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Hydrokinetic Energy of Palaus River in North Sulawesi, Indonesia

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Abstract: The objective of this research was to calculate the electrical energy that can be generated by a kinetic turbine from Palaus river in South East Minahasa Regency, North Sulawesi Province, Indonesia. The calculation was performed by using HOMER 2.68 Beta. There were two data required for the calculation: the profile of daily electricity usage of the buildings around the river and the monthly average flow velocities in a year of the river. The first data were acquired by sharing questionnaires to the residents of Tosuraya village, which is located around Palaus river. The second data were obtained from two sources. Firstly, from direct measurement, which was carried out to measure monthly average flow velocities of several months: June, July, August, September and October. Secondly, for the other months, the monthly average flow velocities were determined by comparing the average flow velocity in June to the monthly average rainfall in South East Minahasa regency. Then, the results of monthly average flow velocities in a year of Palaus river were as follows: January 2.06 m/s, February 3.74 m/s, March 3.24 m/s, 4.11 m/s, May 1.67 m/s, June 1.16 m/s, July 0.82 m/s, August 0.72 m/s, September 0.60 m/s, October 0.57 m/s, November 1.78 m/s and December 3.36 m/s.

After all data were inputted to HOMER 2.68 Beta, it was found that the power generation system for Palaus river recommended by HOMER consisted of Darrieus Hydrokinetic Turbine and a converter, and the electricity produced by the system from Palaus river was 10.294 kWh/year.

Keywords: average flow velocities, hydrokinetic energy, hydropower, Palaus river

1. Introduction

Endowed with many rivers and mountainous and hilly topography, Indonesia has quite large potential of hydro energy. It is estimated that the potential could reach 75 GW with 95.27% of it lies outside Java and Bali Unfortunately, the growing rate of hydro power plant development is very slow. There is only 10.1% (7,572 GW) of the hydro energy potential that has been used to generate electricity[1].

One of the reasons why the utilization of hydro energy is much smaller that its potential is lack of hydro resources data. Accordingly, studies on hydro resources and its technologiesin Indonesia should be increased.

Palaus is one of rivers crossing Ratahan district, South East Minahasa regency, North Sulawesi province, Indonesia. The aim of this research was to calculate the electricity that can be generated from hydrokinetic energy of Palaus river.

There are many studies about hydropower. For instance,Bhat, in his research argued that hydro energy can provide more supply of renewables into grid by creating and selling innovative products of hydropower[2]. Tkac found that currently, the efficiency of hydropower system in micro and small application has significantly increased in macro design, from 65-75% up to 96%[3]. Doda and Mohamad managed to calculate the potential of electricity generated by a hydropower system in Bone Bolango regency, Gorontalo, Indonesia, is 65 kW [4]. Similar research conducted by Hanggara and Irvani found that the power produced by a micro-hydro system in Ngantang district, Malang regency, East Java can supply electricity for 47 houses [5].

Some research on development of hydropower technologies were also carried out widely. For example, Boedi, et al investigated the performance of a vertical axis hinged blade kinetic turbine [6]. Sunoko, et al. studied the relation between the positions of runner angle and the efficiency of an eight curved bladed kinetic water turbine [7]. Kumar and Srivastava investigated the use of aerofoil blade profile for turbines to produce small scale power generator [8].

2. Methods

This research was carried out in three main steps, those are data collection, data analysis and calculation. Each step is explained in the following.

2.1 Data collection

There were two data required in this research:

1. electric load profile in a dayof buildings around Palaus river
2. monthly average flow velocities of Palaus river in a year.

2.1.1 Electric load profile in a day

These data were acquired from questionnaires that inquire the profile of electric usage of buildings around Palaus river for every single hour of a day. The inquiries were about types of buildings, types of electrical equipment, their power (in Watt), their operational hours, and their total energy use (Watt hours).

2.1.2 Monthly average flow velocities

The measurement of monthly average flow velocities was conducted by "float method". In this method, the duration of an object (such as plastic bottle) floated in the stream for a determined distance (in this research: 10 meters) was counted. Then, the velocity could be determined by dividing thedistance by the duration.

