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Optimal Design of Green Energy Systems Based on Photovoltaic Source for Rural Electrification in Malaysia

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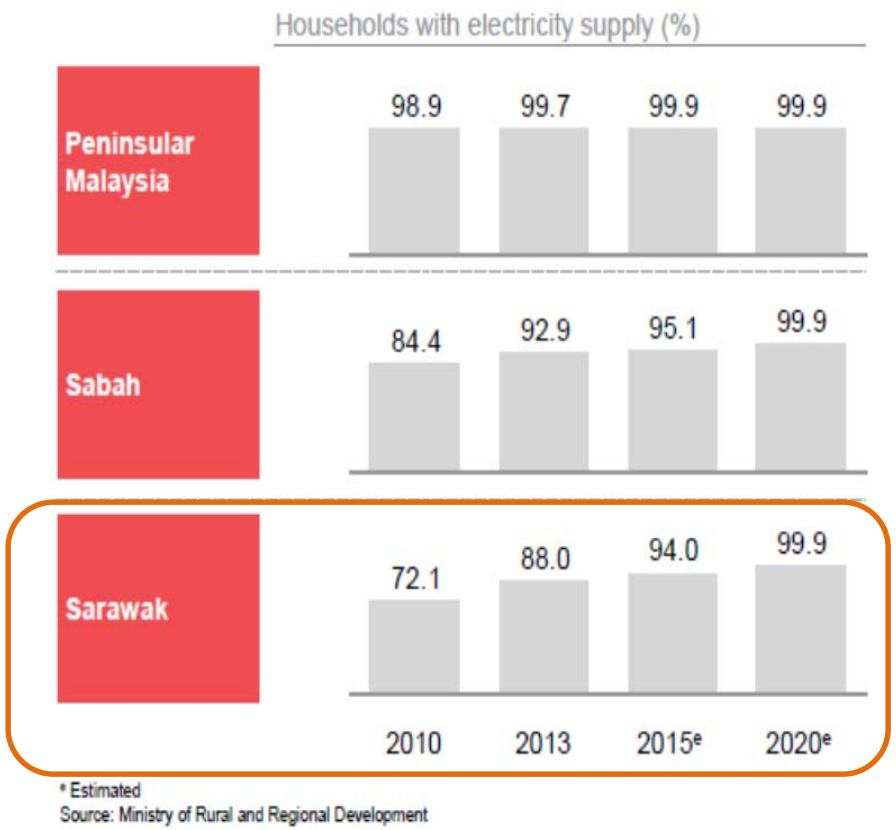
Rural Electrification

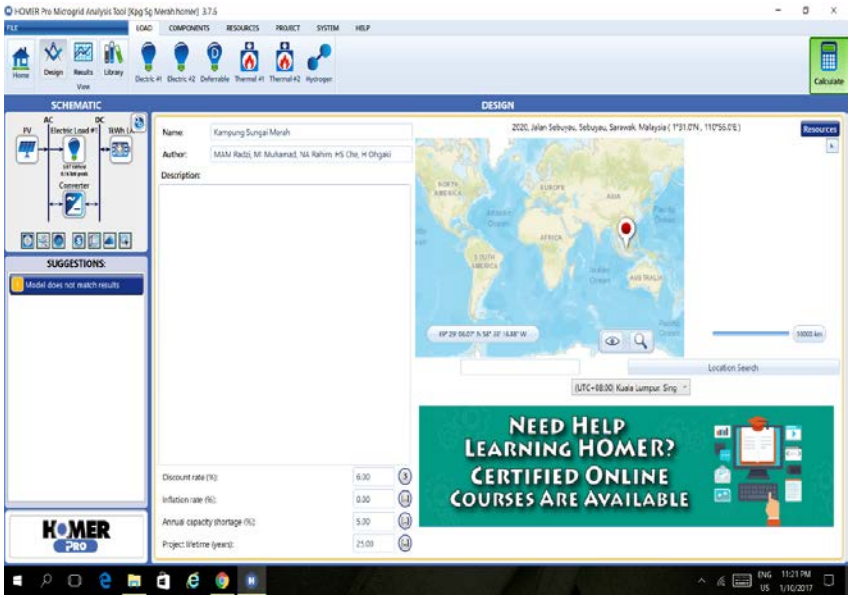


* Estimated
Source: Ministry of Rural and Regional Development

There are various existing works on installing renewable systems, potential of evaluating them for further improvement can be carried out, especially with appropriate design.

