ECONOMICS OF SMALL-SCALE POWER GENERATION FROM RENEWABLE AND HYBRID SOURCES

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Abstract
The problem that influences the world on energy is climate change and until we increase our alternative sources the world will continue to face the energy issue. Besides, greenhouse gas emission is a main issue which is related with current energy access. Another global energy issue is hundreds of millions of people lack access to sufficient energy. In addition, depletion of natural resources become other crucial issue due to global energy consumption is growing in tandem with population growth, energy dependent patterns of usage composed with technological advancements. This study aims to focus on alternative power generation from renewable and hybrid sources in techno economic as a countermeasure for current energy sources issue in isolated communities which remote from the existing electricity transmission and distribution infrastructure. HOMER Pro software and RETScreen software are used to analyze best optimization of hybrid renewable energy system and check financial viability. A comparative analysis is done for 4 cases of energy: solar PV, wind, hydropower, and biogas to obtain estimation of Net Present Cost (NPC), Levelized Cost of Energy (LCOE) and renewable fraction. His work also determines IRR, simple payback and energy production costs.

Keywords
Renewable energy, hybrid energy, system, RETScreen

1. Introduction
Greenhouse gas emissions is a major issue which is related to current energy access. Another global energy challenge is hundreds of millions of people lack access to sufficient energy. In addition, depletion of natural resources become other crucial issues due to global energy consumption is growing in tandem with population growth, energy dependent patterns of usage composed with technological advancements. The global population was 6.84 billion in 2009, rose to 7.59 billion in 2018 (World Bank 2020), and worldwide energy consumption rose from 482 Mtoe to 583 Mtoe in 10 years, an average yearly rise of 1.60 percent (British Petroleum (BP 2020). Furthermore, global electric energy usage was 17,355 TWh in 2009 and rose to 22,964 TWh in 2018, representing a 3.23 percent rise (Esteban and Leary 2012; Siti Masyita Noraziman et al. 2019; United Nations 2019).

International Energy Agency (IEA) estimates the annual average household usage in remote areas is 1,250 kWh will power four lightbulbs for five hours a day, one refrigerator, a fan for six hours a day, a cell phone charger, and a television for four hours a day as of standard devices (International Energy Agency (IEA 2021). The accelerated usage of electrical devices because of technological advancements is the key reason for the higher growth rate of energy consumption than the global population and primary energy demand. Many countries have been forced to explore for alternative ways to fulfil their energy needs because of this situation (Rahman et al. 2019; Rahman et al. 2018). Renewable energy utilizations can counteract the current energy challenges such as greenhouse gas emissions, insufficient energy access and depletion of natural resources (Bayrak and Cebeci 2014). Exploration of new renewable energy is one of main factor for the transition from natural resources to alternative and diversified resources. Similarly, to fight with energy access challenge for remote population, the combination of more than one energy sources is advantageous for distributing power generation, where it would be economically unfeasible to connect these consumers to the centralized generation infrastructure (Esteban and Leary 2012).

There are few studies focusing on Hybrid Energy System (HES) in recent years for centralized power generations. A HES is a system that depending on the availability of local resources, uses more than one primary energy sources, renewable or otherwise, to supply electricity to a particular consumer, and meet a particular power quality standard. Furthermore, Hybridization of primary sources, with or without a storage system, allows weak points of one source to mitigated or complemented by the strengths of another sources, allowing the system to be designed with maximized energy production while minimizing costs and risks of supply disruption (Yunez-Cano et al. 2016).
This study is aims to perform techno economic analysis on alternative power generation from renewable and hybrid sources in isolated communities which remote from the existing electricity transmission and distribution infrastructure. The purpose of this research is to do simulation for evaluating techno-economic and societal merits of renewable resources for various power generation options.

2. Literature review

This section focuses on renewable energy types and techno economics.

2.1Techno-economics

The word techno-economics come from combination of technological and economic concepts. The studies of variety of economic and sociological of the emergence and effects of scientific and technological change started over the last 30 years (Amer et al. 2013; Azimoh et al. 2017). The TEN idea is critical for understanding how technological and socioeconomic elements interact in the growth of any artefact or system: every technical innovation entails the creation of network of interconnection between people, things, and knowledge at the same time. Any organization tasked with encourage innovation for any policy goal should consider how such networks may be built instead of focusing just on money, project management, or technology transfer.

