

A review of available hybrid renewable energy systems in Malaysia

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ABSTRACT

The utilization of conventional sources of energy releases harmful pollutants to the environment causing global warming and acid rain. For that reason, it becomes necessary to use a non-depletable, sustainable and eco-friendly renewable energy as a mean of producing electricity. Malaysia is tropical country rich in resources beneficial in electricity generation as it is in equatorial region therefore it has an abundance of solar irradiance of average annually. In addition, Malaysia's demand in electricity is increasing to 124,677 GWh by 2020. Therefore, the electricity generation from renewable sources in Malaysia is anticipated to grow in the future alongside the government endorsement due to its clean, eco-friendly and free source of energy which can highly reduce the dependency on oil and gas that emits harmful pollutants to the environment. This paper gives a comprehensive review on the renewable projects and researches in Malaysia, challenges that affect popularity of renewable energy in Malaysia and available and successful renewable energy system in Malaysia.

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1. INTRODUCTION

The rapid population growth leads to the huge increment in world energy consumption, which gives rise to environmental issues such as pollutions, greenhouse emissions, and climate change. These environmental problems brought by the large energy consumption are becoming more apparent especially in newly industrialized and developing countries such as China and Malaysia where the energy usage is growing rapidly or used less efficiently, and the environmental impact management are not fully incorporated into the country's industrial activities. The solution to this will be the implementation of renewable energy sources that could greatly bring a positive change to the environment.

There are however, worries and question on whether they would affect the economy of a country positively or negatively. Will a shift from the fossil fuel generated power to the Renewable Energy (RE) sector change the way the world is going to function economically? This is because in terms of the environment, it would bring positive outcome that is very much needed to bring a stop to the climate change the world is facing today. It would be impossible and out of scope to cover the whole world due to time and pages limitation. Instead, the scope of this investigation will be based in Malaysia. This research investigates on the previous research, available and successful renewable energy system such as solar energy, wind

energy and biomass in Malaysia. This review can have a significant contribution to the future development of renewable energy system in the country.

2. RENEWABLE ENERGY IN MALAYSIA

2.1. Solar energy

Solar energy is derived from the conversion of solar radiation into electrical energy with the use of photovoltaic panels. Sampaio and Gonzalez illustrated the essential components of photovoltaic, which are the semiconductors created from two energy bands [1]. Solar energy plays the role of the most dominant renewable energy source, as the amount of incident solar radiation on earth in 1 hour is more than the total consumed energy by humans for the entire year. Technologies to utilize solar energy have gain many interests in recent year due to high depletion rate of fossil fuel and increased population all over the world. The International Energy Agency predicts that solar energy system will become one of the main suppliers of household electricity, contributing to at least 17% of the global electricity demand by the year 2050.

Most photovoltaic technology available in the market uses silicon cells, which can be in the form of monocrystalline and polycrystalline. Another technology in the photovoltaic manufacturing industry uses thin film elements comprises of copper, copper indium selenide (CIS), indium and gallium-diselenide (CIGS), amorphous silicon cells (a-Si) and Cadmium telluride (CdTe) [1, 2]. All these types of solar panel are available at Malaysia market. Furthermore, Malaysia is one of the largest solar panel producers in the world [3].

Solar energy as a source of electricity has been implemented in various countries around the world. Solar electricity has powered 4.6% of total generation in Germany, which equals to 32,000 MW capacity. Meanwhile, Mexico received 0.15% of its total electricity from solar resource, which provides 52 MW of the system capacity [4]. The amount of solar irradiation that Malaysia receive per day is significant and it is around 17 MJ per sq. m in average [5, 6]. However, In Malaysia, photovoltaic technology contributes to 9 MW of electric capacity annually by 2011 [7]