For each visit to Palaus river, the measurement was carried out 20 times, and the average of the measurement results was used to calculate the average flow velocity of the month when the visitation conducted. Actually, the measurement should be carried out every month in a year, but because of the limitation of time, the measurement could only be done for five months, that is June, July, August, September and October 2019. For other months, the average velocities were assessed by comparing an average velocity that had been calculated previously with the data of monthly rainfall of South East Minahasa regency [9].

2.2 Data analysis

Data analysis was performed by using HOMER 2.68 Beta. The electric load profile in a day and the monthly average flow velocities in a year were the main input for HOMER. Apart from the two data, there were some parameters and values must be inputted into HOMER

2.3 Calculation

It was assumed that the electrical energy from Palaus river was generated by a kinetic turbine. After all data were inputted, the calculation of electrical energy could becarried out by HOMER 2.68.

3. Results and Discussions

3.1 Daily electric load profile

Only the daily electric load profile of residential houses was available. Accordingly, the profile of electrical load of all buildings around Palaus river was calculated by multiplying the profile a determined residential house by the number of residential houses around the Palaus river, in this case the number of residential houses in Tosuraya village that is 329.

The daily electric load profile of a determined residential house in Tosuraya village can be seen in Table 1.

Table 1.Daily electric load profile of a determined residential house in Tosuraya village

No	Electrical Equipment	Power (Watt)	Operational Hours	Number of Operational Hours	Energy Consumption (Wh)
1	Lamp A	40	18.00 – 06.00	12	480
2	Lamp B	30	18.00 – 06.00	12	360
3	Lamp C	40	18.00 – 22.00	4	160
4	Lamp D	30	20.00 – 21.00	1	30
5	Lamp E	10	18.00 – 06.00	12	120
6	Magic jar (heating)	35	06.00 – 05.30	23,5	822,5
7	Magic jar (cooking)	350	05.30 – 06.00	0,5	175
8	Water heater	500	17.00 – 17.30	0,5	250
9	Iron	300	15.00 – 16.00	1	300
10	TV	75	17.00 – 22.00	5	375
11	HP charger	12	09.00 – 19.00	10	120
Total of Daily Electrical Energy Consumption of a Household					3,192.5

Data from Table 1, then, were multiplied by the number of houses in Tosuraya village, i.e. 329. So, the daily electric load profile of buildings in Tosuraya village for every single hour of a day is shown in Table 2.

Tabel 2.Daily electric load profile of buildings in Tosuraya village for every hour

Hour in a day	Electrical consumption	
	(W)	(kW)
00.00 – 01.00	37.835	37,84
01.00 – 02.00	37.835	37,84
02.00 – 03.00	37.835	37,84
03.00 – 04.00	37.835	37,84
04.00 – 05.00	37.835	37,84
05.00 – 06.00	89.653	89,65
06.00 – 07.00	11.515	11,52
07.00 – 08.00	11.515	11,52
08.00 – 09.00	11.515	11,52
09.00 – 10.00	15.463	15,46
10.00 – 11.00	15.463	15,46
11.00 – 12.00	15.463	15,46
12.00 – 13.00	15.463	15,46
13.00 – 14.00	15.463	15,46
14.00 – 15.00	15.463	15,46
15.00 – 16.00	114.163	114,16
16.00 – 17.00	15.463	15,46
17.00 – 18.00	122.388	122,39
18.00 – 19.00	79.618	79,62
19.00 – 20.00	75.670	75,67
20.00 – 21.00	85.540	85,54
21.00 – 22.00	75.670	75,67
22.00 – 23.00	37.835	37,84
23.00 – 24.00	37.835	37,84
Total	1.050.333	1.050,33

Daily electric load profile of buildings in Tosuraya village for every hour can be presented in graphical from as shown in Fig. 1.

