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DESIGN AND OPTIMIZATION OF HYBRID POWER PLANT IN HOUSEHOLD SCALES USING HOMER MODELS

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Abstract

The hybrid system is used in power plants by using more than one of system. Presently, utilization of the hybrid system growth and can be used in order to optimize the potential renewable energy resources at each locality. Generally, a home stay (household) is designed to utilize some of the potential of renewable energy in parallel, as energy saving measures. For the purpose study, simulation and optimization of hybrid system with the output target: estimate system capacity, lifecycle cost and green house gas (GHG) emissions are performed using Homer model software (Homer version 3.7.6). The hybrid system applied consisted of PLN grid, biogas generator, photovoltaic (PV), fuel cell (FC), wind turbine (WT), Li Bat, converters, controller, electrolysis and hydrogen storage tank. The simulation results showed that the most optimal system is hybrid system without a Li-Bat. The hybrid system components capacity are 7 kW of Biogas generator, 1 kWp of PV, 1 kW of FC, 1KW of WT, 5 kW of converter, 1 kW of Electrolysis, and 1 kg of H-Tank. Techno-economic parameters consist of Initial Capital ($ 13.100) were the highest of any other combination. COE ($ 0151), NPC ($ 86.197) and Operating Cost ($ 5.654) are lower than the other combinations. The IRR Value about 42.2% and the Renewable Fraction value about 61%.

Keywords: Household Scale, Hybrid Power Plant, Sustainable Energy, HOMER, Simulation

1. Introduction

The term of hybrid power generation system used at power plants that contain more than one generator, usually a combination of conventional generators (diesel or gas) and renewable energy (solar power, Wind Power, thermal power station or Microhydro). Hybrid system has grown and has been operating in many countries to take advantage of the local potential of each, from small scale till big scale (Sandia National Laboratories, 2009). Several advantages HYBRID system (Sukarman and Othman 2005), are: (1) improve the reliability of the system in fulfilling the load, (2) reducing emissions and pollution, (3) provide continuous electrical power supply, (4) increasing the age of the system, and (5) reduce costs and improve the efficiency of electrical energy use. PT PLN is currently implementing the cooperation of buying and selling electricity to households, especially for homeowners who installed solar cell roof of their house. In order to be buying and selling of electricity between PLN with homeowners, kWh meter used is also different, namely kWh of electricity meters 'import-export'. KWh meter for 'export - import' the electricity may be split between the electricity generated from the solar cell or photovoltaic with electricity from the grid.

This paper discusses the use HOMER model to design Hybrid system in a household in Bandung, West Java Province, utilizing new and renewable energy resources available in the local, such as, sun, wind and kitchen organic waste, for electricity supply which is interconnected with the grid power 2200 VA.

The purpose adding Hybrid system is to optimize the utilization of renewable energy as an effort to save electricity payments. Hybrid system has a variety of configurations that can be selected for their designated purpose, among other things: (1) series hybrid system, (2) switched hybrid system, and (3) parallel hybrid system (Nayar et.al 1993).

The simulation used a configuration parallel hybrid system, where, PLN grid, biogas generator and battery bank together in parallel to supply the load. Parallel hybrid inverter system uses two-way (bi-directional) that can serve as inverters (convert dc power into ac) and as a charger and regulator (convert ac power into dc). The pattern of charged or discharged of the Hybrid system using HOMER Control, wherein, when the load is lower than battery bank power, the load is supplied by the battery through the bi-directional inverter (which functions as an inverter) whereas biogas generator and PLN Grid conditioned in the OFF position. At the time of intermediate load exceeds the capacity of the battery, Biogas generator is turned on to supply the load and charge the batteries together with FC, WT and PV (bi-directional inverter and charger functions as a regulator). At peak load, turning biogas generator and bi-directional inverter and PLN Grid together in parallel to supply the load.

2. Research Methods

The method used in this simulation includes three main stages, namely the calculation of daily electrical load in the home, the determination of potential energy sources and technologies are available that can be applied, and the system design. Figure 2 shows a diagram of research methods.