Objective

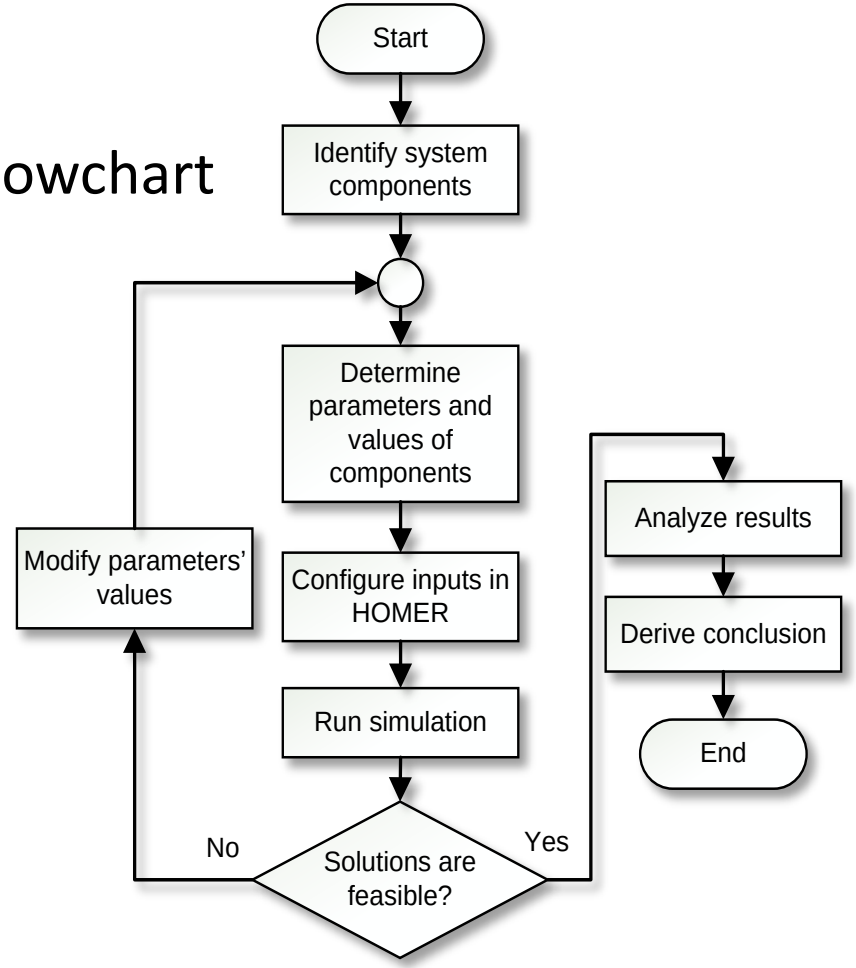
To develop optimal design of fully **green energy systems based on photovoltaic (PV) source** with reasonable cost and appropriate dispatch energy strategy for rural electrification in **two selected areas in Sarawak**

