HYBRID POWER SYSTEM MODELING FOR ELECTRICITY SYSTEM IN SUMBAWA DISTRICT (HYBRID POWER SYSTEM MODELING)

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Abstract

Include the provision of energy management, utilization and enterprise shall be done justice, sustainability and so can not give optimal benefits for the greater welfare of the people. Sumbawa has a variety of potential sources of renewable energy such as; water energy, solar energy, wind energy, geothermal energy and biomass. From a variety of renewable energy potential can be made a model of hybrid power system design for the electrical system in Sumbawa is based on renewable energy in the region.

The purpose of this study was to determine the magnitude of the potential of renewable energy for power generation, knowing large share of renewable energy to the electrical energy needs and design a model of hybrid power system for electrical system in Sumbawa by using HOMER (Hybrid Optimisation Model for Electric Renewables).

The results of this study recommend a model of hybrid power system that is optimum for a total net present cost (NPC) US $ 144,954,400, operating cost of US $ 1,801,515 / year, the cost of electric (COE) US $ 0.090 / kWh of excess electricity and 99,072,760 (kWh / year) and the contribution of each component of the capacity modeling results are; PV Array 4.4%; wind turbine 20.3%; hydro turbine 74.4%; biomass generator 0.8%; G1 and G2 diesel generator as a back-up system by 0.1%. The results of model simulations also show that the model of hybrid power system that is recommended to have much lower levels of emissions than conventional systems where there is a reduction in the level of emissions into the environment by 99.75%. Thus the hybrid power system for electrical system in Sumbawa considered feasible as an alternative solution to meet the electrical energy needs in Sumbawa.

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1. Introduction

Energy resources are natural resources and strategic value is very important in supporting the sustainability of regional development activities in particular sectors of the economy. Given the strategic role of energy management which includes the supply, utilization and enterprise shall be conducted in a fair, sustainable, and optimal in order to provide added value for the greater welfare of the people. The main supply of electrical energy in Sumbawa has been derived from Diesel Power (diesel), this condition is certainly in the long run will cause problems due to the technical and environmental pollution gas emissions and the limited reserves of fossil energy sources in nature.

Nowadays a trend towards an increase in electricity demand in Sumbawa district on different sectors each year along with the increasing number of population and development activities in the area. This condition was not accompanied by increasing the supply of electrical energy, which remains terpasanng power capacity while increasing electrical energy requirements. The consequence is often done rotating power outages, especially during the hours of peak load as a result of the use of the load exceeds the power that can be provided. In the energy sufficiency required real efforts in the search, utilization and development of renewable energy resources locally. Efforts utilization and development of renewable energy sources today still requires a long time and a huge cost, there should be a planning and assessment as early as possible is supported by policy and the allocation of sufficient funds in the energy sector better. For this we need an energy planning studies that can provide the real picture of current conditions and future forecasts regarding how should potential energy resources are managed and utilized for the sustainable development of the area in Sumbawa district. Utilization of renewable energy sources in the past have not been a priority in national and regional development planning. Besides, the persistence of the budget constraints and the ability to perform mapping, planning and utilization of renewable energy potential in the region as a source of energy that can support the development process in the region. In the utilization of renewable energy sources in the area there are a few potential technologies to be developed in Sumbawa district like; biomass technology, hydro power technology, wind power technology, solar technology and geothermal technologies.

From the real conditions that have been described, the identification problem in this study focused on an effort to design hybrid power systems for the electrical system in Sumbawa district. The purpose of this study was to determine the magnitude of the potential of renewable energy in Sumbawa district for power generation, knowing large share of renewable energy to the electrical energy needs and designing a model of hybrid power system for electrical system in Sumbawa district.

An off-grid electrical systems require reliable techno-economic analysis to find renewable energy system configuration that is optimal in the long-term, analysis of the genetic algorithm which is used to evaluate two conditions so as to minimize the total cost of the optimal configuration in which the hybrid component specification from the manufacturer are used in the calculation of dimensions which represents the actual power derivation (Razak, et al, 2007).

Hybrid power system aims to find a system of electric energy generation stand-alone hybrid suitable for off-grid applications in remote areas with difficult access where the system has only one energy source of diesel power. Good and proper optimization for this system is a complex process due to the high number of variables that exist and the non-linearity performance of some components of the system so we need a device to do the simulation and optimization techniques appropriately (Agustin and Lopez, 2009).

A design scenario for supplying electrical energy to meet the demand for clean water in remote areas in the Maldives accompanied by economic analysis and environmental considerations for the effective operation system by utilizing renewable energy sources and a diesel generator which reverse osmosis desalination plan as deferrable load. Economic issues are analyzed such as the initial capital cost, fuel consumption and annual costs, the net present cost (NPC), the cost of electricyty (COE) produced by the system per kWh and the payback period for the project in addition to a variety of environmental considerations such as the amount of emissions of CO_2 and NOx, and particulates released into the atmosphere where the simulation is based on the actual condition settings (Setiawan et al, 2008).