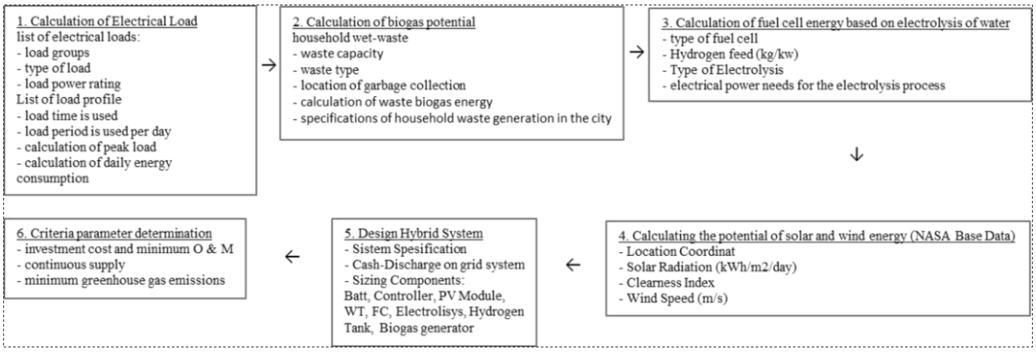


Fig. 1: Method Research

3. Homer System Description

HOMER is an acronym for Hybrid Optimization Model for Electric Renewables, one of the popular tools to design Hybrid system using renewable energy. HOMER simulates and optimizes power generation systems both stand-alone and grid-connected which may consist of a combination of wind turbines, photovoltaic, micro hydro, biomass generators (diesel / petrol), micro turbine, fuel-cell, battery and hydrogen storage, servicing burden electrical or thermal (Lambert, Gilman, and Lilienthal 2006). Figure 1 shows a flow simulation and optimization of HOMER Program.

HOMER simulates the operation of the system by providing energy balance calculations for every 8.760 hours a year. If the system is interconnected with the grid (ON GRID) and using the battery and the ICE generator, HOMER can also specify the run and off the generator as well as determine whether the battery is charged or discharged. Furthermore, HOMER determine the best configuration of the system and then estimate the cost of installing and operating the system during the period of operation (life time costs) as the initial cost, the cost of replacement of components, the cost of O & M, fuel costs, and others. When performing the simulation, HOMER determine all possible system configurations, then displayed sequentially by presents net costs-NPC (also called life cycle costs). If a sensitivity analysis is required, HOMER will repeat the simulation process for each variable sensitivity set. Relative error of about 3% yearly and monthly relative error of about 10% (Sheriff and Ross 2003).

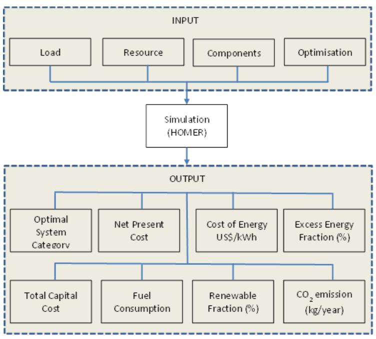


Fig. 2: Simulation and Optimization HOMER

4. Results and Discussions

4.1. Location

Figure 3 and Table 1 shown general information about household used in this study.

Fig. 3: House hold Location

Table 1: General Information

Location[1]	06°56'46.24"S 107°38'35.40"E
Electricity rates	R1/TR
Power limit	2200 VA
Tariff	IDR. 1457.72 per kWh.

1) Source: HOMER

4.2. Load

The types of power tools used in the simulation, as follows; lamp; irons; cooking ware; washing machines; water pump; air conditioning; dispenser; water heater; electrical apparatus for entertainment; communications equipment; computer hardware; storage and cooling food.

The various types of the equipment above, there are tools that continuously operates for 24 hours and 7 days per week, 41% (900 watts) of maximum power (= 2200 watt). Assumptions in the simulation expressed electricity consumption is constant throughout the year. The type of electricity consumption in use can be shown in Figure 4.

