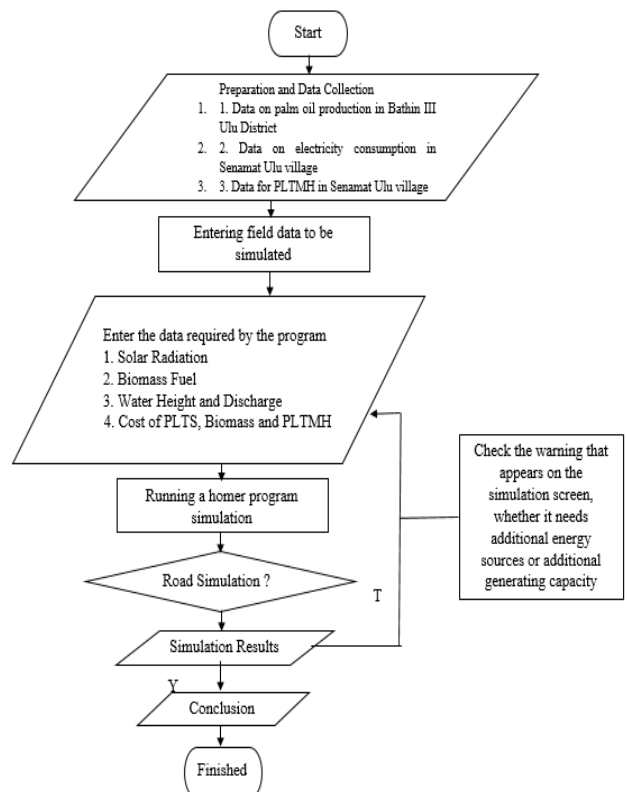

Figure 2. Flowchart of Research Methodology Thesis

RESULTS AND DISCUSSION

Electricity Potential of Biomass

Based on the research that has been done, table 1 shows the potential for palm oil that can produce electricity and table 2 shows the potential for electricity generated by biomass. The 2018 data was selected for research, which is where in table 1 it can be seen the number of shells and palm fibers that can be used. The amount of palm kernel shells is obtained from 5% of palm oil production and palm fiber is obtained from 13% of palm oil production. While in table 2, the potential for biomass electricity is 6,113.65 kW consisting of 2,189.08 kW shells and 3,924.57 kW palm fiber.

Table 1. Potential of Oil Palm Shells and Fibers

Year	Production (Tons)	Palm shells (Tons)	Palm fiber (Tons)
2014	1.720	86	223,6
2015	6.901	345,05	897,13
2016	58.305	2.915,25	7.579,7
2017	58.305	2.915,25	7.579,7
2018	58.305	2.915,25	7.579,7

Table 2. Biomass Electrical Power Potential

Year	Production (Tons)	Total Electrical Energy in one year (kWh)	Average Electric Power Potential (kW)
2018	58.305	53.555.549,9	6.113,65

Design Simulation Analysis

Biomass-PV-Li-ion-Converter- Micro-hydro

Simulation I is a combination of components of Biomass-PV-Li-ion-Converter and Micro-hydro. The results of the first simulation consist of the electricity production of each component, NPC, COE, electricity price per kWh and the emission value generated from the combination of these power plants. Figure 3 details the electricity production from the Biomass-PV-component Micro-hydro in kWh/year. Simulation I obtained an NPC of $275,091 and a COE of $0.0768/kWh.

The total electricity production obtained in the first simulation is 232,652 kWh/year. Based on Figure 3, it is known that electricity production consists of 21.5% Biomass, 67.1% Micro-hydro and 11.5% PV. Micro-hydro is the largest power generating plant.
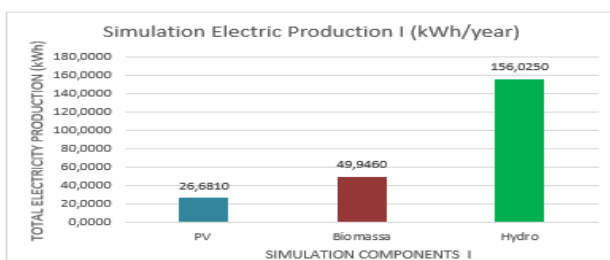

Figure 3. Simulation I Electricity Production

The total cost of each component is detailed in Figure 4. The total cost of each component is obtained by adding up the cost of capital, component replacement, operation and maintenance as well as the fuel used. Biomass is the component that has the largest cost, which is 61.44% of NPC.
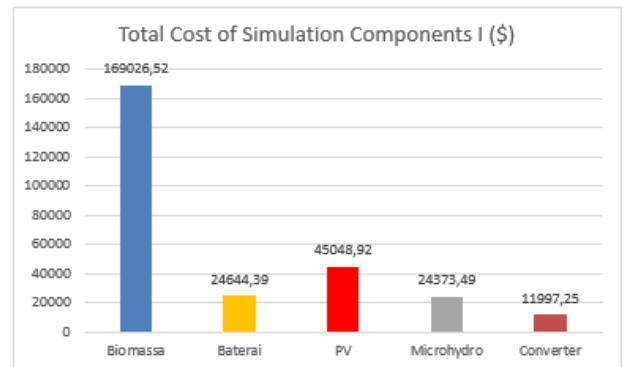