Moreover, numerous researches have been done by many researchers around the world on photovoltaic technology. Pan et al. conducted a study on the effectiveness of a portable solar photovoltaic to provide electricity for a vehicle cabin using wireless power transfer method [8]. Khare et al. analysed the functionality of solar renewable in India [9]. Bakhtyar et al. performed a review on the Malaysian policy of feed-in tariff for solar electricity market [7]. Wong et al. examined a study on the grid-connected photovoltaic concept by focusing on voltage issues [10]. Rahman et al. evaluated the effects of operational conditions like ambient temperature, irradiation intensity, humidity and dust on the energy competency of photovoltaic technology in Malaysia [11, 12]. Parida et al. conducted a review on photovoltaic technology, its capacity producing ability, the varying existing performance and reliability assessment models, sizings and grid distribution and connection [12]. Kaa et al. used crisp and fuzzy technique to analyse the data to determine the most dominant design of five photovoltaic technologies that are currently available in the market [13]. Brabec discussed the techno-economical analysis of organic photovoltaics innovation, while Garcia-Valverde et al. and Wender et al. performed the life cycle evaluation of this technology [14, 15]. Fisac et al. studied the photovoltaic development model with thermoelectric by integrating temperature gradient to its structure for power production [15]. Sampaio et al. determined the photovoltaic cells technological development by analysing patents and obtained a set of patent types which have high precedence in technology [16, 17]. Sinke examined the improvement of photovoltaic advancements and their impact to global sustainable energy system [17]. Husain et al. reviewed transparent solar panels technologies and Mitzi et al. evaluated the prospect and efficiency constraint of photovoltaic technologies [18, 19]. Shah et al., Meillaud et al. and Giraldo et al. performed a study on the perspectives, operation principles and physical performance constraint for the case of thin-film photovoltaic cells [20-22]. Jeon et. al. proposed a technique to estimate optimum financial subsidy and research and development investment for photovoltaic advancements by using system dynamics [22]. Zhou and Carbajales-Dale assessed performance and energy return on investment (EROI) for photovoltaic technology landscape [20]. Makrides et al. conducted a research on the effect of temperature on different photovoltaic models [21, 23]. Domitrievska et al. analysed the Raman scattering crystalline evaluation for this technology [24].

2.2. Wind energy

Wind energy is the kinetic energy from air motion due to the irregular heating by the Sun to the environment [9]. Electricity can be generated from the harnessing of wind energy by implementing wind turbines that converts the kinetic energy from the wind into electricity [13, 25]. The average wind speed at Malaysia is around 2 m/s which not suitable for wind turbine to generate electricity. However, still some regions of Malaysia at certain time have higher wind speed around 7 -15 m/s. Furthermore, the important

issue of wind energy at Malaysian is the non-uniformity of the wind blow. It means that wind speed varies during the year [26]. Over the years, Malaysia has seen the development in wind turbine technology. According to Akorede et al., the highest energy output by wind energy in Peninsular Malaysia is in Mersing which contributed to 378 MWh of capacity every year [27]. This is then followed by Chuping, which produces 254 MWh annually. Meanwhile, wind electricity in Melaka is accounted to 29 MW h per annum [27, 28].

Research has been done to investigate techno-economic, development and feasibility of wind turbine technology in Malaysia [29]. An appraisal by Ho studied on the trend of wind technology in Malaysia based on past, present and future scenario, Goh et al. performed wind energy evaluation by utilizing K-means clustering and Mycielski algorithm for a case study in Kudat, Malaysia [29, 30]. Khalid et al. analysed the economic feasibility of wind resource in Malaysia with numerical weather prediction (NWP) method [31]. Albani et al. conducted optimization of wind energy feed-in tariff (FiT) rates in Malaysia by cost-based approach [32]. Hamdan et al. evaluated a review for Vertical Axis Wind Turbine (VAWT) system in the field of micro energy harvester in Structural Health Monitoring (SHM) for the case of Malaysia [33]. Wong et al. performed a review on VAWT efficiency advancements using flow augmentation method [34]. Suffer et al. and Kadhim et al. modelled and performed numerical simulation for four cavity blades and aerodynamic VAWT respectively [27, 28]. Loon et al. and Aravind et al. conducted analysis on the concept of magnetic levitation on VAWT [35]. Wen et al. investigated performance optimization for small Horizontal Axis Wind Turbine (CS-SHAWT) [17, 29]. Wang et al. studied the impacts of irregular wind on a newly developed cross-axis wind turbine performance [36]. Hussain et al., Razliana et al. and Daut et al. proposed wind power as an alternative power source in Perlis [30, 37]. Al-Aqel et al. examined the potential of small wind turbines for highways in Malaysia [32]. Khalid and Nor Musa proposed a newly concept of VAWT farms in a mission to harvest aerodynamic energy losses on highways in Malaysia [32]. Zaharim et al. assessed the effect of wind technology for rural area dwellers in Mersing [33]. Masseran et al. evaluated wind power regional assessment based on several wind speed densities [33]. Islam et al. analysed the wind energy possibility in Kudat and Labuan using Weibull distribution function [29, 31]. Bhayo et al. evaluated wind energy conversion system on static and dynamic features using wind turbine simulator [36]. Rosmin et al. conducted efficiency comparison between three micro-sized blade rotor models based on Malaysian wind speed context [32, 34]. Chong et al. assessed the design of an energy recovery system for wind turbine generator to conserve energy in commercial buildings [34]. Yap et al. designed the optimization of exhaust air energy recovery for wind turbine generator on shroud-augmented dual-rotor case using hybrid non-destructive assessment technique [33-35].