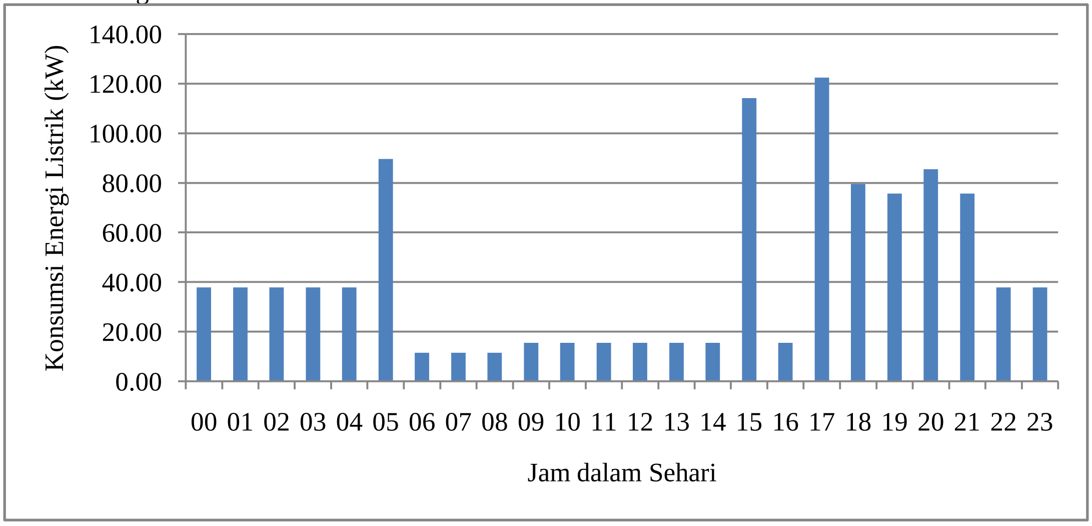


Figure 1. Daily electric load profile of buildings in Tosuraya village for every hour

As can be seen in Fig. 1, the most electrical usage occurs at 17.00 when TV, water heater, magic jar (heating) and HP charger are on. While the least happens from 06.00 to 09.00 when some lamps and magic jar (heating) are used.

3.2 Monthly average flow velocities

As explained previously, the monthly average flow velocities for June, July, August, September and October were obtained from direct measurements in Palaus river. The average flow velocities for other months were determined by using, the monthly rainfall data of South East Minahasa regency. The rainfall data of the other months were compared to the average flow velocity and the rainfall in June in order to calculate the average flow velocities of the other months. Table 3 shows the monthly rainfall in South East Minahasa regency in 2018 and the calculation results of monthly average flow velocities of Palaus river.

Table 3. Monthly average flow velocities of Palaus river

Month	Rainfall (mm^3)	Monthly average flow velocity of Palaus river (m/s)
January	156	2,06
February	284	3,74
March	246	3,24
April	312	4,11
May	127	1,67
June	88	1,16*
July	98	0,82*
August	46	0,72*
September	19	0,60
October	111	0,57
November	135	1,78
December	255	3,36

As can be seen that the highest average flow velocity occurs in April, while the lowest happens in October. The average velocities vary due to seasonal changes.

3.3 Data analysis

Data analysis was performed by using HOMER 2.68 Beta. At first, an electrical generation system must be formed in HOMER with an assumption that the electricity from Palaus river will be generated by a kinetic turbine. A converter was required to convert the DC current produced by the kinetic turbine into AC current. Therefore, as can be seen in Fig. 2, a primary load, Darrieus H Turbine (which is the only kinetic turbine available in HOMER 2.68 Beta), and a convertershould be selected. Because all buildings in South East Minahasa regency has been electrified by State Electricity Company, the option "System is connected to grid" should be selected.

Other values regarding other technical and economic aspects as the inputs for the software were estimated by using the default values in HOMER or based on a rough estimation.