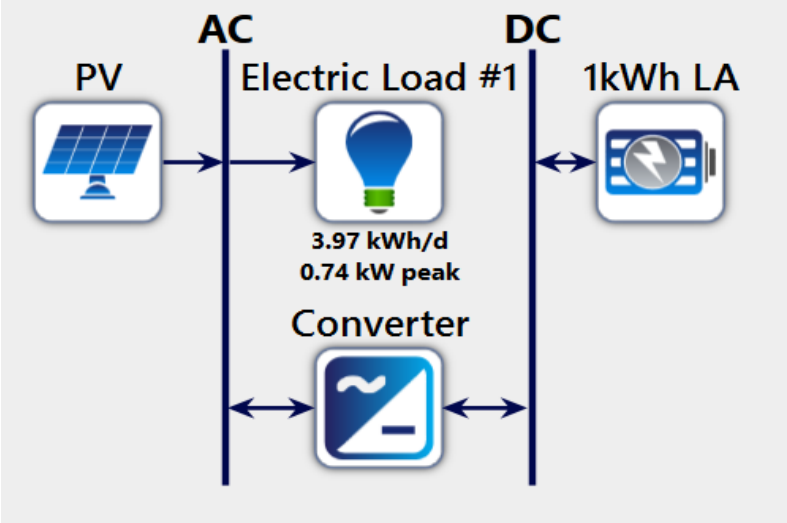


Studied Areas

Assessment

Flowchart





Configuration of the system

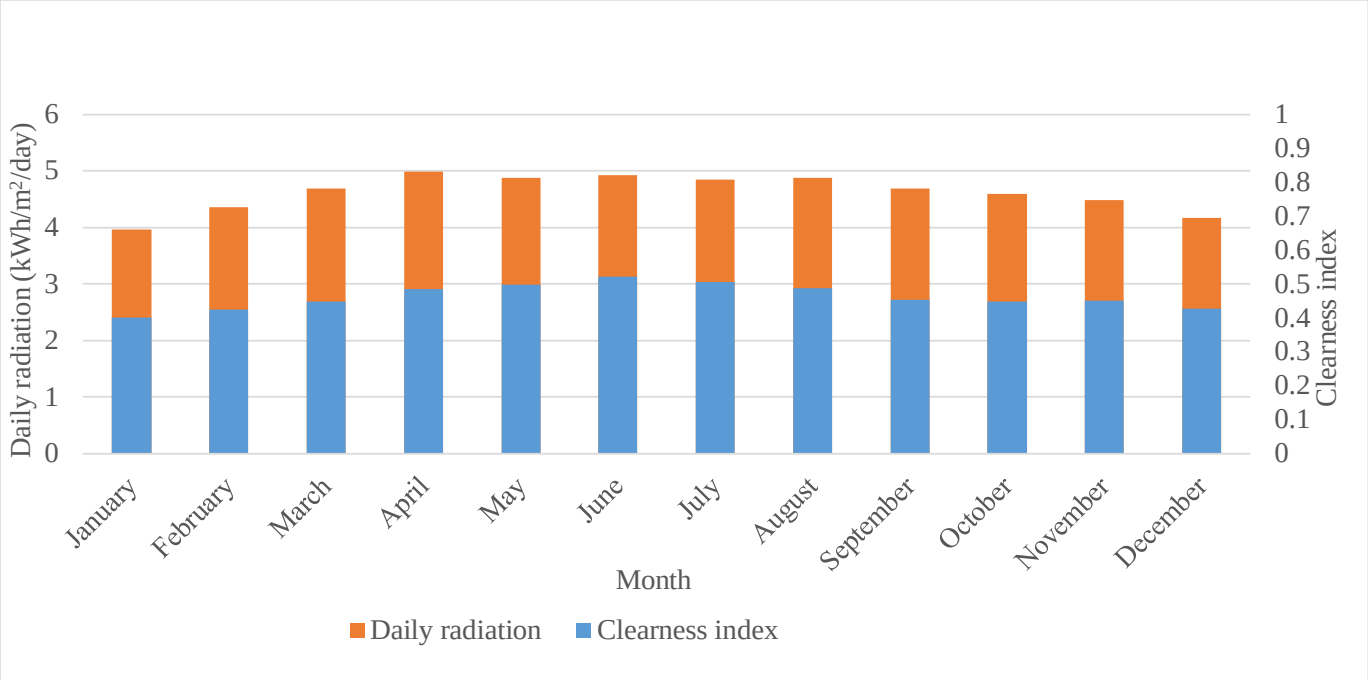
Kampung Opar - Loads

Electric appliance	Power (W) per hour	Operating hour per day	Average usage (Hour/day)	Usage for 1 unit per day (Wh)	Number of unit	Total usage for 1 house per day (Wh)
Compact fluorescent light bulb	22	18 to 23	5	110	2	220
Refrigerator	120	0 to 24	8	960	1	960
Television	70	18 to 23	5	350	1	350
Fan	50	18 to 23, 13 to 14 (Lunch)	6	300	1	300
Water pump	150	12 to 14	2	300	1	300
					TOTAL	2130

From: Fadaeenejad, M., Radzi, M.A.M., AbKadir, M.Z.A., Hizam, H., 2014. "Assessment of hybrid renewable power sources for rural electrification in Malaysia," *Renewable and Sustainable Energy Reviews*, 30, 299–305.