Figure 4. Total Cost of Simulation Components I

Based on Figure 5 it is known that PV has the largest electricity price/kWh compared to Biomass and *Microhydro,* which is $0.107/kWh. The COE value is obtained from the average electricity price/kWh of the three components.
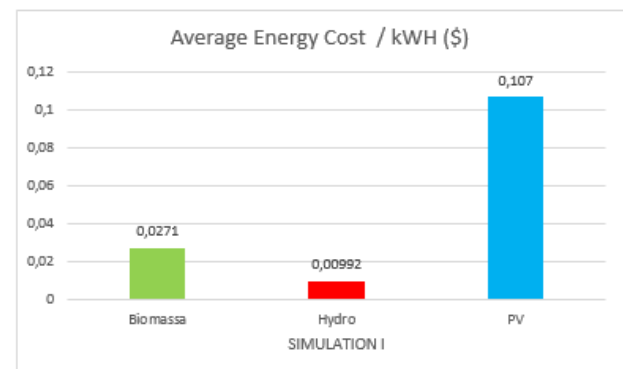

Figure 5. Average Energy Cost / kWh

Biomass-Micro-hydro

Simulation II is a combination of Biomass and components Micro-hydro. The results of simulation II consist of the electricity production of each component, NPC, COE, electricity price per kWh and the emission value generated from the combination of these power plants. Figure 6 details the electricity production from the components Biomass-Micro-hydro in units of kWh/year. Simulation II earned an NPC of $340,068 and a COE of $0.0949/kWh.
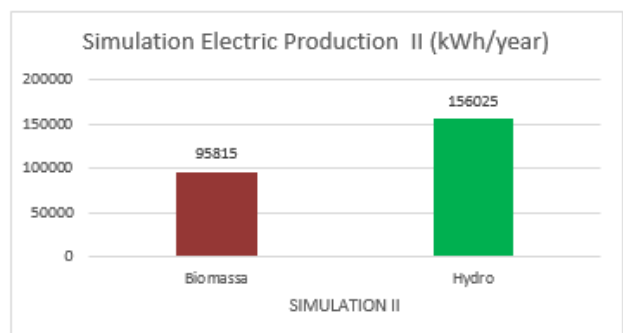

Figure 6. Simulation II Electricity Production

The Total electricity production obtained in simulation II is 251,840 kWh/year. Based on Figure 4.5, it is known that

electricity production consists of 38% Biomass and 62% *Micro-hydro*. *Micro-hydro* is the largest power generating plant.

The total value of the total cost (NPC) is the total cost of all components of the plant, which is the sum of all the costs of biomass andplants *microhydro*. This can be seen in Figure 7. Figure 7 details the total cost of each component. The total cost of each component is obtained by adding up the cost of capital, component replacement, operation and maintenance as well as the fuel used. Biomass is the component that has the largest cost, which is 92.83% of NPC.
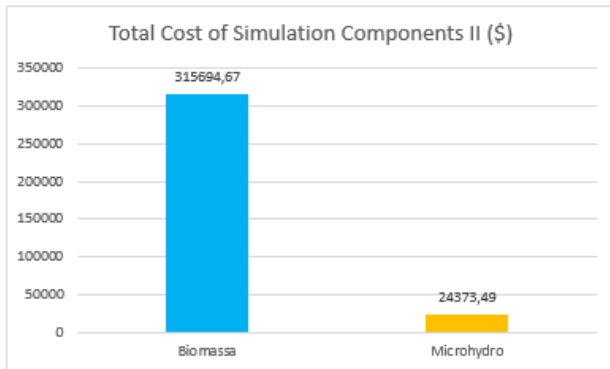

Figure 7. Total Cost of Simulation Components II

Biomass--PV- Micro-hydro Converter

Simulation III is a combination of components of Biomass-PV-Converter and *Microhydro*. The results of simulation III consist of the electricity production of each component, NPC, COE, electricity price per kWh and the emission value generated from the combination of these power plants. Figure 8 details the electricity production from the Biomass-PV-component *Microhydro* in units of kWh/year. Simulation III obtained an NPC of $340,395 and a COE of $0.0950/kWh.