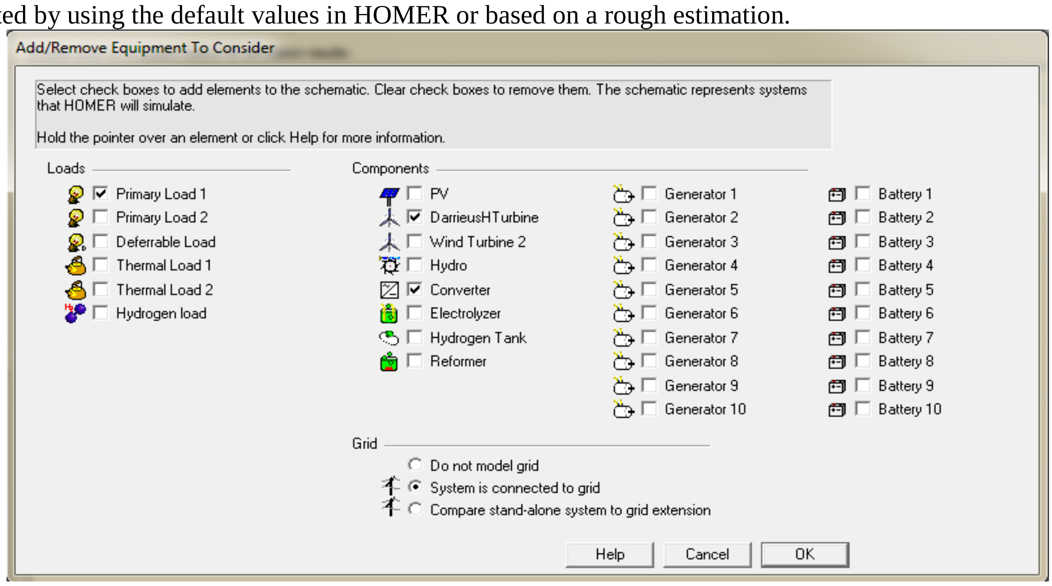


Figure 2 Selection of components in HOMER for power generation system from Palaus river

Secondly, the primary load was entered. So, the data of daily electric load profile of buildings around Palaus river as presented in Table 2 were inputted to HOMER. The result can be seen in Fig. 3.