2.3. Biomass

Biomass are the organic wastes of plants and animals, which is a type of renewable energy that can generate electricity through biofuels [36]. Biofuels are the type of biomass in the form of gas and liquid, that can be obtained by applying different sorts of technology [36, 37]. Malaysia has high capability of biomass resources. The important exist resources at Malaysia are agriculture waste such as rice husk and sugarcane bagasse, forest residue and wood waste, animal manure, municipal solid waste, dedicated biomass crops and palm oil biomass. Malaysia is one of the largest palm oil exporters in the world. Therefore, huge amount of the palm oil waste is available at Malaysia. As an example, around 80 million tons of pam oil waste was produced in 2011. The two of main sources of biomass in Malaysia are palm oil waste and sugar cane waste [38].

Several researchers emphasised that biomass energy is preferred as the solution for an eco-friendly resource of electricity generation due to its ability to absorb the amount of carbon dioxide it releases in the production, which is sustainable [36-39]. In addition, biomass is known for its abundancy, local availability and capability to generate low-cost electricity with elevated performance.

According to Jayakumar et al., biomass accounted for a percentage of 4% of Malaysian total energy consumption alongside with coal, natural gas, hydroelectricity and petroleum by 2012 [40]. Seng et al. described the percentage of biomass wastes utilized for electricity in Malaysia is only 5%. Sabah utilized biomass from palm oil waste to generate electricity with annual capacity of 3,300 GWh [41]. However, the remaining 95% of total biomass waste in the country remained as wastes and not utilized due to the difficulties in transportation cost to transfer the wastes from plantation to power stations.

Research has been done to analyse the biomass electricity and technology in Malaysia. Evaluation on the transportation decision tool regarding biomass supply chain is conducted involving biomass allocation planning, processing station selection and vehicle capacity constraint. Tan et al. designed the spatial and economic aspect for oil palm biomass as energy production in the objective to minimize issues regarding transboundary haze [42, 43]. Mohd Shaharin et al. suggested on ways to strengthen palm oil biomass industry for the case of Malaysia [43, 44]. Nor Aishah and Amin uses INCAM model to perform assessment on

carbon dioxide emission reduction in the context of biomass power plants in Malaysia for the year of 2016 [40]. Ng et al., Mohd Shaharin et al., Abnisa et al. and Ooi et al. studied the potentiality of palm biomass in Malaysia [43-45]. Mohd Shaharin et al. and Darshini et al. conducted an industry survey on sustainable electricity production from oil palm biofuel and biomass [46-48]. Mekhilef et al. and Shafie et al. assessed the current prospects of biomass energy [49].

3. SIZING AND OPTIMIZING OF RENEWABLE ENERGY IN MALAYSIA

Malaysia is a tropical country rich in resources beneficial in electricity generation as it is located in equatorial region, situated in the range of 1° and 7° North and 100° and 120° East, therefore having an abundance of solar irradiance of average 1700 W/m² annually [3, 32, 33]. Meanwhile, its annual average wind velocity of around 1.2 to 4.1 m/s, where the highest wind velocity is recorded in the east of Peninsular Malaysia [18]. Malaysian government has taken many initiatives to exploit the substantial available energy sources including announcing to include renewable energy as a fuel for electricity generation complementing gas, oil, coal and hydro in its eighth Malaysia Plan [3]. According to 'World development indicators: Electricity production, sources and access' (2017), the statistics show the generation of electricity in Malaysia from renewable resources accounted to 0.6 percent of the total generation by 2015. Therefore, the electricity generation from renewable sources in Malaysia is anticipated to grow in the future alongside the government endorsement due to its clean, eco-friendly and free source of energy which can highly reduce the dependency on oil and gas that emits harmful pollutants to the environment.

Henceforth, the optimizing and sizing of hybrid renewable energy by the researchers becomes essential to mitigate the intermittent nature of renewable energy. Many researchers have taken their part in doing the study on the optimization for hybrid renewable energy system in Malaysia. Halabi and Mekhilef in their study optimized the hybrid configurations for a village in Sabah, Malaysia involving diesel generators and PV array for both on-grid and off-grid modes of operation and obtained the most optimal solution consisting of PV arrays of 300 kWp, two diesel generators of 50 kW and 100 kW, a 150 kW converter and 330 kWh battery banks [34, 35]. Izadyar et al. utilized Homer to find the potential regions for the implementation of hybrid renewable energy system in Malaysia [36]. The results concluded Langkawi and Tioman islands have the most potential for solar and wind hybrid, while Teluk Burau and Durian which located in Langkawi has an attractive opportunity for solar/wind/micro hydropower hybrid. In addition, solar and micro hydropower combination is the most optimal to be implemented in Lawas and Ranau, located in Sarawak and Sabah respectively. Ngan and Tan simulated hybrid optimization in Homer for Johor Bahru with the optimal configuration consisting PV, wind, diesel and battery system as an alternative from the existing stand-alone diesel system [37].