2.2 Major of renewable energy sources

Renewable energy, also known as green energy, is derived from naturally replenished sources or processes. In other word, sunlight, and wind, for example, continue to shine and blow, but their availability is dependent on the weather. Figure 1 shows renewable energy generation in the world from 1965 until 2019. From the chart, around 60% of total electricity generation comes from hydropower, which is the most common modern renewable energy source. Wind and solar power, on the other hand, are quickly growing. Not to mention, hydropower has been utilised to generate electricity since 1965, while wind and solar power were built in the 1980s. Total renewable energy production in 2019 was 7027.73 TWh, up 2.5 times in 20 years. In other word, renewables are anticipated to supply one-third of the world's electricity by 2025, according to the International Energy Agency (IEA 2021).

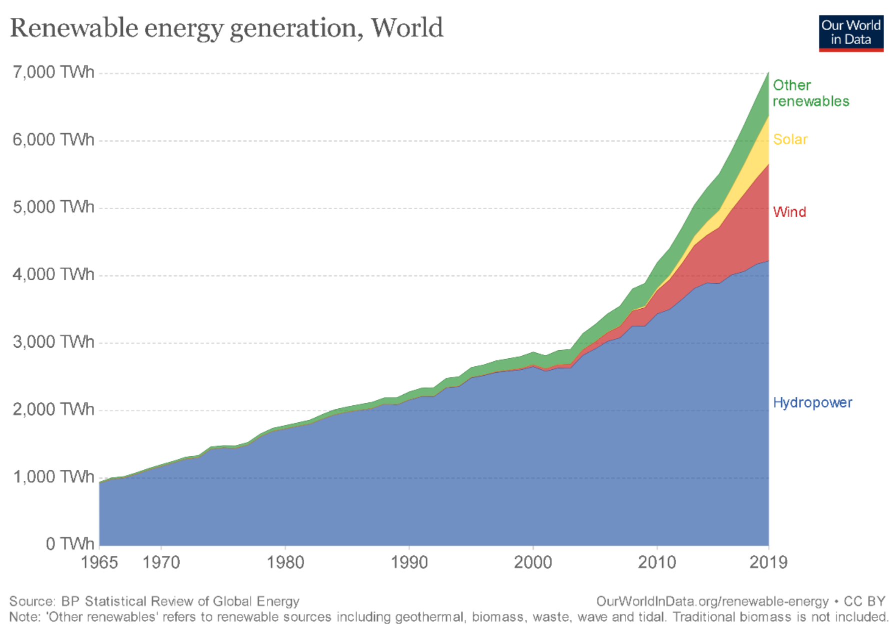

Figure 1. Renewable energy generation, world (BP, 2020)

2.3 Hybrid energy sources

The hybrid renewable energy system (HRES) comprises of two or more renewable energy sources, such as wind and solar power plants, to provide greater efficiency of combined system power generation as well as extra maneuvering capacity with a steady energy supply. In addition to the time of a temporary lack of sunlight and wind, the system will rely on batteries to provide power to users. Plus, if the system creates more electricity than it needs, the control unit will sell the extra electricity to the centralized electric grid at a feed-in tariff.

2.4 Global successful cases

Based on worldwide experience, the UK market for hybrid energy systems is growing every year, with expectations to reach 900 MW of cumulative capacity generation by 2024. By 2024, China's hybrid power systems market is expected to expand by more than 3% (IEA 2021). A site near Hanover in northern Germany has previously been selected for the installation of an IREF (90%, 7% wind, 3% solar) and as a research center for renewable energies — solar, wind, and biomass energy, as well as their arrangement. The optimization of energy autonomy in decentralized living regions, as well as the promotion of regional resource management, receive special attention. The center will be responsible for research and teaching, as well as technology transfer and collaboration with national and international organizations. The trade and industry will be able to introduce, demonstrate, and commercialize the items. One of the research center's main goals is to work with low-income nations on topics such as sustainable energy and food production.

3. Methodology

This study will use simulation software: HOMER Pro and RETScreen to simulate energy system configurations and provide sensitivity analyses for clean energy project.

3.1 Load profile for study

- Location: Kampung Pantai Semut Api, Kota Bharu, Kelantan
- Longitude: 102.272195°E, Latitude: 6.196117°N
- Average wind speed: 3.49 m/s
- Annual solar radiation: 1705 kWh/m2

3.2 Electric Consumption

For this study, target population based on 100 households in rural area at Kota Bharu. Daily load profile of typical household in Malaysia as researched by Ismail et al., (2013) as shown in Table 1.

Table 1. Electricity consumption of a typical household in Malaysia

Equipment	Wattage (W)	Usage (h)	Daily load demand (kWh / day)	Annual load demand (kWh / year)
9V lamps	9 x 40	6	2.16	788.4
1 TV	80	6	0.48	175.2
1 Refrigerator	100	24	2.40	876.0
4 fans	4 x 100	5	2.00	730.0
1 washing machine	250	2	0.50	182.5
Total			**7.54**	**2752.10**

3.3 Cost for Energy System Supply

The cost assumptions for simulation are presented in Table 2.