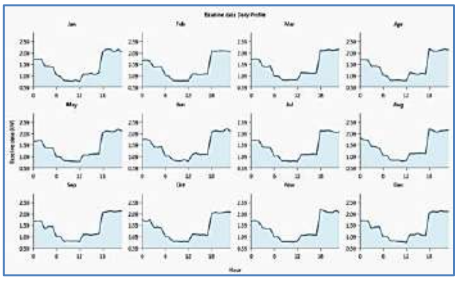


Fig. 4: Baseline Data Daily

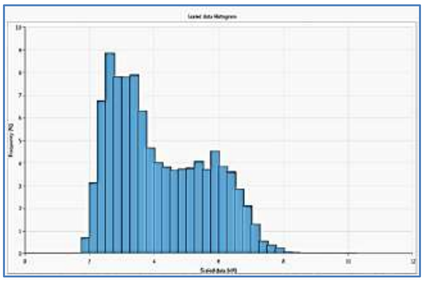


Fig. 5: Electricity Consumption

Figure 4 shows the load profiles are being simulated with 2.2 kW peak load that occurs from 18:00 until 23:00. In this simulation assumed that the peak load occurs because all the residents conducting activities within the house after work with all the facilities available. While most low load power consumption occurred at 09.00 am to 12.00 noon. Assumptions carried in this simulation states that the main occupants in the home at this time to go to work and do all activities outside the home. The frequency for the electrical load that occurs can be shown in Figure 5. The greatest frequency is 8.84% at a scale of 2.8 kW

4.3. Potential of New and Renewable Energy Systems

4.3.1. Household Waste for Biogas

The digits of waste in Indonesia are between 2-3 liters / person / day with a density of 200-300 kg / m^3 and composition of organic waste 70-80%. This goes along with calculation methods according to ISO 19- 964-1994. Housing is the largest source of the waste. The composition of wet waste or organic waste by 73-78% and the total of wet waste up to 85% are junk leftovers. Characteristics of waste can be grouped according to its properties, such as:

- Physics Characteristics: The most important is the density, moisture content, volatile content, ash content, calorific value, the size distribution.
- Chemical Characteristics: particularly that describes the chemical make-up of the waste consisting of the elements C, N, O, P, H, S, etc.

Table 2: Characteristics of Waste in Bandung City

Parameters	Value
Humidity (% kg-wet)	64.27
pH	6.27
Organic Content (% kg-wet)	44.70
Carbon (% kg-dry)	44.70
Nitrogen (% kg-dry)	1.57
Phosphor (% kg-dry)	241
Ash Content (% kg-dry)	23.09
Heating Value (kcal/kg)	1197

In this simulation, the specified conversion process waste into biogas through anaerobic fermentation process using a digester. This is determined by the availability of raw material composition of household waste with wet waste or organic waste by 73-78% dominant from food. Availability of the amount of daily waste that can be collected in trash receptacle housing is a maximum of 250 kg per day. Therefore, the design of the size of the digester biogas created has to feed daily volume amounted to 240 kg of organic waste per day with a stay of feed made as optimal as possible under the terms of the design of the biogas digester. Based on the daily amount of feed can be determined that the biogas produced enough to operate the generator with capacity up to 10 kWh of electricity for 8 hours per day.

4.3.2. Fuel Cell, Electrolysis and Hydrogen Storage Tank

For Fuel Cell, the selected equipment types of hydrogen feeds. Because the price is still expensive so the determination of the FC power capacity is limited to only 1 kW. The hydrogen and oxygen as the feed will be supplied using a powerful 1 kW water electrolysis to meet the hydrogen needs. Electricity for electrolysis will be supplied at the time of low load only from 09.00 am to 12.00 pm, every day. Hydrogen product obtained is stored in Hydrogen-tank with 1 kg of hydrogen capacity.

4.3.3. Solar Cell (Photovoltaic) and Wind Turbine (WT)

a) Solar Cell

Data Surface meteorology and solar energy (SMSE) of the National Aeronautics and Space Administration (NASA) has been used as a source of information on the analysis location. SSMSE NASA database derived from the meteorological parameters and solar energy were recorded for 22 years (1983-2005) by more than 200 satellites. Data Accuracy is 6 - 12% (NASA 2010). For this simulation only parameter the intensity of solar radiation on a horizontal surface and the clearness index is used. Data sun's daily average was obtained for 4.81 kWh / m2 / day. Such information can be shown in Figure 6. In designing this simulation, the power capacity for PV types Flat Plate is 1 kWp for reasons prices are still high.