A hybrid power generation system that is optimal for a remote village in Iran Abolhassan Sheikh, consisting of wind turbine components and systems existing local grid which will decrease operating costs by 23% and reduced carbon dioxide emissions by 32% when compared to the diesel generator only , but it also can increase the working capacity of the existing system (Asrari, et al, 2010).

Research is slightly different from the configuration of the hybrid power system is done to obtain the optimal solution to meet the needs of electrical energy in 12 villages of Tehri district Garwal Uttarakhan region of India with the optimal configuration of hybrid systems using 5 units of wind turbine capacity of 10 (kW), the battery's 25 units (6 V, 6.94 kWh), the converter 35 (kW) and 65 diesel generators (kW) and configuration of this system has cost net present cost (NPC) is the lowest (Rajoriya, et al, 2010). Renewable energy hybrid systems with control management using fuzzy logic control technique to obtain electrical energy at a cost competitive and more profitable than other energy sources, where a mathematical model of the model with MATLAB / Simulink as part of this system was developed and used to track its performance and simulation this result indicates that the presence of viable control technique (Atia et al, 2012).

2. Methodology

Research on Modeling of Hybrid Power Systems for Electrical System was conducted in the area of administrative and strategic areas in Sumbawa district. This study used energy modeling software HOMER (Hybrid Optimisation Model for Electric Renewables) to perform the simulation and optimization of the system being modeled.

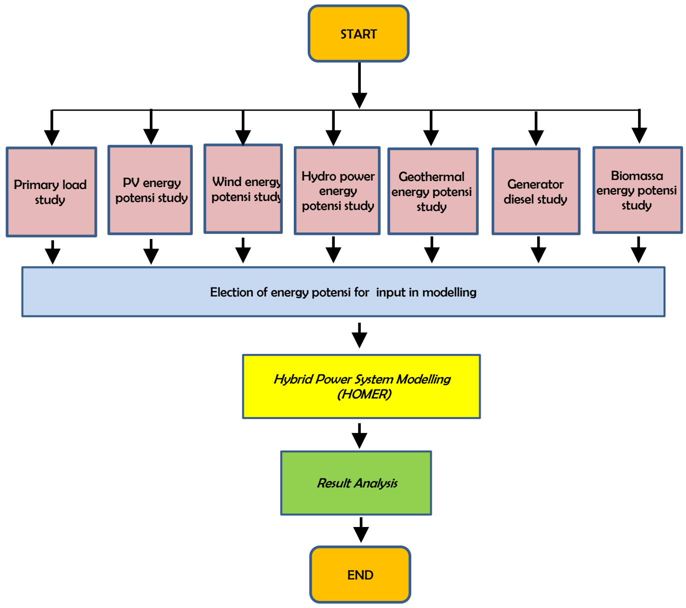

Figure 1 Flow chart of research methodology

Variety of appropriate and relevant data used in this modeling process such as:

- Electricity and electrical energy data consumption in Sumbawa from PT. PLN (Persero) BAPPEDA Areas Sumbawa and Sumbawa.
- Climatology data from BMKG Mataram.
- Wind and solar potential data from Solar and Wind Energy Resource Assesstment/maps.nre.gov (SWERA) and NASA Surface Meteorology and Solar Energy: RETScreen data for various locations in Sumbawa district.

From the data available renewable energy potential is then carried out the selection of potential sources of renewable energy as an input in the modeling process according to the capabilities of the software HOMER used.

3. Results and Discussion

Results

The amount of solar energy potential obtained from the Solar and Wind Energy Resource Assesssment (swera) and from this there are two sources of data references is Direct Normal Irradiance (DNI) and the Low Resolution NASA Global Horizontal Irradiance (GHI) NASA Low Resolution as shown in the following figure:

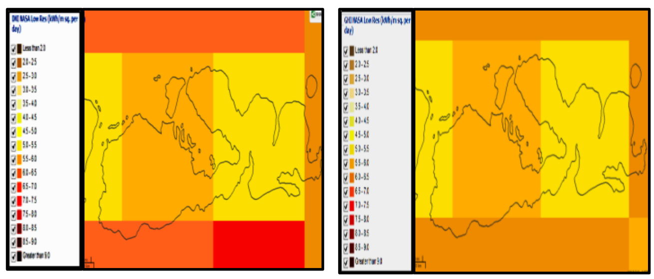

Figure 2 *DNI and GHII NASA Low Resolution Map*

Table 1 The potential of solar energy

No.	Month	Average of radiation intensity (kWh/m^2/d) (NASA & SWERA)
1	Januari	5,770
2	Pebruari	5,650
3	Maret	6,150
4	April	6,080
5	Mei	5,800
6	Juni	5,360
7	Juli	5,490
8	Agustus	6,200
9	September	6,960
10	Oktober	7,200
11	Nopember	6,620
12	Desember	6,240
Average		**6,127**