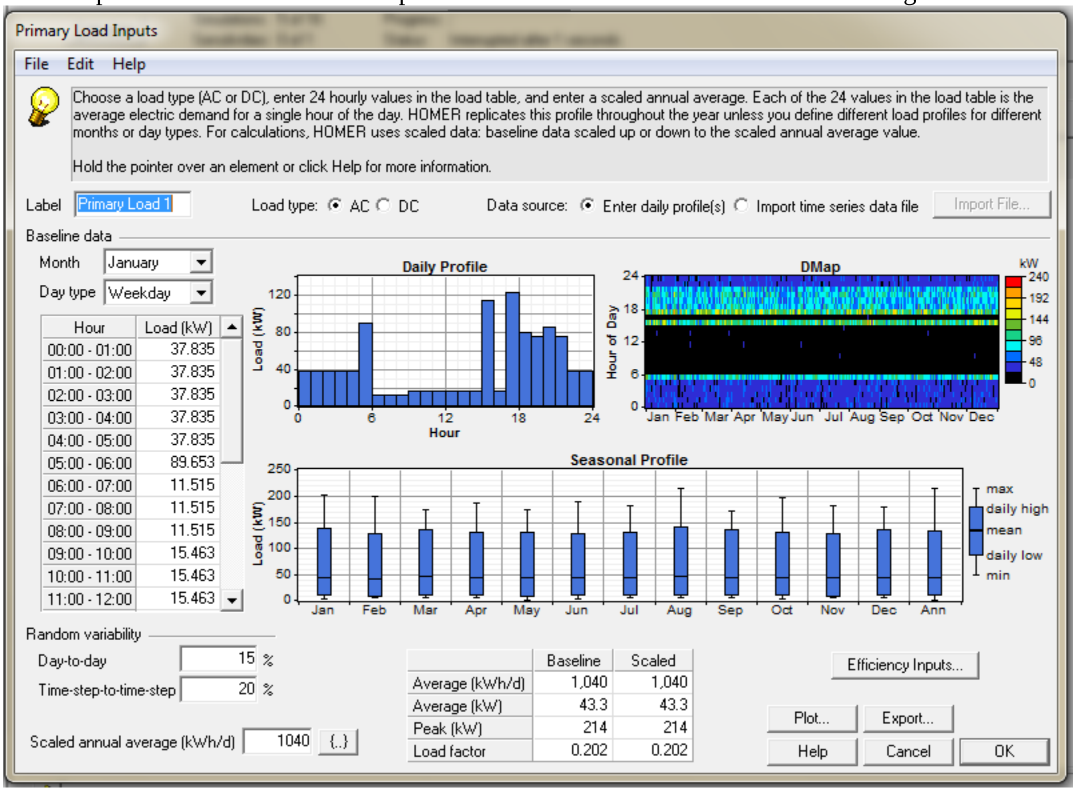


Figure 3. Primary load inputs

Thirdly, the resource data were inputted to the software. As previously explained, the hydrokinetic energy of Palaus river was generated by Darrieus Hydrokinetic Turbine. However, HOMER 2.68 Beta do not provide a resource data for a kinetic turbine. So, the data of monthly average flow velocities were inputted in “Wind Resource Inputs” in HOMER, because the characteristic of wind turbines can be assumed similar to kinetic turbines.

However, the data of monthly average flow velocities as presented in Table 3 must be prepared in another file (such as Excel) and after that, the file was imported to HOMER by clicking “Import File…” in Wind Resource Inputs window. The monthly average flow velocities in this research cannot be inputted to HOMER through “Enter monthly averages” in Wind Resource Inputs tab. By inputting the average velocity from “Import File…”, HOMER will nottake into account other typical wind parameters that can make the analysis and calculation incorrect. Figure 4 shows the resource inputs of this research.