Ten houses – 21.3 kWh

Kampung Opar – Solar Irradiance



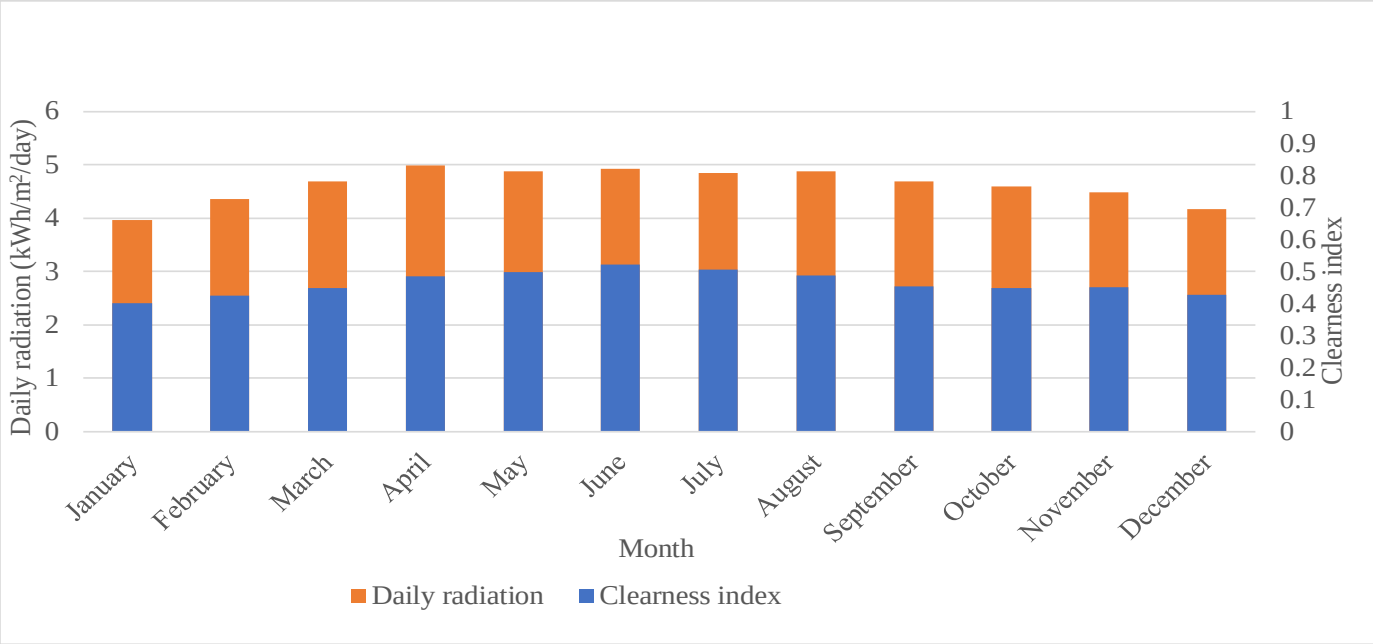
Annual average irradiance is 4.62 kWh/m²/day

Kampung Sungai Merah - Loads

House	Electrical appliance	Power (W) per hour	Average usage (Hour/ day)	Usage for 1 unit per day (Wh)	Unit	Total usage for 1 house per day (W/h)
1	Compact fluorescent light bulb 1	26	5	130	1	130
	Compact fluorescent light bulb 2	20	5	100	1	100
	Compact fluorescent light bulb 3	18	5	90	7	630
	CRT television	72	5	360	1	360
	Table fan	48	6	288	2	576
	Ceiling fan	60	6	360	1	360
2	Compact fluorescent light bulb	18	5	90	8	720
	LCD television	50	5	250	1	250
	Table fan	48	6	288	1	288
3	Compact fluorescent light bulb	18	5	90	3	270
	Table fan	48	6	288	1	288
					TOTAL	3972