Determination of the location and magnitude of the wind energy potential is based on the following map:

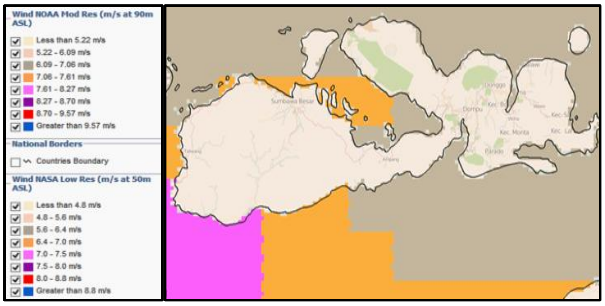

Figure 3 *Wind NOAA moderate resolution* and *NASA low resolution*

This modeling process using secondary data is the measurement result of the two different sources, namely from the NASA Surface Meteorology and Solar Energy: RETScreen Data and Solar and Wind Energy Resource Assessment swera/maps.nrel.gov. From both these sources sought potential wind energy and solar energy are the best at coordinates 16 predetermined locations in the region admsnistrasi Sumbawa.

Table 2 Potential of wind energy

No.	Month	Average wind speed (m/s) *NASA & SWERA*
1	Januari	6,773
2	Pebruari	6,511
3	Maret	5,285
4	April	4,661
5	Mei	5,234
6	Juni	6,583
7	Juli	6,344
8	Agustus	6,560
9	September	5,329
10	Oktober	4,798
11	Nopember	4,824
12	Desember	5,636
Rata-rata		**5,712**

Based on the measurement results obtained from both sources of data are then taken the average value of the best potential for wind energy and solar energy of 16 reference location coordinates. Furthermore, the best results for the potential of wind energy and solar energy are presented in the following

The potential energy of water is pretty much there in Sumbawa when compared with other districts. This is evident from the large number of existing river and the large watersheds (DAS) as a rainwater catchment area that will eventually go into the nearby water bodies. One of the biggest river in the district of Sumbawa Brang Beh river located in Lunyuk with 2,255 ± watershed area (km^2). From measurements and calculations have been carried out by the Central River Region I Nusa Tenggara, the magnitude of the flow rate obtained monthly average Brang Beh river like the following:

Table 3 The potential of hydro power

No.	Month	Average flow rate of the river Q	
		(m^3/s)	(L/s)
1	Januari	300,310	300.310,00
2	Februari	294,750	294.750,00
3	Maret	266,090	266.090,00
4	April	278,320	278.320,00
5	Mei	281,430	281.430,00
6	Juni	232,310	232.310,00
7	Juli	204,720	204.720,00
8	Agustus	194,890	194.890,00
9	September	182,560	182.560,00
10	Oktober	173,870	173.870,00
11	Nopember	291,910	291.910,00
12	Desember	292,410	292.410,00
Average		**249,464**	**249.464,167**

In general it can be calculated the amount of potential energy derived from agricultural waste, plantations and farms based on their availability in Sumbawa as shown in the following:

Table 4 Potential of biomassa energy

No.	Type of commodity	The potential energy	
		(GJ/thn)	(kWh/thn)
1	Pertanian & perkebunan	3.271.428,446	908.802.822,300
2	Peternakan	678.032,750	188.357.498,000

From the simulation results with HOMER electrical energy load as shown in the figure below, note that the peak load exceeding 13,232 average load (kW) occurs in the range of hours of 17:00 to 22:00 pm, while the peak load exceeding 15,000 (kW) range occurred hours of 17:00 to 21:00 pm.

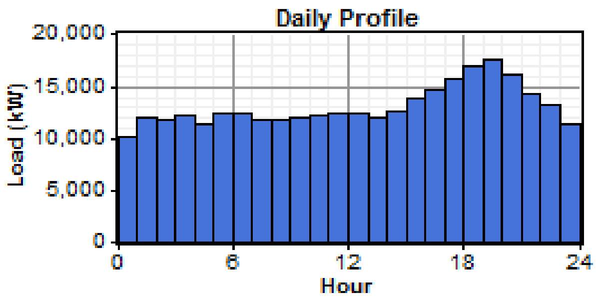

Figure 4 Daily load profile

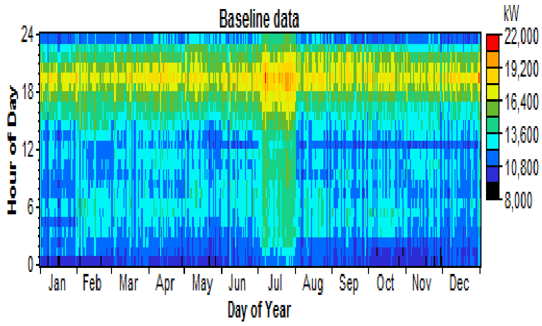

Figure 5 Daily load map

Table 5 Electrical load system

Load	*Baseline*	*Scaled*
Average (kWh/d)	318.872	318.872
Average (kW)	13.286	13.286
Peak (kW)	29.673	29.673
Load factor	0,448	0,448