Ismail et al. investigated the techno-economic feasibility evaluation on hybrid system in a typical village in Malaysia. The results indicated the most optimal configuration for the location comprising of a system having PV modules, a diesel generator and a battery bank [38]. Lau et al. performed the feasibility study on stand-alone photovoltaic/diesel generator hybrid system by varying the load sizes, annual real interest rate and diesel price for Malaysian islands [39]. Due to the complexity in fuel transportation for isolated islands in Malaysia, the diesel price can fluctuate and hence, became a concern for the practicality of existing standalone diesel generator system that is currently utilized as the main source of electricity in those islands. The study indicated that the use of photovoltaic/diesel generator/battery hybrid system is feasible at high diesel prices. For the case of Pemanggil Island, Malaysia, Anwari et al. assessed the practicality of hybrid wind and diesel energy with battery systems prospective and acquired that this hybrid scenario is more feasible and economically wise than the existing standalone diesel generator system [40]. The study was particularly based on the variation of diesel costs and wind irradiances. Ashourian et al. appraised the optimal green technology hybrid system in Juara village, situated in Tioman Island, Malaysia by considering the load profile and its geographical condition. The result indicated the most feasible hybrid configuration when the cost of diesel reaches to \$2.10/L consists of photovoltaic panels and wind turbines having capacities of 200 kW and 40 kW respectively combined with a battery storage [41]. Another study on the hybrid system for Tioman Island conducted by Basir Khan et al. resulting in the most optimal PV-hydro-diesel configuration in standalone mode that was simulated in Homer software. This configuration gives the lowest NPC of \$ 31, 901, 944 [42]. Ho et al. evaluated the scenario of biomass and solar town for a smart eco-village, Iskandar Malaysia (IM) and proposed that the most optimal configuration to meet the load demand comprises of 412 kW biogas thermal power station, a direct-fired biomass of capacity 417 kW, 136 kW photovoltaic modules and 3046 kWh sodium sulfur battery [43].

Hossain et al. evaluated the optimization for tourist attractions in South China Sea, Malaysia using Homer software and obtained the optimized system resulted consisting of wind, diesel generator, photovoltaic, converter and battery with NPC of \$ 17.15 million and COE of \$ 0.279/kWh [44]. Fadaeenejad

et al. performed a research on the sizing for hybrid system for a village in Malaysia and suggested the most cost-effective configuration is photovoltaic/wind/battery hybrid system [45, 46]. Shezan et al. appraised the techno-economic analysis of hybrid concept to power two residential hotels in Cameron Highlands. The result suggested a hybrid system involving a 4 kW diesel generator, 15 units of 10 kW wind turbines and 2 units of battery backup as the most economically and technically feasible to supply the demand [47, 48].

4. REVIEW OF SOME SUCCESSFUL HYBRID RENEWABLE ENERGY SYSTEMS IN MALAYSIA

Although the hybrid renewable energy system is not considered new in the research field in Malaysia, there is only quite a number that is implemented in this country as the renewable system applied currently are mostly comprises of standalone system utilizing only a single source of renewable energy, such as standalone photovoltaic system, which is quite popular in the rural parts of the country [50-52]. A few of the application of Hybrid Renewable Energy System (HRES) in Malaysia is reviewed below.

4.1. Hybrid photovoltaic/diesel standalone system

The hybrid system is in Pulau Banggi and Tanjung Labian, Sabah. For Pulau Banggi, the photovoltaic provide 69.21% of the total electricity generation, large generators of capacity 400 kW produce 37% and small generators contributed to a proportion of 3.54%. The renewable fraction of the whole system is 50.4%, with excess energy at 9.3%. Other than that, the hybrid system in Tanjung Labian has 86.90% of its total energy production from photovoltaic, while large generators of capacity 500 kW produced 9.42% and small generators generated 3.68% of electricity. The renewable fraction of the system is indicated by 80.7%, while the excess energy is at 17.4% [50, 51]. In addition, solar hybrid power system which incorporated both solar photovoltaic and diesel generators as the source back up has light up homes in Bario Highlands, Rumah Dau and Long Urun in Sarawak. The hybrid system in Bario Highlands provides 887 kW capacity of energy, powering up 233 households, shops and offices [52-54]. Besides, Rumah Dau hybrid system provides electricity for 26 households and a school with the energy capacity of 129.6 kW [55- 57]. Furthermore, 689 kW solar/diesel generator hybrid system in Long Urun has light up 245 households in 12 villages, namely Long Data Sengelang, Long Ketuet, Long Balau, Long Sivau, Long Apok, Long Liten, Uma Pawa, Rumah Pera, Long Tengah 1, Long Tengah 2, Uma Badeng and Long Dulit [58].