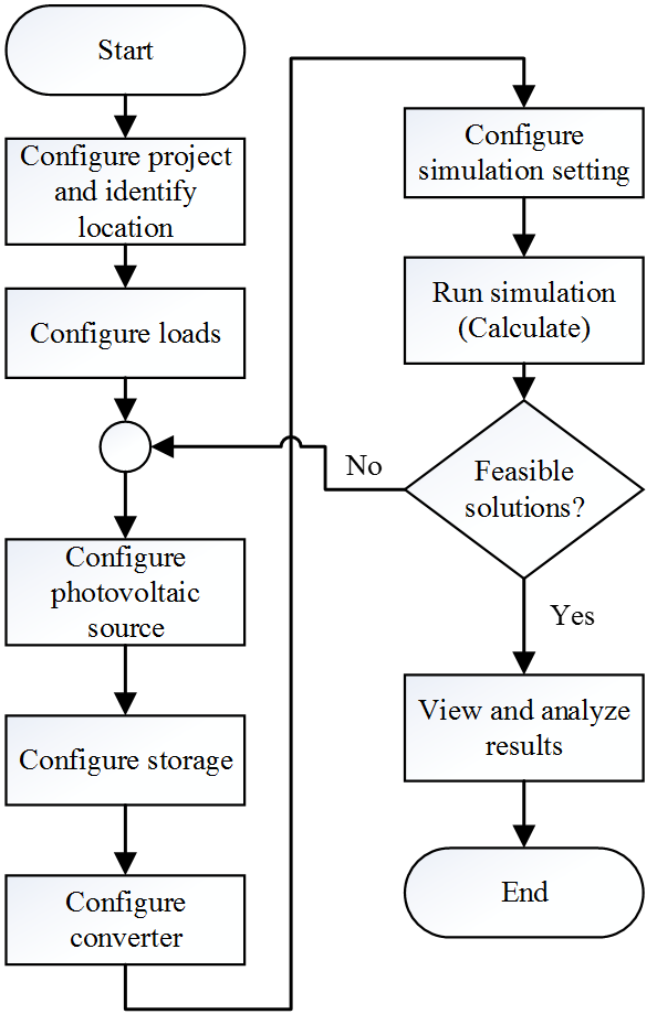
Surveyed by UMPEDAC

Kampung Sungai Merah – Solar Irradiance



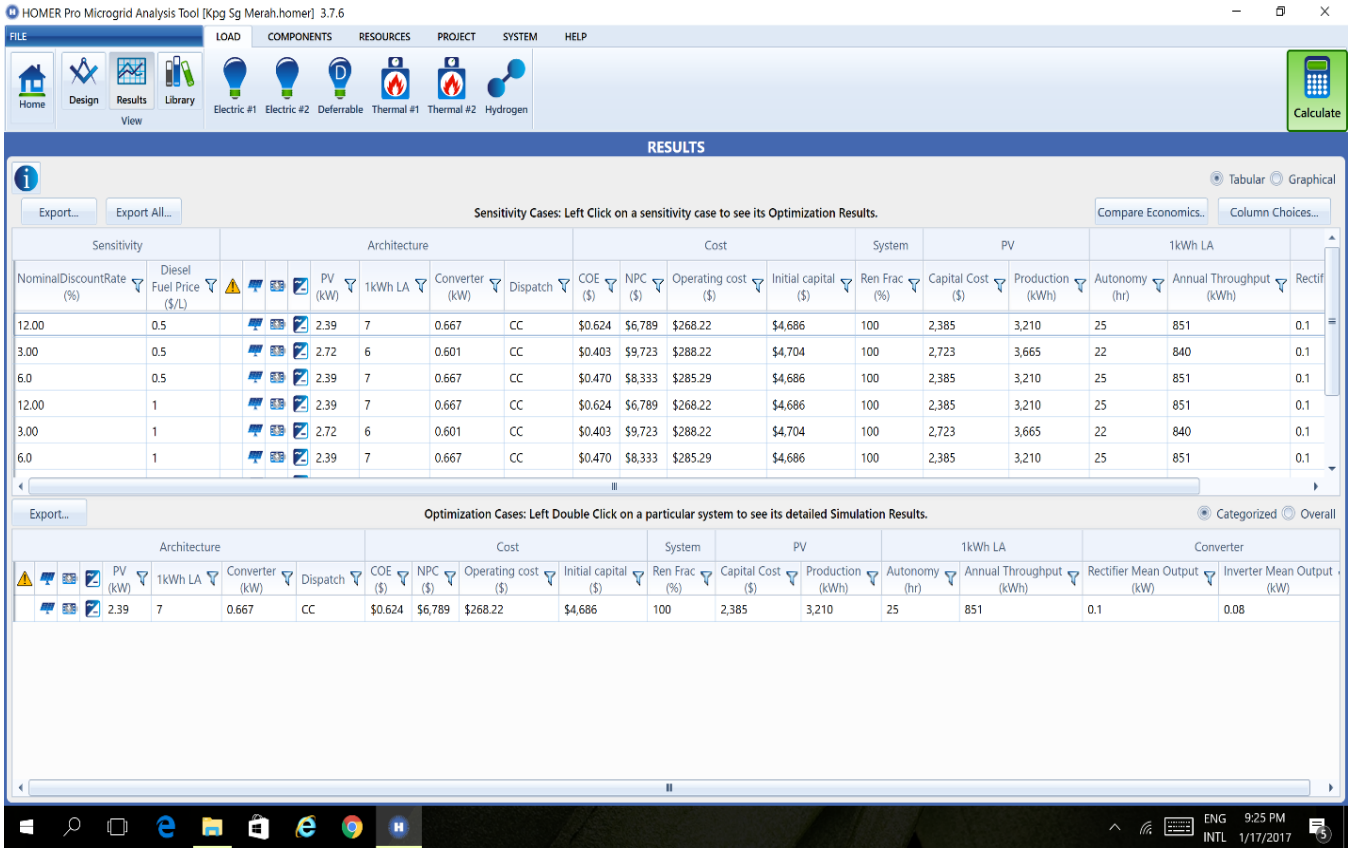
Annual average irradiance is 4.62 kWh/m²/day

Simulation in HOMER



Optimization variables		
Component	Capacity	
	Kampung Opar	Kampung Sungai Merah
Converter	0 – 5 kW	0 – 5 kW
Battery	0 – 50 kWh	0 – 15 kWh
Photovoltaic	0 – 30 kW	0 – 10 kW
Sensitivity inputs		
Nominal Discount (%)	Diesel Fuel Price (USD)	
3, 6 and 12	0.5, 1, and 2	

Results in HOMER



Sensitivity Analysis

Optimization

Optimal Design

Component/Parameter	Value	
	Kampung Opar	Kampung Sungai Merah
Architecture/PV (kW)	13.3	2.39
Architecture/1kWh LA	36	7
Architecture/Converter (kW)	3.22	0.67
Architecture/Dispatch	Cycle charging	Cycle charging
Cost/Cost of energy (COE) (USD)	0.652	0.624
Cost/Net present cost (NPC) (USD)	**38,052**	**6,789**
Cost/Operating cost (USD)	1,660	268.22
Cost/Initial capital (USD)	25,029	4,686
System/Renewable fraction (%)	100	100
PV/Capital Cost (USD)	13,264	2,385
PV/Production (kWh)	17,858	3,210
1kWh LA/Autonomy (hour)	24	25
1kWh LA/Annual Throughput (kWh)	4,526	851
Converter/Rectifier Mean Output (kW)	0.6	0.1
Converter/Inverter Mean Output (kW)	0.4	0.08