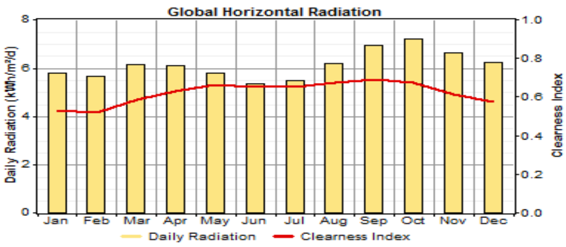

Figure 6 Daily radiation and clearness index profile

Simulation results with HOMER solar energy potential is obtained that the magnitude of the average daily solar radiation potential best of 6.129 (kWh / m 2 / d) with a clearness index of 0.618.

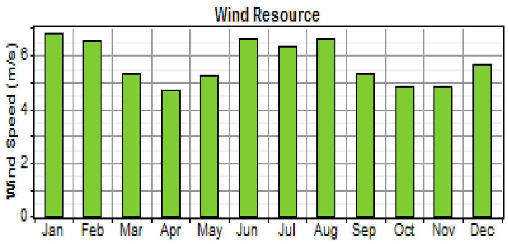

Figure 7 Wind speed average monthly profile

From the simulation results obtained with HOMER magnitude of the wind speed average annual best of 5.709 (m / s) with a planned height of a horizontal axis wind turbine 50 (m) from ground level or 67 (m asl).

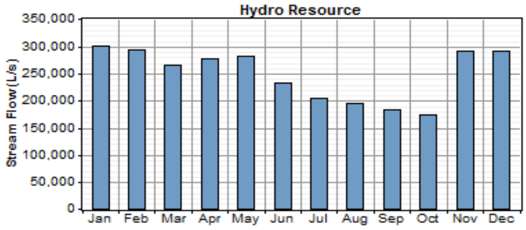

Figure 8 Hydro power potential profile

HOMER simulation by including parameters of data flow rate for water turbine design for Q = 60,000 (L / s) and the effective head h = 12 (m) obtained a nominal amount of power that can be generated by 6,004 hydro power (kW) by assuming the magnitude of residual flow rate amounted to 52,000 (L / s).

In the hybrid power system modeling, the potential use of waste biomass from agriculture, especially rice crop wastes that have the greatest amount of production among others.

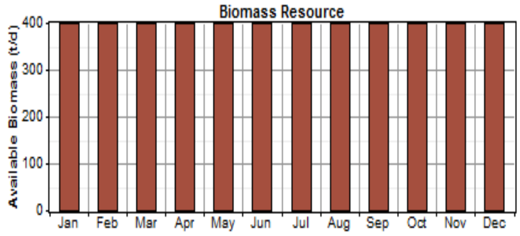

Figure 9 Biomassa potential profile

Based on the ratio of the amount of production and the availability of waste energy that rice plants known that the production of biomass waste in a year amounted to 146,471.150 (tons) on psimistik scenario there is the potential energy of 2387479.745 (GJ), it is certainly a huge potential to be used as a source of energy and other purposes in the district.

HOMER modeling results by providing a general scheme of hybrid power system for electrical system in Sumbawa with a support system components such as the main load, wind turbines, water turbines, generators diesel, biomass-fueled generators, PV, converter and battery. Overall hybrid power system components in HOMER arranged in a scheme such as the following:

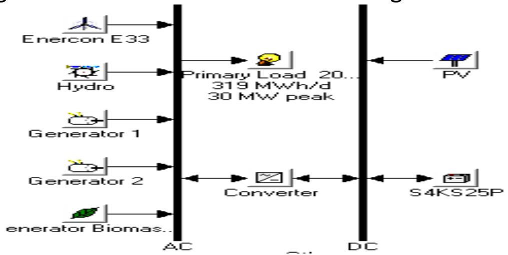

Figure 10 Hybrid power system architecture

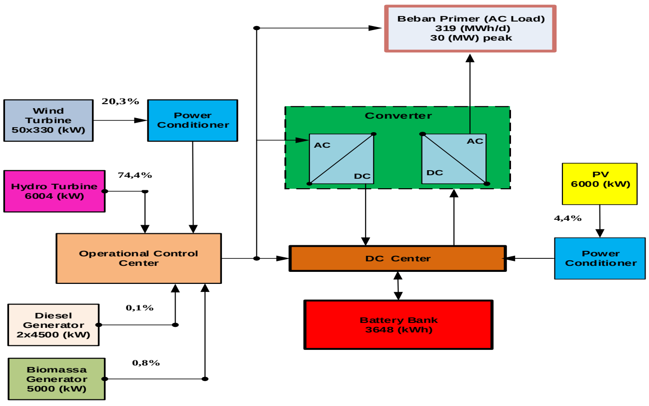

Figure 11 Scheme of hybrid power system

Hybrid power system simulation process conducted by the HOMER system components configuration produces 128 power plants with a variety of hybrid systems are possible. Good decision-making in determining and selecting the most optimal system configuration for the system is not only based on the cost factor alone, but should also consider other factors that have a strong influence on the overall system to be built.

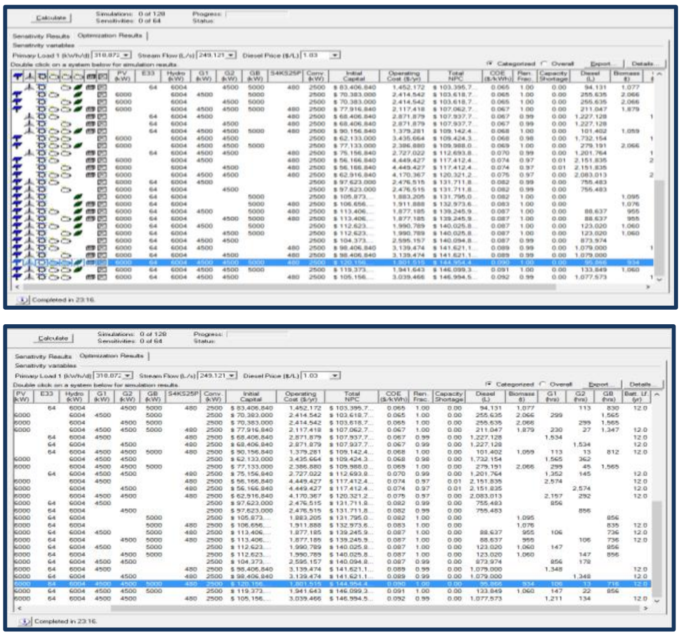

Figure 12 Simulation results of system with HOMER

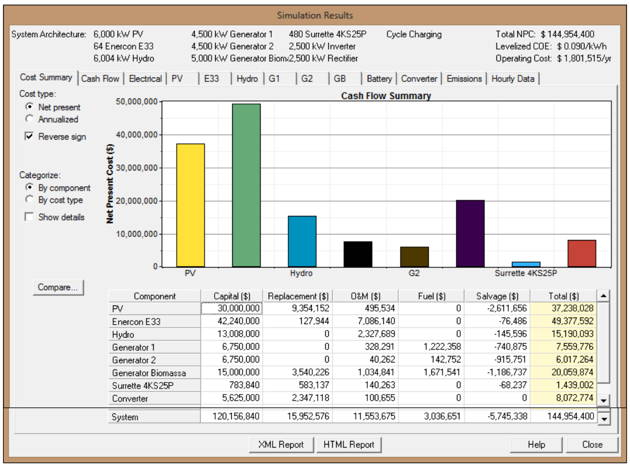

Figure 13 Economic performance of hybrid system

In this hybrid power system total capital (capital) to invest the necessary systems are US $ 120,156,840; the total cost of system replacement cost US $ 15,952,576; Total operating costs and maintenance (O & M) US $ 11,553,675; total fuel cost system US $ 3,036,651; total system cost can be saved (salvage cost) US $ 5,746,338; total net present cost (NPC) system US $ 144,954,400; annual system operating costs (operating costs) of US $ 1,801,515 / year. From the simulation results above it is known that the cost of electric energy production by hybrid system (COE) is US $ 0.090 / kWh and the total value of investment according to the largest system components exist on wind turbine components at US $ 49,377,592.

When a comparison between the simulation results of the economic performance of the hybrid system with a conventional system there is a striking difference in various factors of economic performance of the system as shown by the following table:

Table 6 Comparison of economic performance systems

No.	Faktor kinerja ekonomi sistem	Sistem konvensional	*Hybrid power system*
1	*Capital ($)*	29.880.000	121.156.840
2	*Replacement ($)*	117.152.272	15.952.576
3	*O&M ($)*	77.721.928	11.553.675
4	*Fuel ($)*	511.166.720	3.036.651
5	*Salvage ($)*	-3.523.719	-5.746.338
6	*Cost of electric (COE) ($/kWh)*	0,495	0,090
7	*Operating cost ($)*	54.955.576	1.801.515
8	*Net present cost (NPC) ($)*	732.396.736	144.954.400