The total electricity production obtained in simulation III is 251,907 kWh/year. Based on Figure 4.7, it is known that electricity production consists of 38% Biomass, 61.9% *Microhydro* and 0.0669% PV. *Microhydro* is the largest power generating plant.
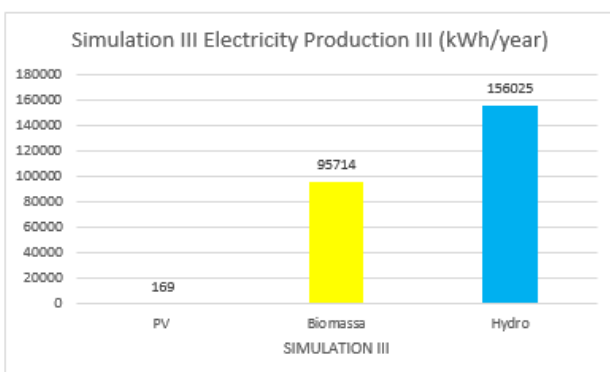

Figure 8. Simulation III Electricity Production

The total value of the total cost (NPC) is the total cost of all components of the generator, which is the sum of all the costs of biomass, PV,plants *microhydro* and *converter*. This can be seen in Figure 9 which details the total cost of each component. The total cost of each component is obtained by adding up the cost of capital, component replacement, operation and maintenance as well as the fuel used. Biomass is the component that has the largest cost, which is 92.73% of NPC.
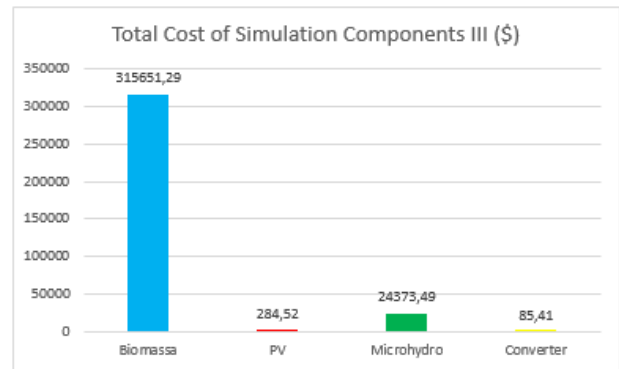

Figure 9. Total Cost of Simulation Components III

Based on the analysis of 3 Homer simulations, it is known that simulation I is better than simulation II and III because in determining the most optimal simulation seen from the smallest NPC and COE values compared to the NPC values in the other 2 simulations where NPC $275,091 and COE $0.0768/kWh. The total value of the total cost (NPC) is the total cost of all components of the plant, which is the sum of all the costs of biomass, PV,plants *micro-hydro* and *converter* (capital costs, component replacement, operational and maintenance costs). The value of COE is influenced by the production of electricity produced, so to obtain the value of COE, namely the multiplication of each electricity production against each average energy cost (*levelized cost of energy*) divided by the total amount of electricity production. To find out the payback period (*simple payback*) by dividing the initial cash out of a project by the net cash income generated by the project each year. The COE value in simulation I is the most optimal because it is the smallest compared to simulations II and III and the COE value is smaller at $0.0768, equivalent to Rp. 1,049.13 compared to the standard COE PLN of Rp. 1,352. The emission value also affects the optimality of a simulation. The optimal simulation has a low emission level so that the simulation is said to be environmentally friendly. The conclusion of the results obtained based on the analysis of the 3 simulations is shown in Table 3 of the simulation results.

Based on table 3. it can be concluded that the greater the electricity production, the greater the NPC and COE values. The emission value also affects the NPC and COE values, the smaller the emission levels, the smaller the NPC and COE values.

Table 3. Simulation Results

Simulation	Net Present Cost (NPC) $	Cost Of Energy (COE) $/kWh	Electricity Production (Kwh/Year)
I	$ 275.091	$ 0,0768	232.652
II	$ 340.068	$ 0,0949	251.840
III	$ 340.395	$ 0,095	251.907

CONCLUSIONS

The simulation results from the optimization of the hybrid power plant resulted in the following conclusions, the potential for electric power from the biomass plant at Senamat Ulu, which is 6,113.65 kW consisting of 2,189.08 kW shells and 3,924.57 kW palm fiber using Senamat Ulu plantation data in 2018 with palm oil production of 58,305 tons and can produce total electrical energy in one year 53,555,549.9 kWh. The most optimal generator model is simulation I in terms of the smallest NPC and

COE economies, namely NPC $ 275,091 and COE $ 0.0768/kWh where Biomass is 49,946 kWh/year with electricity price of $ 0.0271/kWh, PV 26,681 kWh/ year with electricity price of $ 0.107/kWh, Micro-hydro 156.025 kWh/year with electricity price of $ 0.00992/kWh, Storage Li-ion 8,643 kWh/year and converter 288,331 kWh/year. Meanwhile, for a simple payback, it takes 5.8 years.