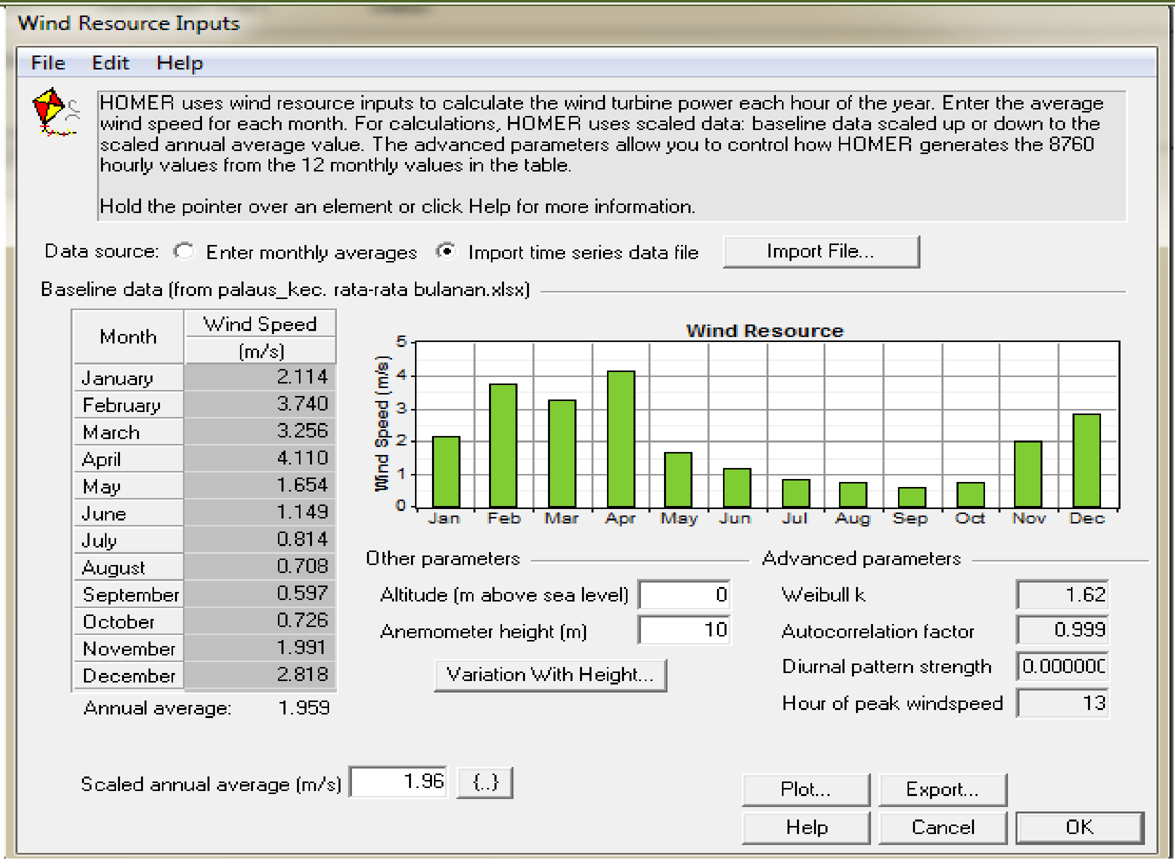


Figure 4. Resource input

Fourthly, the data of turbine were entered to HOMER. Darrieus Hydrokinetic Turbine was selected because it is the only kinetic turbine available in HOMER database.The result of inputting turbine data is shown in Fig. 5.

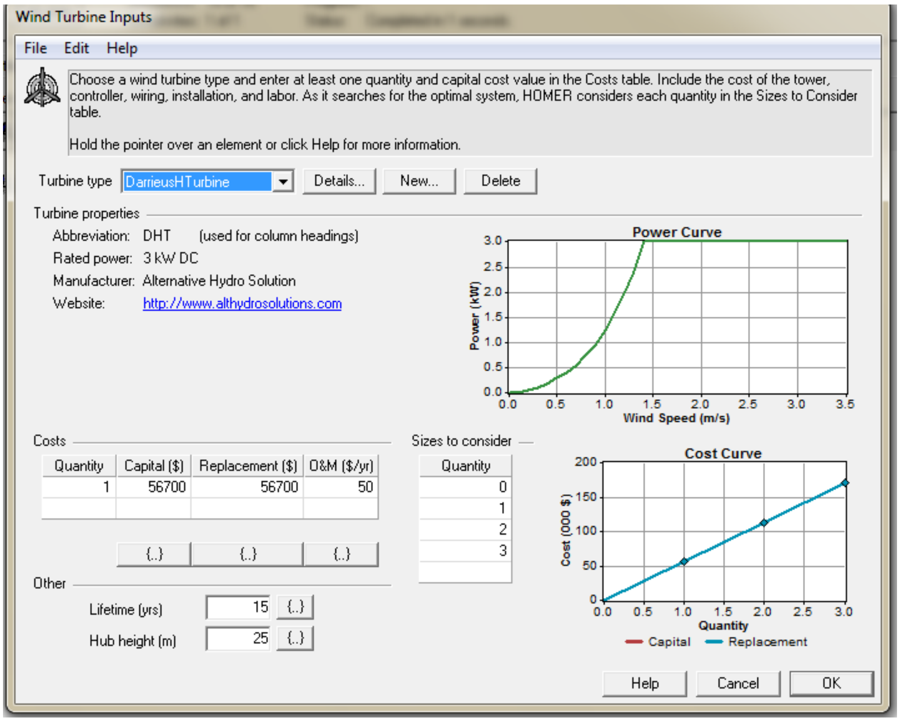


Figure 5. Turbine inputs

Lastly, the data of converter were entered to the software. A converter was required to convert the DC current produced by the turbine to AC current. The result of inputting converter data is shown in Fig. 6.