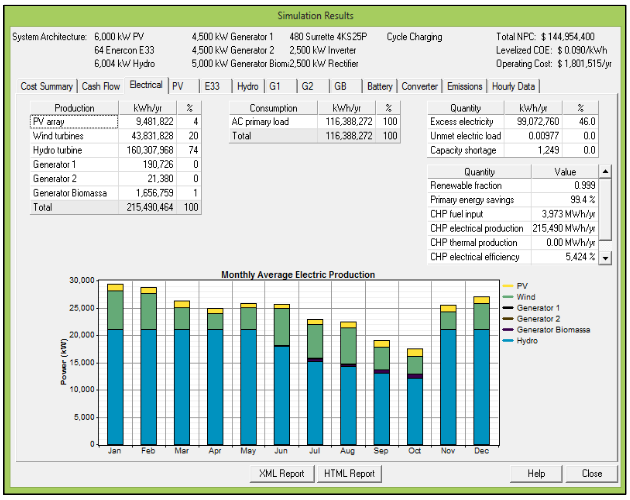

Figure 14 Results of electrical energy production

From the information HOMER simulation results for the performance of electric energy production systems is known that the largest percentage of electrical energy production of hybrid system is given by the hydro turbine components by 74%, 20% wind turbine, PV 4% and 1% biomass generator. While the production of electrical energy by diesel generators G_1 and G_2 in the hybrid system is relatively very small close to 0%, so it can be said in a hybrid power system is a diesel generator serves as a back-up system.