REFERENCES

[1] M. Kalantar and SM Mousavi G., "Dynamic behavior of a stand-alone hybrid power generation system of wind turbine, microturbine, solar arrayand battery storage," Appl. Energy, vol. 87, no. 10, pp. 3051– 3064, 2010.

[2] S. Singh, M. Singh, and SC Kaushik, "Feasibility study of an islanded microgrid in rural area consisting of PV, wind, biomass and battery, 2016. energystorage system," Energy Convers. Manag., vol. 128, pp. 178– 190, Nov.2016.

[3] H. Benchraa, Abdelbari Redouane, Imad El Harraki, "Techno economic feasibility study of a hybrid Biomass/PV/Diesel/Battery system for powering the village of Imlil in High Atlas of Morocco," IEEE, vol.18, no. 9, 2018.

[4] MM Samy, MB Eteiba, and WI Wahba, "Viability study of grid connected PV/Wind/Biomass hybrid energy system for a small village in Egypt," in Power Systems Conference (MEPCON), 2016 Eighteenth International Middle East , 2016, pp. 46–51.

[5] Kunal K. Jagtap1, Ganesh Patil2, PK Katti3, SB Kulkarni, "TechnoEconomic Modeling of Wind-Solar PV and Wind-Solar PV-Biomass HybridEnergy System", IEEE, vol.16, no.7, 2016.

[6] Faten Hosney, A. Alabi, A. Yusuf, and T. Olukan, "A comprehensive review on biomass and solar energy for sustainable energy generation in Nigeria," Renew. sustain. Energy Rev., vol. 69, pp. 620–641, Mar. 2017.

[7] S. Ahammad, Alimul Haque Khan, Tabassum E Nur, "A Hybrid of 30 KW Solar PV And 30 KW Biomass System for Rural Electrification in Bangladesh", IEEE, vol.15, no.9, 2015.

[8] S. Barakat, MM Samy, MB Eteiba, and WI Wahba, "Feasibility Study of Grid Connected PV-Biomass Integrated Energy System in Egypt," Int. J. Emerg. electr. Power System, vol. 17, no. 5, 2016.

[9] E. Koutroulis, D. Kolokotsa, A. Potirakis, and K. Kalaitzakis, "Methodology for optimal sizing of stand-alone photovoltaic/windgenerator systems using genetic algorithms," Sol. energy, vol. 80, no. 9, pp. 1072–1088,2016.

[10] P. Paliwal, NP Patidar, and RK Nema, "Determination of reliability constrained optimal resource mix for an autonomous hybrid power system using Particle Swarm Optimization," Renew. Energy, vol. 63, pp. 194–204, Mar. 2014.

[11] M. Sharafi and TY ELMekkawy, "Multi-objective optimal design of hybrid renewable energy systems using PSO-simulation based approach," Renew. Energy, vol. 68, pp. 67–79, Aug. 2014.

[12] Yasser Maklad, An Introduction and Costing of a Biomass/Wind/Pv Hybrid Energy System for Electricity MicroGeneration to Domestic Buildings in Armidale NSW, Australia, Global journal of research Analysis, Vol.3 , No.4, 2014, pp. 70-74.

[13] G. Otchere-Appiah, EB Hagan, Potential for Electricity Generation from Maize Residues in Rural Ghana: A Case Study of Brong Ahafo Region, International Journal of Renewable Energy Technology Research, Vol. 3, No. 5,2014, pp. 1 – 10.

[14] M. Kashif Shahzad, Adeem Zahid, Tanzeel ur Rashid, Mirza Abdullah Rehan, Muzaffar Ali, Mueen Ahmad, "Techno-economic feasibility analysis of a solar-biomass off grid system for the electrification of remote rural areas in Pakistan using HOMER software", Renewable Energy (2017), doi:10.1016/j.renene.2017.01.033. in press.

[15] S. Barakat, MM Samy, HH Sarhan, SA Al-Ghamdi, "A Hybrid PV Biomass Generation Based Microgrid for the Irrigation System of a Major Land Reclamation Project in Kingdom of Saudi Arabia (KSA) - Case Study of Albaha Area," IEEE, vol.18, no.6, 2018.

[16] Solar Energy in Urban Bangladesh: An Untapped Potential, Nazmul Hasan Shiblee, Dhaka, Bangladesh, ChE Thoughts, December 2013, Volume, Issue 01.

[17] CMI Hussain, B. Norton, and A. Duffy, "Technological assessment of different solar-biomass systems for hybrid power generation in Europe," Renew. sustain. Energy Rev., vol. 68, pp. 1115–1129, Feb. 2017.

[18] MB Eteiba, S. Barakat, MM Samy, and WI Wahba, "Optimization of an Off-Grid PV/Biomass Hybrid System with Different Battery Technologies," Sustain. Cities Soc., 2018.