Sensitivity Analysis – Kampung Opar

Sensitivity/Nominal Discount Rate (%)	Sensitivity/Diesel Fuel Price (USD/L)	Architecture/PV (kW)	Architecture/1kWh LA	Architecture/ Converter (kW)	Architecture/Dispatch	Cost/COE (USD)	Cost/NPC (USD)	Cost/Operating cost (USD)	Cost/Initial capital (USD)	System/Renewable Fraction (%)	PV/Capital Cost (USD)	PV/Production (kWh)	1kWh LA/Autonomy (hour)	1kWh LA/Annual Throughput (kWh)	Converter/Rectifier Mean Output (kW)	Converter/Inverter Mean Output (kW)
12	0.5	13.3	36	3.22	CC	0.65	38,052	1,660	25,029	100	13,264	17,858	24	4,526	0.6	0.4
3	0.5	13.5	35	3.27	CC	0.43	56,189	1,791	25,005	100	13,523	18,208	24	4,515	0.6	0.4
6	0.5	13.5	35	3.27	CC	0.50	47,608	1,768	25,005	100	13,523	18,208	24	4,515	0.6	0.4
12	1	13.3	36	3.22	CC	0.65	38,052	1,660	25,029	100	13,264	17,858	24	4,526	0.6	0.4
3	1	13.5	35	3.27	CC	0.43	56,189	1,791	25,005	100	13,523	18,208	24	4,515	0.6	0.4
6	1	13.5	35	3.27	CC	0.50	47,608	1,768	25,005	100	13,523	18,208	24	4,515	0.6	0.4
12	2	13.3	36	3.22	CC	0.65	38,052	1,660	25,029	100	13,264	17,858	24	4,526	0.6	0.4
3	2	13.5	35	3.27	CC	0.43	56,189	1,791	25,005	100	13,523	18,208	24	4,515	0.6	0.4
6	2	13.5	35	3.27	CC	0.50	47,608	1,768	25,005	100	13,523	18,208	24	4,515	0.6	0.4

Sensitivity Analysis – Kampung Sungai Merah

Sensitivity/Nominal Discount Rate (%)	Sensitivity/Diesel Fuel Price (USD/L)	Architecture/PV (kW)	Architecture/1kWh LA	Architecture/ Converter (kW)	Architecture/Dispatch	Cost/COE (USD)	Cost/NPC (USD)	Cost/Operating cost (USD)	Cost/Initial capital (USD)	System/Renewable Fraction (%)	PV/Capital Cost (USD)	PV/Production (kWh)	1kWh LA/Autonomy (hour)	1kWh LA/Annual Throughput (kWh)	Converter/Rectifier Mean Output (kW)	Converter/Inverter Mean Output (kW)
12	0.5	2.39	7	0.67	CC	0.624	6,789	268.22	4,686	100	2,385	3,210	25	851	0.1	0.08
3	0.5	2.72	6	0.60	CC	0.403	9,723	288.22	4,704	100	2,723	3,665	22	840	0.1	0.08
6	0.5	2.39	7	0.67	CC	0.470	8,333	285.29	4,686	100	2,385	3,210	25	851	0.1	0.08
12	1	2.39	7	0.67	CC	0.624	6,789	268.22	4,686	100	2,385	3,210	25	851	0.1	0.08
3	1	2.72	6	0.60	CC	0.403	9,723	288.22	4,704	100	2,723	3,665	22	840	0.1	0.08
6	1	2.39	7	0.67	CC	0.470	8,333	285.29	4,686	100	2,385	3,210	25	851	0.1	0.08
12	2	2.39	7	0.67	CC	0.624	6,789	268.22	4,686	100	2,385	3,210	25	851	0.1	0.08
3	2	2.72	6	0.60	CC	0.403	9,723	288.22	4,704	100	2,723	3,665	22	840	0.1	0.08
6	2	2.39	7	0.67	CC	0.470	8,333	285.29	4,686	100	2,385	3,210	25	851	0.1	0.08

Conclusion & Future Prospect

The work has successfully been carried out to design and simulate the renewable energy systems. The results conclude the optimized results with the lowest NPC.

Appropriate design with comprehensive analysis through powerful software tool like HOMER should provide better future prospect in ensuring **sustainable renewable systems**. The supplied electricity later will provide better life for rural people.

The future work is to consider multi sources for more sustainable renewable systems.

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