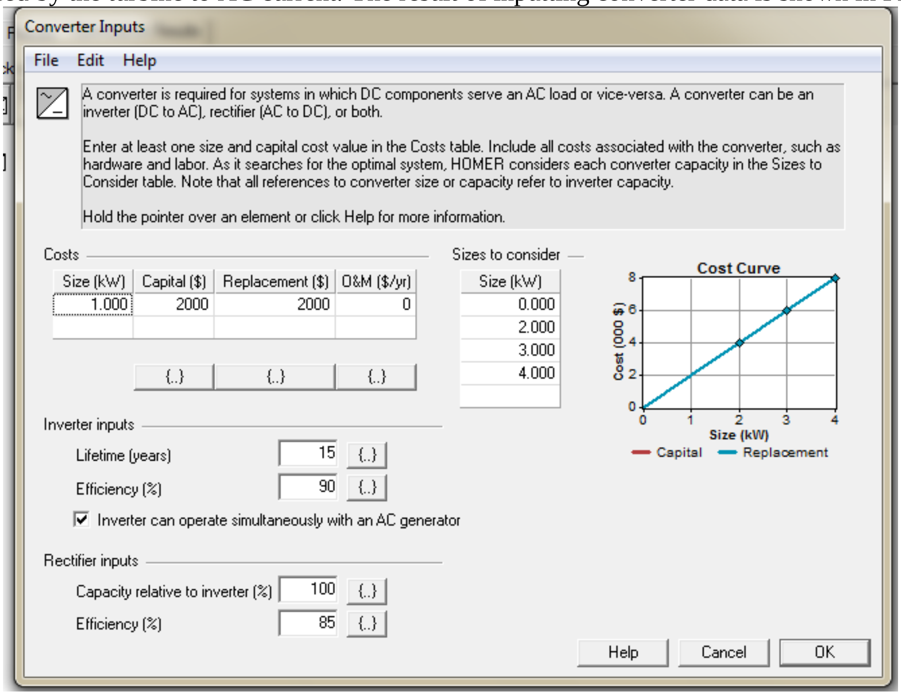


Figure 6. Converter inputs

3.4 Calculation

A schematic of the electricity generation system in Palaus river was displayed after all of the inputs of load, resource and components were entered. Fig. 7 shows the schematic provided by HOMER.

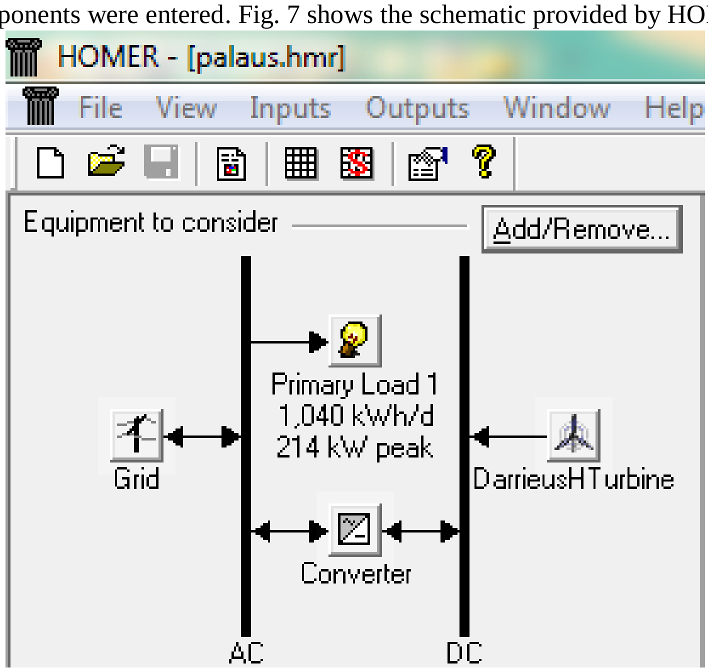
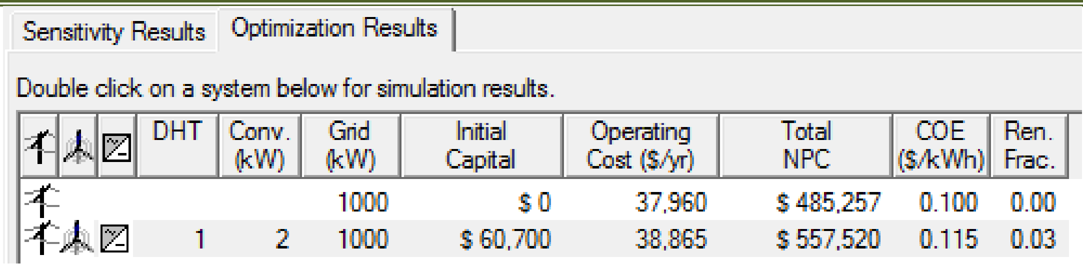


Figure 7. Schematic of electricity generation system in Palaus river

As can be seen in Fig. 7, the electricity generation system in Palaus river comprises a unit Darrieus Hydrokinetic Turbine and a converter. The load is 1.040 kWh/day and the peak is 214 kW. The electricity for meeting the load was supplied by the system and grid.

Then, the calculation was performed. After doing the calculation and simulation, HOMER 2.68 Beta displayed the system as can be seen in Fig. 8.