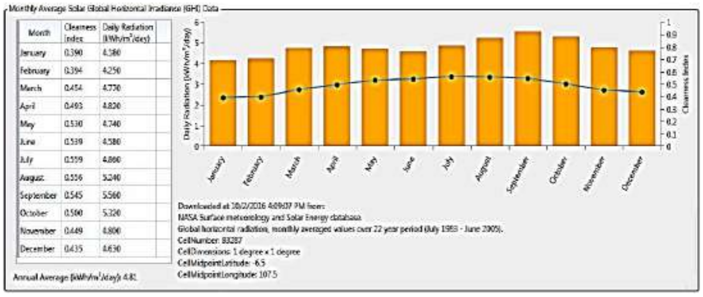


Fig. 6: Monthly Average Solar GHI Data (Source: HOMER Pro 3.7.6)

b) Wind Turbine (WT)

For the wind potential at the location of the research and simulation can know the data as shown in Figure 7. Sources of data obtained from Homer Pro 3.7.6 as the data potential of the sun. From these data it is known that the daily wind speed average of 3.81 m / s. The data obtained in anemometer height of 50 m above the ground on the altitude 1450 m asl. In designing this simulation, the power capacity is designed only for WT 1 kWp who has overall loss factor of 4.9% for reasons of prices are still high.

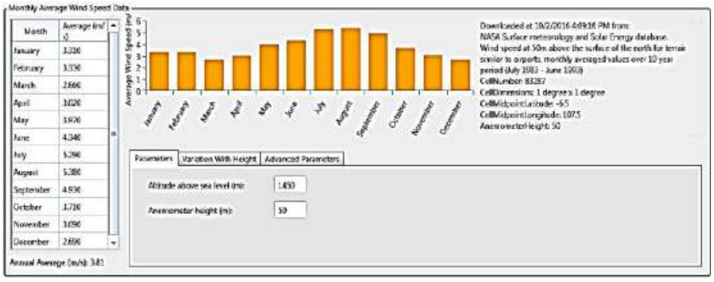


Fig. 7: Monthly Average Wind Speed Data (Source: HOMER Pro 3.7.6)

4.4. System Design

In the simulation, set a few options available components based on source, such as; The primary load in the form of electrical load, biogas generators, PV (photovoltaic), WT (wind turbines), FC (Fuel Cell), converters, controllers and battery bank. Figure 8 shows the design of the selection of components in HOMER.

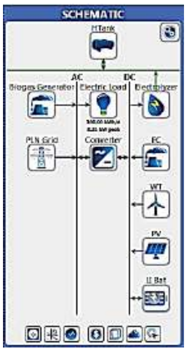


Fig. 8: Design Hybrid Systems on HOMER Pro 3.7.6

There are some parameters that are determined in advance by the designer as inserted into HOMER simulation program to achieve the objectives. Some parameters can be specified as shown in Table 3.

Table 3: Input Parameters

No	Input Parameters	Note
1	PLN Grid	Simple Rate
		Grid Power Price 0.2 $/kWh
		Grid Sellback Price 0.25 $/kWh
2	Biogas Generator	Biomass Resource 240 kg/day ($10/ton)
		System Price 500 $/kW
3	H-tank	Price 500 $/kg
4	Electrolyser	Price 500 $/kW
5	FC	Fuel: Storage Hydrogen
		Price 1500 $/kW
6	Converter	Parallel With Generator
		Price 100 $/kW
7	Controller	HOMER Cycle Charging
		Price 100 $
8	Li-Bat	Price 250 $/kWh
9	PV	Price 1500 $/kWp; Flat Plate PV; No Tracking; eff. 13%.
10	WT	Price 1500 $/kWp
11	Financial	Discount rate 8%
		Inflation Rate 2%
		Project Life Time 25 Years

4.5. Design Results

The HOMER program simulation results can be shown in Table 4. Hybrid system most optimal combination is achieved by PV (1 kW); WT (1 kW); Biogas Generator (7 kW); FC (1 kW); Li-Bat (none); Electrolyzer (1 kW); H-tank (1 kg) and the converter (5 kW).