Table 2. Cost assumptions for all equipment

Equipment	Capital (MYR)	Replacement (MYR)	O&M (MYR/year)

Solar PV	2700/kW	2700/kW	135/kW
Wind Turbine	4,917,500	4,917,500	40,000
Battery	422,000	422,000	8000.00
Inverter	60/kW	60/kW	3/kW
Hydropower	1,730,000	1,730,000	43,250
Biogas	168,760	168,760	8,000
Diesel Gen.	30,444	30,444	0.050 MYR/hr

3.4 Types of Energy Supply

There are 4 cases of energy for power generation are evaluated by using HOMER Pro as shown in Table 3, Table 4, Table 5 and Table 6 while for RETScreen® evaluation will be based on HOMER Pro results.

Table 3. Solar Power energy

No	Types of energy supply
1	Wind + PV + Diesel Gen + Storage
2	PV + Diesel Gen + Storage
3	PV + Storage
4	Hydro+PV+Storage

Table 4. Wind turbine energy

No	Types of energy supply
1	Wind + PV + Diesel Gen + Storage
2	Wind + DG
3	Hydro + Wind + Storage

Table 5. Hydropower energy

No	Types of energy supply
1	Hydro + Storage
2	Hydro+PV+Storage
3	Hydro + Generator
4	Hydro + Wind + Storage

Table 6. Biogas energy

No	Types of energy supply
1	BioCo
2	BioCo + PV
3	BioCo + PV + Storage

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4. RESULTS

4.1 Optimization Results

Several types of configurations based on solar PV, wind, hydropower, and biogas cases are discussed in this study. Summary from these energy, Figure 2 shows NPC values and LCOE values. The lowest NPC is RM 2,657,514 with LCOE RM 0.73 from hybrid energy system of solar PV, diesel generator, and storage. For the second-best option is combination between hydropower and storage system which is not much different value of NPC and LCOE at RM 2,826,480 and RM 0.77 respectively. The cost of solar PV is RM 2700 per kW and efficiency rate at 15.7% only are affected to high cost of NPC. Thus, the combination with 100kW diesel generator is successful to reduce the NPC cost. This hybrid system is using only 200kW of solar PV only.

Biogas plant and hybrid system located at all third last ranking of best option for optimization with LCOE value is RM 1.31, RM 1.47, and RM 1.66. The NPC is almost third time higher than lowest NPC. Biogas needs fuel resources from palm oil where the price is RM350 to RM450/ton of Empty Fruit Bunch (EFB) and higher than current price of coal.