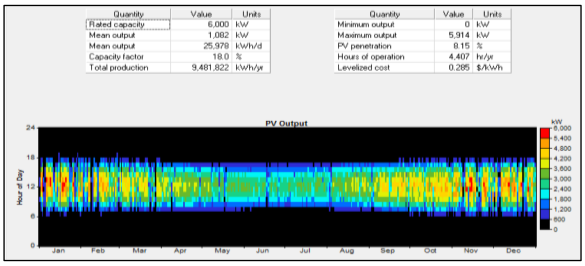

Figure 15 PV performance profile

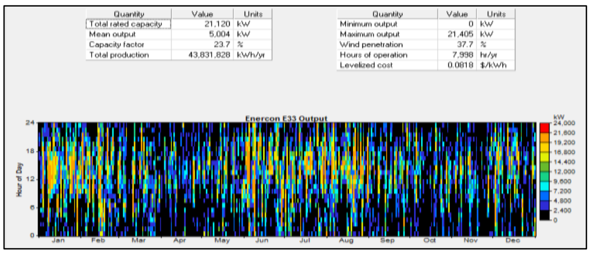

Figure 16 Wind turbine performance profile

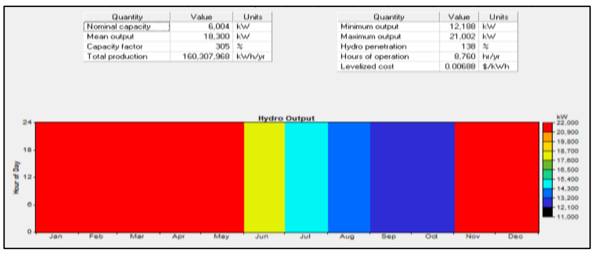

Figure 17 Hydro power perfomance profile

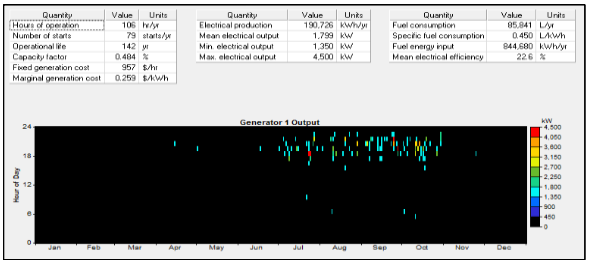

Figure 18 Diesel generator G_1 perfomance profile

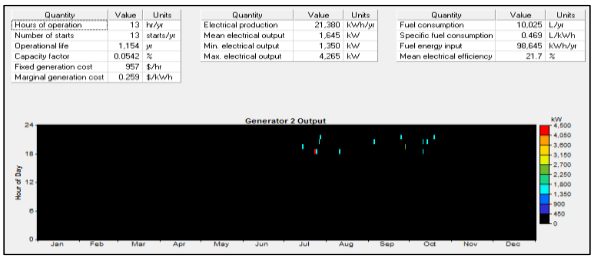

Figure 19 Diesel generator G_2 perfomance profile

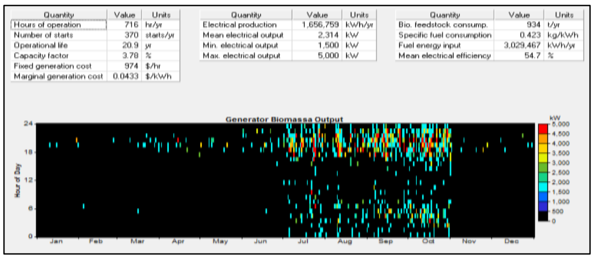

Figure 20 Biomass generator performance profile

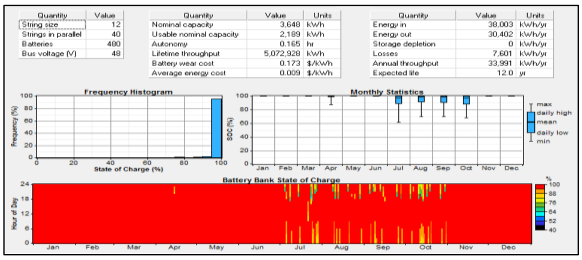

Figure 21 Battery performance profile

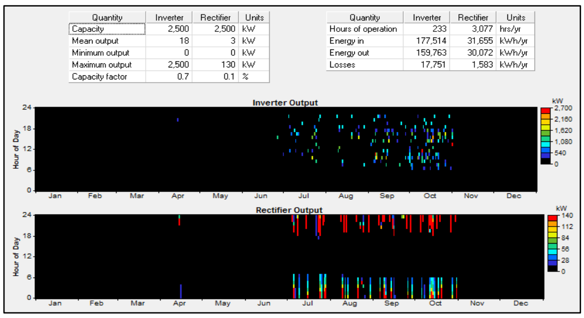

Figure 22 Converter perfomance profile

Analysis of the sensitivity of the hybrid power system modeling aims to determine the influence of the rate of change of one or more parameters contained in the modeling of the final results of this modeling system.

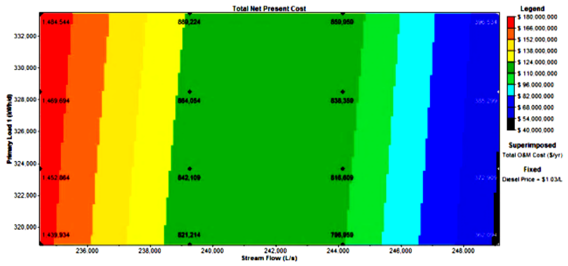

Figure 23 Effect of primary load on NPC

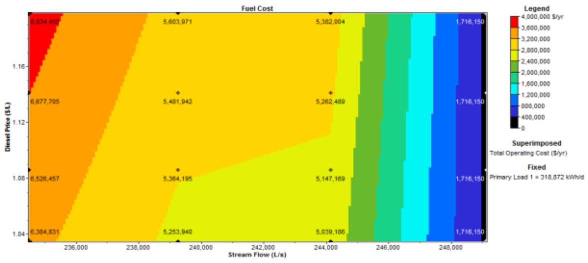

Figure 24 Effect of fuel cost on the cost of fuel system

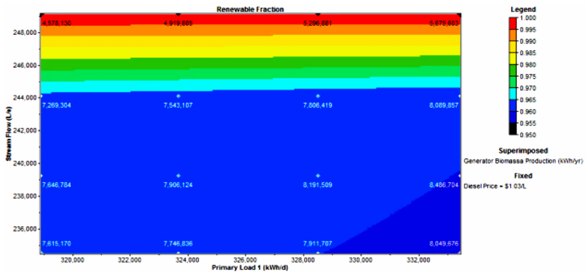

Figure 25 Effect of *stream flow* on *renewable fraction*

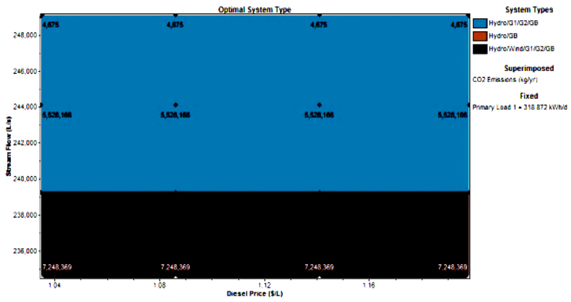

Figure 26 Effect of *stream flow* on optimal system type

Discussion

In general, from the simulation results given by HOMER economically be selected configuration is a configuration that has a value of initial capital and total net present cost (NPC) is the lowest of the other configurations. It is quite natural that the decision making is based only on the economic side only. But the selection of this configuration is technically not able to provide a high level of system reliability and good. When one or more components of the system or are impaired in the repair of the low level of reliability of the system into which the continuity of supply of electrical energy to the hybrid power system will decrease.