Table 4: The Results of HOMER Simulation

Architecture											Cost			
PV (kW)	WT	Biogas Generator (kW)	FC (kW)	LI Bat	PLN Grid (kW)	Electrolyzer (kW)	HTank (kg)	Converter (kW)	Efficiency1	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)
1.00	1	7.00	1.00		999,999	1.00	1.00	5.00		CC	$0.151	$86,197	$5,654	$13,100
	1	7.00	1.00		999,999	1.00	1.00	5.00		CC	$0.158	$88,612	$5,957	$11,600
1.00	1	8.00	1.00	1	999,999	1.00	1.00	5.00		CC	$0.171	$97,330	$6,419	$14,350
	1	8.00	1.00	1	999,999	1.00	1.00	5.00		CC	$0.178	$99,879	$6,732	$12,850
1.00	1		1.00	1	999,999	1.00	1.00	5.00		CC	$0.254	$119,924	$8,785	$6,350
	1		1.00	1	999,999	1.00	1.00	5.00		CC	$0.259	$122,211	$9,078	$4,850

System	Biogas Generator					FC					PV		WT			
Ren Frac (%)	Hours	Production (kWh)	Fuel (kg)	O&M Cost ($)	Fuel Cost ($)	Hours	Production (kWh)	Fuel (kg)	O&M Cost ($)	Fuel Cost ($)	Capital Cost ($)	Production (kWh)	Quantity	Capital Cost ($)	Production (kWh)	O&M Cost ($)
61	4,380	29,127	88	3,066	876	1,216	391	82	12	0	1,500	1,286	1	1,500	570	1
59	4,380	29,127	88	3,066	876	1,216	391	82	12	0			1	1,500	570	1
60	4,380	28,908	88	3,504	876	1,184	381	80	12	0	1,500	1,286	1	1,500	570	1
58	4,380	28,908	88	3,504	876	1,191	382	80	12	0			1	1,500	570	1
0.0						899	899	189	9	0	1,500	1,286	1	1,500	570	1
0.0						899	899	189	9	0			1	1,500	570	1

LI Bat					Converter		PLN Grid			
Quantity	Electrolyte	CellStacks	Autonomy (hr)	Annual Throughput (kWh)	Rectifier Mean Output (kW)	Inverter Mean Output (kW)	Capacity	MonthlyCapacity	Energy Purchased (kWh)	Energy Sold (kWh)
					0.3	0.1	999,999		17,155	7,566
					0.4	0.07	999,999		17,737	6,816
1	0	0	0.17	2,094	0.4	0.2	999,999		17,653	7,539
1	0	0	0.17	2,121	0.5	0.1	999,999		18,326	6,826
1	0	0	0.17	0.8	0.7	0.02	999,999		43,624	0
1	0	0	0.17	0.8	0.8	0.006	999,999		45,094	0

4.6. *Economic Analysis*

Hybrid systems require Cost of Energy (COE) and Net Present Cost (NPC) is the lowest and the benefits are saving electricity payment every month. This is shown also in Table 4, Energy Purchased the least 17.155 kWh and provide Energy Sold 7.566 kWh is highest among the other Hybrid system combination.