Sensitivity Results | Optimization Results

Double click on a system below for simulation results.

	DHT	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.
			1000	$ 0	37,960	$ 485,257	0.100	0.00
	1	2	1000	$ 60,700	38,865	$ 557,520	0.115	0.03

Figure 8. Options of electricity generation system in Palaus river recommended by HOMER

First option was ignored because in this system, the electricity was only provided by grid. So, based on the objective of this research, the second option was selected.

By double-clicking the second option, HOMER will display the results of calculation and simulation. The electricity produced by the turbine can be seen in “DHT” tab. The results are shown in Fig. 9.

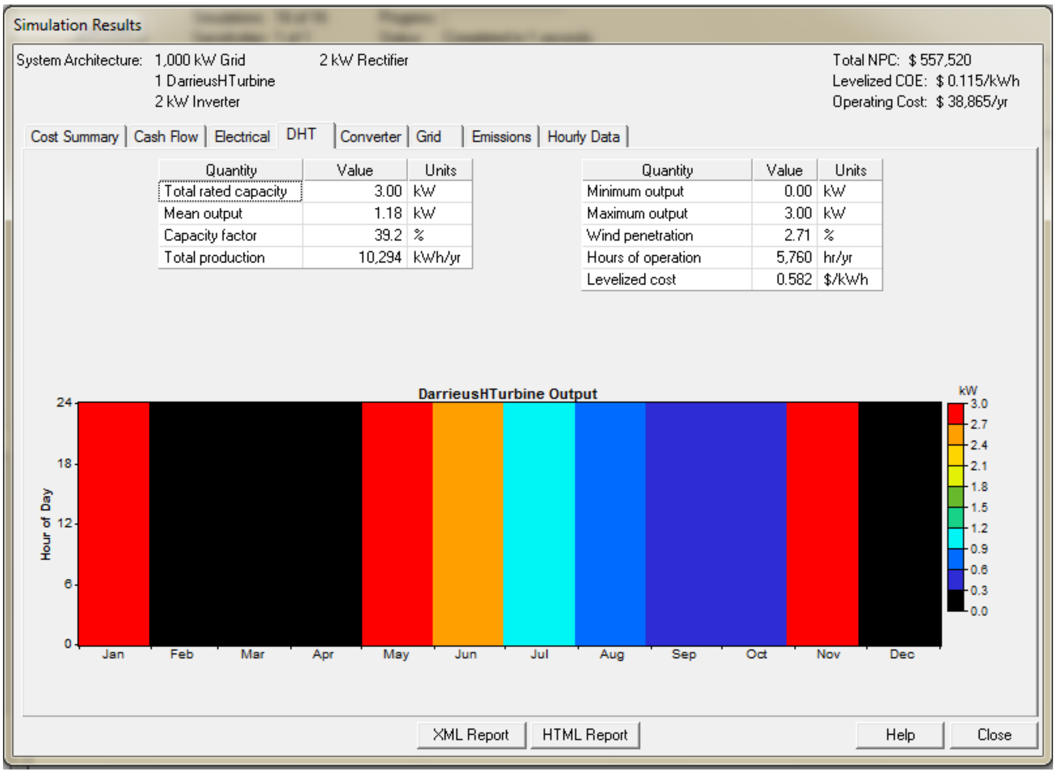


Figure 9. Calculation and simulation results

As can be seen in Fig. 9, the power generated from Palaus river by using a kinetic turbine is 10,294 kWh/year.

4. Conclusion

Because the potential energy in hydro is quite large in Indonesia, research to encourage the utilization of hydropower in Indonesia should be increased, particularly research on identifying the potential of hydropower of rivers. Accordingly, hydropower in Indonesia can be harnessed optimally. By using HOMER 2.68 Beta, the hydrokinetic energy from Palaus river can be calculated. The electricity was produced by a system that comprises one unit of Darrieus Hydrokinetic Turbine and a converter which can only generate 10,294 kWh/year. In the future, this kind of research need to be improved by using an equipment for measuring the flow velocities (such as current meter), and also better software for doing the analyzing and calculation (such as HOMER Pro).

5. References

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