4.2. Hybrid photovoltaic/wind/diesel standalone system

The hybrid photovoltaic/wind/diesel standalone system is applied to a fishermen village, located at Perhentian Island, Malaysia. The purpose of the hybrid system is to provide a continuous supply of electricity and reduce the dependency on diesel generators that was previously the main source of electricity in the village. The components of the hybrid system include 100 kW PV module, 2 units of wind turbines at capacity 100 kW, 1 unit of 100 kW diesel generator set, 240 Volt DC 480 kWh battery storage, set control system for multiple generator and hybrid control system. It is notable that the total energy production from renewable sources recorded to be 75 kW as photovoltaic provides 39 kW of electricity and both wind turbine produces 18 kW individually [56].

4.3. Hybrid photovoltaic/wind standalone system

The photovoltaic/wind HRES is implemented at Samunsan Forest and Wildlife Sanctuary, which is 60 km north of Kuching, Sarawak. The purpose of the hybrid system is to provide an eco-friendly and reliable electricity for the community living in the area, scientists and tourists. The system component incorporated 900 W PV module, 2.5 kW wind turbines launched on a 26 m tower, 30 kW diesel generator, 2 units of 2 kWh lead acid batteries, 5 kW inverter and remote monitoring set. The generation of electricity by wind turbines are the most throughout the year. When the wind velocity is low especially in the summer, PV provides its maximum output complemented by diesel generators to supply the increasing demand from research, community and tourism activities [21, 59].

Table 1 shows the renewable energy target at Malaysia from 2015 to 2050. Based on this table Malaysia will improve and increase their capability to generate electricity by solar energy in future [49, 57]. Based on the review, some of the reasons and challenges that affect popularity of renewable energy in Malaysia are listed in Table 2.

Table 1. Renewable energy generation target in Malaysia 2015-2050 (MW) [53]

Year	Biomass	Biogas	Mini-Hydro	Solar PV	Solid Waste	Total
2015	330	100	290	65	200	985
2020	800	240	490	190	360	2,080
2025	1,190	350	490	455	380	2,865
2030	1,340	410	490	1,370	390	4,000
2050	1,340	410	490	18,700	430	21,370

Table 2. Challenges that affect popularity of renewable energy in Malaysia

Type of energy	Challenges that affect popularity of renewable energy in Malaysia				
Solar energy	Cost	Average of 2 months cloudy or raining day per year	High ambient temperature (inefficiency of solar panels)	land required for harvesting solar energy	Battery short lifespan due to overused without recharging
Wind energy	Low average wind speed	Noise pollution	Disturbance and destruction of ecosystems	Affect fauna, especially birds	Waste of space (land) for turbine installation
Biomass	Difficult to transport	Complexity in harvesting, collecting and processing	Low efficiency of equipment to produce energy	Low number of market players for biomass energy business	Requires financial assistance and technological support
Hybrid	Cost	Complexity in finding the best combination of hybrid system	Highly dependent on meteorological condition	Highly dependent on availability of energy sources	Lack of trained personnel

5. CONCLUSION

This paper conducted a review on the available renewable energy system in Malaysia. Based on the review various research has been conducted by researchers to analyse the performance of renewable energy system such as solar, wind, biomass and hybrid renewable energy in Malaysia. Malaysia government had aimed to generate 5.5% of total electricity from renewable energy by 2015. However, the new target for Malaysia is 20% by 2030. Based on the review some of the renewable energy such as wind energy might be not feasible for Malaysia. But, still it can be the suitable alternative for certain region where we have high wind speed at some period time of the year such as Perhentian Island. According to the review, just 5% of the biomass wastes utilized for electricity in Malaysia. It means that the huge amount of the capability of biomass energy is wasting and Malaysia can concentrate to generate electricity from existing biomass. Based on the review, Hybrid renewable energy system is not yet popular in Malaysia due to cost and low wind speed. Therefore, there is only quite a number that is implemented in this country as the renewable system applied currently are mostly comprises of standalone system utilizing a single source of renewable energy such as standalone photovoltaic system, which is quite popular in the rural parts of the country.

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