Table 5: Economy Comparison

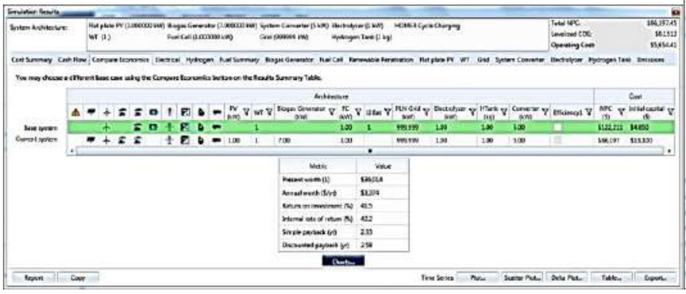


Table 6: Cost Summary

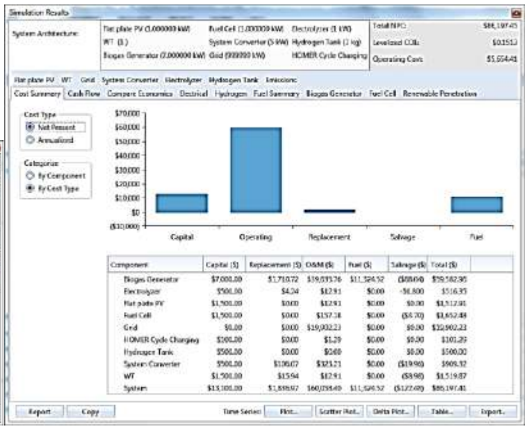


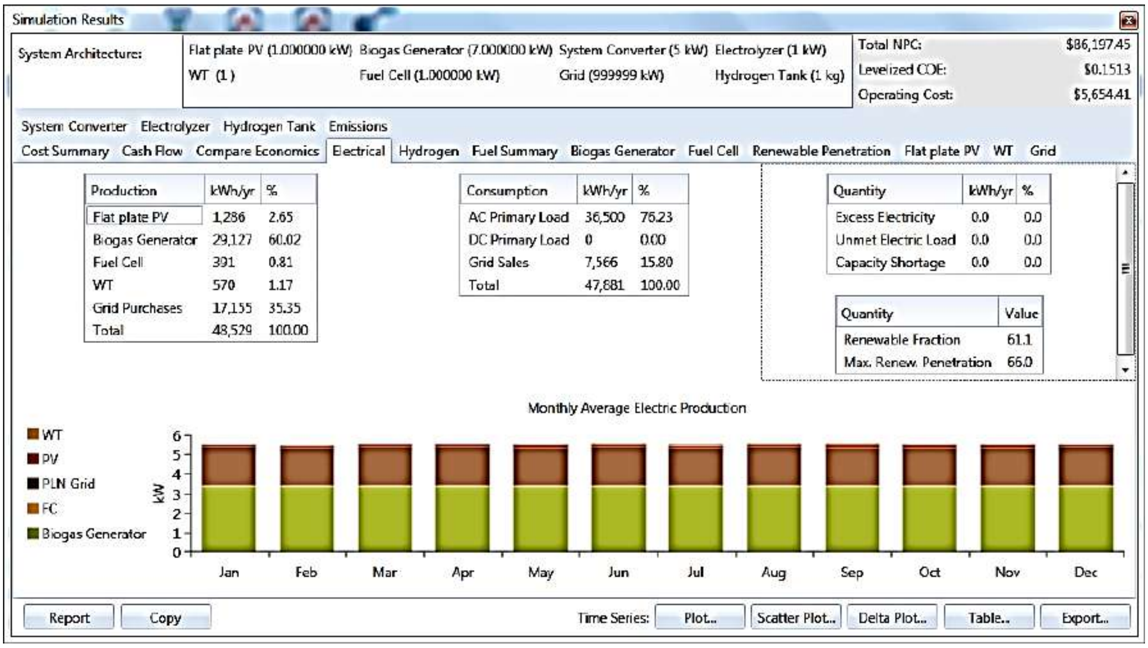
Table 5 shows the combination of selected hybrid system (Base System HOMER plus PV and Biogas Generator without Li Bat) requires a value Initial Capital's most expensive compared with the Base System HOMER (grid, FC, PV, Li Bat, converters, electrolysis and hydrogen storage tanks). The selected combination of hybrid systems provide NPV (Net Present Cost) most low and also provide value IRR 42.2% the highest of the other. In Table 6 demonstrated that the combination of hybrid systems, biogas generator is a component of the most high O & M costs, but also is a component that provides the greatest energy supply Renewable Fraction among others.

4.7. *Analysis of Electricity*

From Table 7 obtained information that the largest power supply is obtained from biogas generator (> 60%) of the total supply of the required load current carrying AC electricity. 35.35% electricity obtained from GRID PLN, 2.65% is obtained from PV, 1:17% of WT and only 0.81% is obtained from FC.