Conditions like this will be a problem in the future if there is no back-up system is well prepared. Good decision-making in determining and selecting the most optimal system configuration for the system is not only based on the cost factor alone, but should also consider other factors that have a strong influence on the overall system to be constructed as follows :

- The amount of power requirements and its growth
- The potential of renewable energy sources
- The level of reliability of supply (supply)
- Conditions of the local area or region
- Energy sector policy both locally, nationally and regionally related to the utilization of new energy sources and renewable

Based on the results of simulation using HOMER to two types of electric power generation systems; conventional systems and hybrid systems can be made a general summary that shows the comparison between the two types of systems as shown by the following table:

Table 7 The comparison between conventional systems and hybrid systems

No.	Quantity	Konvensional System	Hybrid System
1.	*Capital (US$)*	29.880.000,0	120.156.840,0
2.	*Replacement (US$)*	117.152.272,0	15.952.576,0
3.	*O&M (US$)*	77.721.928,0	11.553.675,0
4.	*Fuel (US$)*	511.166.720,0	3.036.651,0
5.	*Salvage (US$)*	-3.523.719,0	-5.745.338,0
6.	*Total NPC (US$)*	732.396.736,0	144.954.400,0
7.	*Levelized COE (US$/kWh)*	0,495	0,090
8.	*Operating Cost (US$/yr)*	54.955.576,0	1.801.515,0
9.	*Excess electricity (kWh/yr)*	0,104	99.072.760,0
10.	*Unmet electric load (kWh/yr)*	685.192,0	0,00977
11.	*Capacity shortage (kWh/yr)*	1.146.425,0	1.249,0
12.	*Renewable fraction (%)*	0,0	0,999
13.	*Carbon dioxide (kg/yr)*	101.786.952,0	254.190,0
14.	*Carbon monoxide (kg/yr)*	251.247,0	629,0
15.	*Unburned hydrocarbons (kg/yr)*	27.830,0	69,7
16.	*Particulate matter (kg/yr)*	18.940,0	47,4
17.	*Sulfure dioxide (kg/yr)*	204.406,0	507,0
18.	*Nitrogen oxide (kg/yr)*	2.241.894,0	5.614,0

In connection with the matter, in order to obtain a high level of system reliability with the level of utilization of the potential of local renewable energy resources in an optimal configuration of the selected hybrid power system that utilizes four existing renewable energy sources in Sumbawa district such as water energy, wind energy, solar energy and biomass energy.

From the results of the sensitivity analysis are known at the level of the price of diesel fuel is still an increase in the primary load and a decrease in flow rate yearly average will lead to an increase in the value of the total net present cost and cost of operation and maintenance (O&M) per year in the modeled system. On the other hand the increase in the price of diesel fuel at a level fixed main load does not significantly affect the total net present cost of the system but only affects the total system operating cost. In addition, the sensitivity analysis is also known that the decline in stream flow within a certain limit load conditions resulting in increased functionality remains the main diesel generators G_1 and G_2 as well as the function of wind turbines on hybrid systems. This condition eventually triggers increased production of exhaust gas emissions into the air which is certainly not desirable.

Of the three modeling parameters used in the sensitivity analysis found that the variable flow rate in the model has a high degree of sensitivity to the condition of the system being modeled. Change variable flow rates the average system on the load of primary and diesel fuel prices are fixed, will result in changes in the various variables that exist in the system as the total net present cost (NPC), O & M cost, fuel cost, operating cost, the total production of electric energy, capacity shortage and the level of exhaust emissions into the environment generated by the system. This is caused by the dominance of hydropower potential in the contribution rate of production of electrical energy in the system reaches 74.4% of the total production. Reliability in the supply of the average flow rate will be strongly influenced by environmental conditions such as the condition of the river basin (DAS), catchment, springs, forests and plants in the vicinity, the people residing in areas upstream and downstream of the river. Everything has potential that can affect the quality of the river so that the future needed better attention by all parties.

4. Conclusion

1. The amount of renewable energy potential in Sumbawa; energy potential of 29,337 water (MW), the potential energy of 5.366 s / d 6.127 (kWh / m 2 / day), wind energy potential 103.694 s / d 114.149 (W / m 2), and the energy potential of biomass based 3949461.196 (GJ / year) .
2. To meet the electrical energy needs in Sumbawa with 319 primary load (MWh / d) and 30 peak load (MW) of renewable energy in the amount of sharing this hybrid system can reach 99.9% of the total potential energy is used as input in the model sharing with composition in the system; Wind Turbine 20.3%; Hydro Turbine 74.4%; PV 4.4%; 0.8% Biomass Generator and Diesel Generator as a back-up of 0.1%.
3. Hybrid power system recommended for electrical systems in Sumbawa provide optimum simulation results on :
   - total net present cost of US$ 144,954,400
   - operating cost US$ 1,801,515 / year
   - cost of electric (COE) US$ 0.090 / kWh
   - excess electricity 99,072,760 (kWh / year)
4. From the comparison of the simulation results of conventional systems and hybrid systems showed that the hybrid system can reduce the level of emissions of CO_2, CO, SO_2, NO, unburn hydrocarbons and particulate matter into the environment by 99.75%.

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