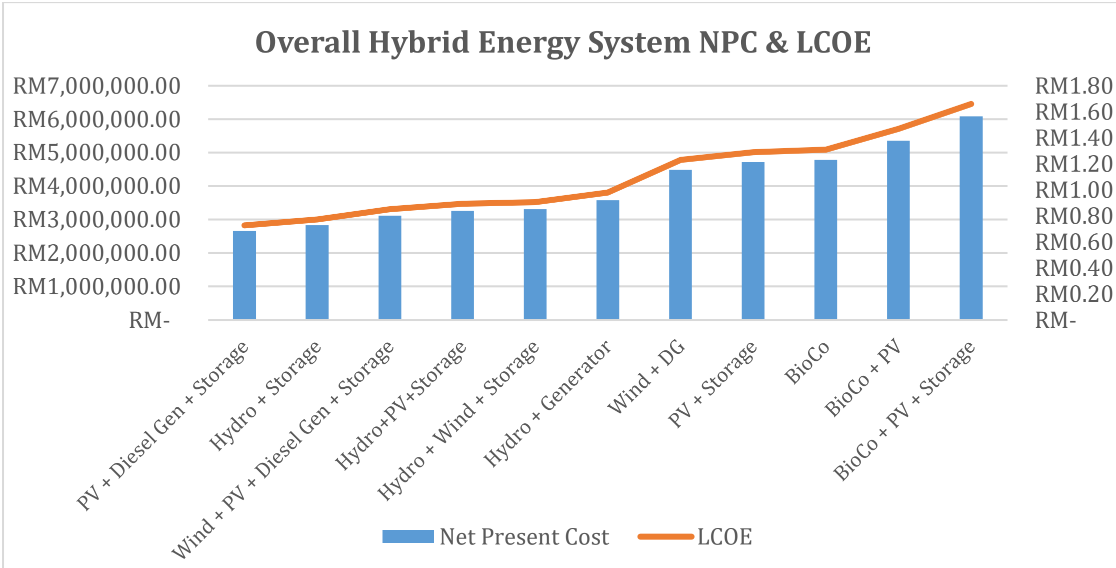

Figure 2. Overall hybrid energy system NPC and LCOE

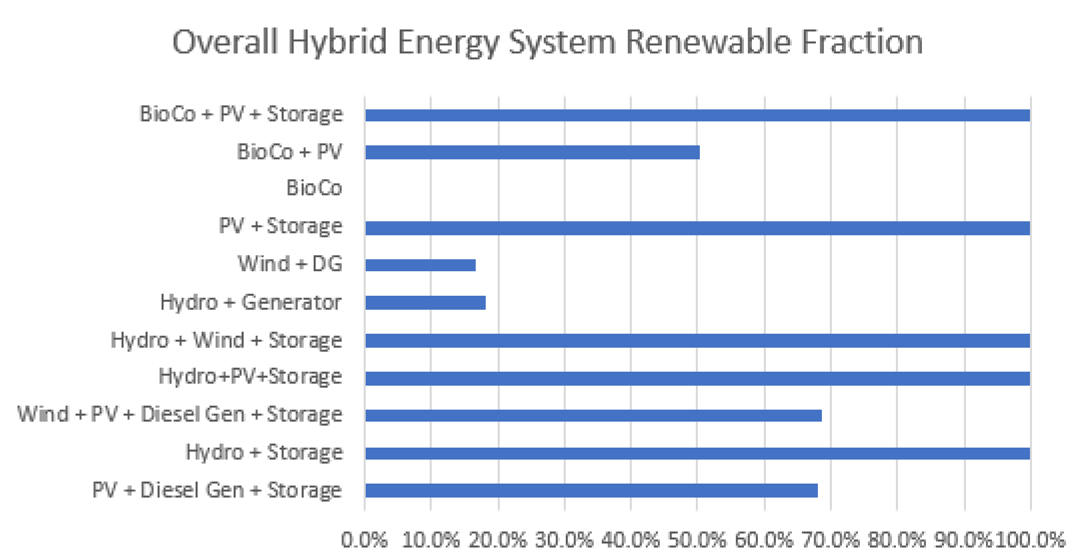

Figure 3. Overall hybrid energy system renewable fraction

Figure 3 shows renewable fraction for overall hybrid energy system. For three system only produced less than 50% renewable energy specifically biogas plant, wind turbine with diesel generator and hydro with generator. The cost of diesel generator is cheaper than wind turbine and hydropower which caused electric power output from renewable energy of wind turbine and hydropower are less than diesel generator.

4.2 RETScreen Analysis

From the Table 7, the combination of solar PV, diesel generator and storage have short simple payback which is 8.7 years only and annual savings is more than RM 300,000.00 with energy production cost of RM 0.29/kWh only. Then, combined wind, solar PV, diesel generator and storage has the highest annual savings and revenue about RM 2000 more than number 1 energy system, but simple payback is 13.4 years. For serial number 1 and 3 are almost same system except two units additional wind turbine 10kW. The reason serial number 1 and number 3 have the short simple payback and low energy cost are reduced total PV output by combining with other technologies.

Table 7. RETScreen Analysis Results

RETScreen							
Sl. No	Types of energy supply	After tax IRR equity	After tax IRR assets	simple payback year	GHG reduction cost MYR/tCO2	Annual savings and revenue	Energy Production cost MYR/kWh
1	PV + Diesel Gen + Storage	11.2%	6.2%	8.7	21	RM311,951	RM0.29
2	Hydro + Storage	4.3%	1.5%	20.2	224	RM92,054	RM0.48
3	Wind + PV + Diesel Gen + Storage	6.1%	2.8%	13.4	36.19	RM313,125	RM0.33
4	Hydro+PV+Storage	4.6%	1.7%	18.1	116	RM191,443	RM0.40
5	Hydro + Wind + Storage	3.1%	0.5%	23.6	297	RM92,641	RM0.54

5. Conclusions

Comparing all results from HOMER Pro analysis and RETScreen® analysis, hybrid energy system of solar PV, diesel generator and storage system is the best choice to do investment in small scale. For this system, the NPC value and LCOE value is the lowest. Besides renewable energy fraction is more than 50% which is 68%. Then, refer to RETScreen® analysis, energy production cost is the lowest RM 0.29 only and has higher annual savings and revenue. This proposed system has fastest simple payback at 8.7 years only. Other than this system, hybrid energy system consists of hydropower, solar PV, and storage system. Although, the energy production cost is under third rank after number three, but as known wind speed in selected area is not enough to generate electric power. For the situation of any malfunction of solar PV, wind turbine will not be able to supplement the shortage due solar PV failure, thus combination of hydropower and solar PV is better choice.

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