Total electricity consumption amounted to 47.881 kWh / year and 15.80% of the total are the results obtained from the hybrid system. This condition is based on the assumption of no excess electricity, unmet electricity load and capacity shortage.

Table 7: Electrical



Simulation Results

System Architecture:	Flat plate PV (1.000000 kW) Biogas Generator (7.000000 kW) System Converter (5 kW) Electrolyzer (1 kW) WT (1) Fuel Cell (1.000000 kW) Grid (999999 kW) Hydrogen Tank (1 kg)	Total NPC:	$86,197.45
		Levelized COE:	$0.1513
		Operating Cost:	$5,654.41

System Converter Electrolyzer Hydrogen Tank Emissions
Cost Summary Cash Flow Compare Economics Electrical Hydrogen Fuel Summary Biogas Generator Fuel Cell Renewable Penetration Flat plate PV WT Grid

Production	kWh/yr	%
Flat plate PV	1,286	2.65
Biogas Generator	29,127	60.02
Fuel Cell	391	0.81
WT	570	1.17
Grid Purchases	17,155	35.35
Total	48,529	100.00

Consumption	kWh/yr	%
AC Primary Load	36,500	76.23
DC Primary Load	0	0.00
Grid Sales	7,566	15.80
Total	47,881	100.00

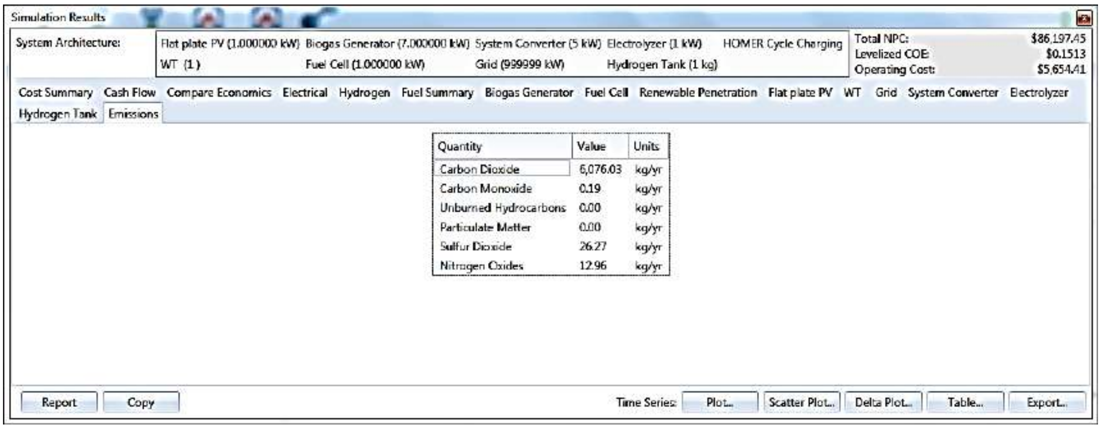
Quantity	kWh/yr	%
Excess Electricity	0.0	0.0
Unmet Electric Load	0.0	0.0
Capacity Shortage	0.0	0.0

Quantity	Value
Renewable Fraction	61.1
Max. Renew. Penetration	66.0

4.8. Greenhouse Emissions Analysis

This hybrid system produces emissions of carbon dioxide (CO2) 6,076.03 tons / year and nearly all generated by Grid PLN. Becouse the net CO2 emissions from biogas generator, DC, PV and WT is zero (= 0).Untuk kasus ini Grid PLN menghasilkan emisi CO2 sebesar 632.00 g/kWh.

Table 8: Emissions



Simulation Results

System Architecture:	Flat plate PV (1.000000 kW) Biogas Generator (7.000000 kW) System Converter (5 kW) Electrolyzer (1 kW) HOMER Cycle Charging WT (1) Fuel Cell (1.000000 kW) Grid (999999 kW) Hydrogen Tank (1 kg)	Total NPC:	$86,197.45
		Levelized COE:	$0.1513
		Operating Cost:	$5,654.41

Cost Summary Cash Flow Compare Economics Electrical Hydrogen Fuel Summary Biogas Generator Fuel Cell Renewable Penetration Flat plate PV WT Grid System Converter Electrolyzer Hydrogen Tank Emissions

Quantity	Value	Units
Carbon Dioxide	6,076.03	kg/yr
Carbon Monoxide	0.19	kg/yr
Unburned Hydrocarbons	0.00	kg/yr
Particulate Matter	0.00	kg/yr
Sulfur Dioxide	26.27	kg/yr
Nitrogen Oxides	12.96	kg/yr

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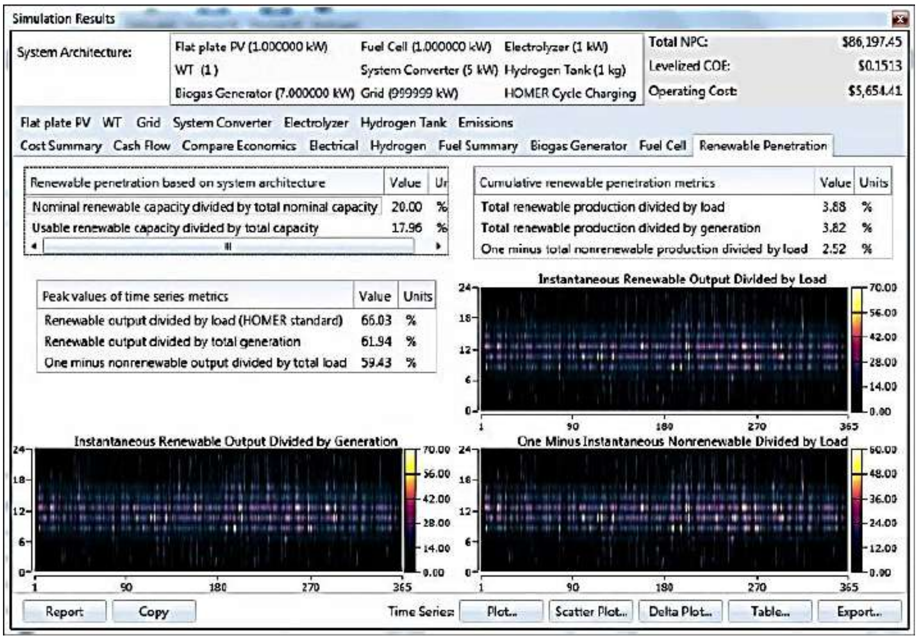
4.9. Renewable Penetration Analysis

Table 9 shows the Renewable Fraction of the hybrid system was chosen by 61%, and ultimately provide a significant contribution to the economic and greenhouse emissions. the condition of the hybrid system can be used as a model for carbon credit project (Carbon Emission Reduction-CER) in a larger scale.

Table 9: Renewable Penetration



5. Conclusion

In this simulation obtained full information to conduct techno-economic assessment of the hybrid system is designed. The parameters of the techno-economics can be concluded as follows;

1. Base system HOMER Pro version 3.7.6 in this case consists of components; grid, WT, FC, Li Bat, converters, electrolysis and hydrogen storage tank is comparative economics of the hybrid system is the most optimal.
2. Hybrid System the most optimal is selected Base System + PV and biogas without Li Bat.
3. The combination of selected hybrid system requires Initial Capital ($13.100) highest compared with other combinations.
4. The combination of selected hybrid systems requires COE ($ 0151), NPC ($ 86.197) and Operating Cost ($ 5.654) is the lowest compared with other combinations.
5. The combination of selected hybrid systems requires O & M (= $ 60,058.40) and over 50% (=$ 39,635.76) is the cost of O & M Biogas Generator.
6. The combination of selected hybrid system provides IRR 42.2% the highest of the other.
7. 60.02% Electric Supply is supplied by Biogas Generator from the total electricity supply.
8. Biogas Generator is a hybrid system component that require O & M highest.
9. CO2 emissions produced from PLN Grid.
10. Renewable Fraction hybrid system was chosen by 61%.

6. References

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