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Comprehensive Review on Renewable Energy Initiatives at Universiti Malaysia Pahang Al-Sultan Abdullah

Muhammad Ikram Mohd Rashid[1], Mohd Izwan Ismail[2], Agus Nugroho[3]

[1]Faculty of Electrical & Electronic Engineering Technology, Universiti Malaysia Pahang Al-Sultan Abdullah
[2]Centre for Property Development & Management, Universiti Malaysia Pahang Al-Sultan Abdullah
[3]Surface and Coatings Technology Research Group, National Research and Innovation Agency (BRIN), Jakarta, 10340, Indonesia

Corresponding author: mikram@umpsa.edu.my

Abstract
The transition to renewable energy is crucial in achieving sustainability and carbon neutrality. This study reviews the renewable energy initiatives implemented at Universiti Malaysia Pahang Al-Sultan Abdullah (UMPSA), including solar, wind, hydro, and biodiesel energy systems. The findings reveal that UMPSA has installed a total solar energy capacity of 3.58 MWp, supplying up to 75% of the campus's electricity needs. Solar energy installations generated 269,318 kWh between 2022 and 2023, significantly reducing reliance on fossil fuels. Wind energy has also been integrated, with wind turbines generating up to 22 kW since 2012, supporting campus operations and research activities. Additionally, small-scale hydro systems, including the Sea-Lite seawater electrolysis and pico hydro projects, contributed 1,116.9 kWh of electricity annually. Furthermore, the biodiesel initiative has produced 2,640 litres annually, generating 10,150 kWh of energy while promoting waste-to-energy conversion. These efforts align with Malaysia's 2050 carbon neutrality goal and demonstrate the potential of academic institutions in leading the renewable energy transition. The study concludes that UMPSA's integrated renewable energy systems provide significant environmental, economic, and educational benefits. Future recommendations include expanding renewable energy projects, enhancing efficiency, and fostering collaborations with industry and government to strengthen Malaysia's green energy agenda. The results of this study highlight the role of universities in promoting sustainable energy solutions and provide a model for similar institutions to adopt renewable energy strategies.

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1. Introduction
In facing the challenges of climate change and increasing global energy needs, renewable energy is one of the leading solutions to achieve environmental sustainability [1–4]. Renewable energy reduces carbon emissions and offers excellent energy efficiency and independence opportunities for various institutions, including universities [5–9]. Universiti Malaysia Pahang Al-Sultan Abdullah (UMPSA) has demonstrated its commitment to supporting the green energy transition through various renewable energy-based initiatives, such as solar, wind, hydro, and biodiesel. Implementing these projects is in line with Malaysia's carbon-neutral target by 2050 and supports the achievement of the Sustainable Development Goals (SDGs) related to clean and affordable energy [10–12].

Universities have a strategic role in the research and implementation of renewable energy technologies due to their capacity to develop innovation, raise environmental awareness, and be an example in adopting green energy [13–16]. Previous studies have shown that solar and wind energy use on higher education campuses has contributed significantly to reducing fossil-based energy consumption [17–19]. At UMPSA, various solar power installations have been implemented since 2016, including solar power systems for research and operations and solar-based campus lighting [20]. These efforts have generated more than 269,318 kWh of electricity during 2022-2023, contributing to the energy efficiency of the campus.

In addition to solar energy, UMPSA has also adopted wind energy as part of its energy source diversification efforts [21]. The geographical advantage of the campus located near the coast allows the use of wind for electricity generation [22–24]. Previous studies have shown that coastal areas have great potential for wind-based electricity generation, especially in supporting electricity supply in regions not yet covered by the primary grid [25]. Implementing small- to medium-scale wind turbines at UMPSA has generated additional energy that can be used for operational purposes and student research, showing great potential for further application.

In addition to solar and wind power, UMPSA has also implemented small-scale hydropower systems to increase the utilization of renewable energy [26]. This program includes a seawater electrode project (Sea-Lite) and a pico hydro system implemented in several campus facilities. Previous studies have indicated that electricity generation through microhydro energy can be a sustainable solution in academic environments with limited water resources [27]. At UMPSA, this implementation serves as an additional source of electricity and an educational facility for students to understand hydro-based green energy technologies [28].

Using biodiesel as an alternative energy source is also essential to UMPSA's sustainable energy strategy. Using used cooking oil from campus activities, the biodiesel program has produced around 2,640 liters of biodiesel per year, equivalent to 10,150 kWh of energy production. Previous studies have shown that converting used cooking oil to biodiesel reduces cooking oil waste and provides long-term economic benefits [29]. This implementation proves that a circular economy approach to energy management can be effectively applied in higher education environments [30].

Based on the results and discussions of various studies and the implementation of renewable energy at UMPSA, it can be concluded that universities have an essential role in developing and implementing green energy solutions. Using solar, wind, hydro, and biodiesel energy, UMPSA has demonstrated how academic institutions can pioneer the sustainable energy transition [31]. In the future, expanding renewable energy projects and increasing technological efficiency will be key to achieving clean energy targets and supporting the sustainability agenda at the national and global levels.

2. Methodology

This study uses a case study approach with quantitative and qualitative analysis of the implementation of renewable energy at Universiti Malaysia Pahang Al-Sultan Abdullah (UMPSA). The research methods include collecting primary and secondary data from various sources, including university annual reports, operational data on renewable energy systems, and related literature studies.

Data Collection

a. Primary data were obtained through direct observation of renewable energy systems implemented at UMPSA, including solar PV, wind turbines, micro hydro systems, and biodiesel production.
b. Semi-structured interviews were conducted with related parties, such as technical staff, researchers, and campus energy managers, to understand the challenges and effectiveness of implementing this energy system.
c. Secondary data were collected from university reports, scientific journals, and online sources relevant to implementing renewable energy in the academic environment.

Data Analysis

a. Quantitative analysis was conducted to evaluate the performance of renewable energy systems based on parameters such as power capacity, annual electricity production, and energy conversion

efficiency. Electricity production data were processed using descriptive statistical analysis techniques to identify patterns and trends in renewable energy utilization at UMPSA.

b. Qualitative analysis is used to understand the impact of renewable energy implementation on the academic environment, including benefits in education, research, and carbon footprint reduction. A literature review is used to compare the findings of this study.

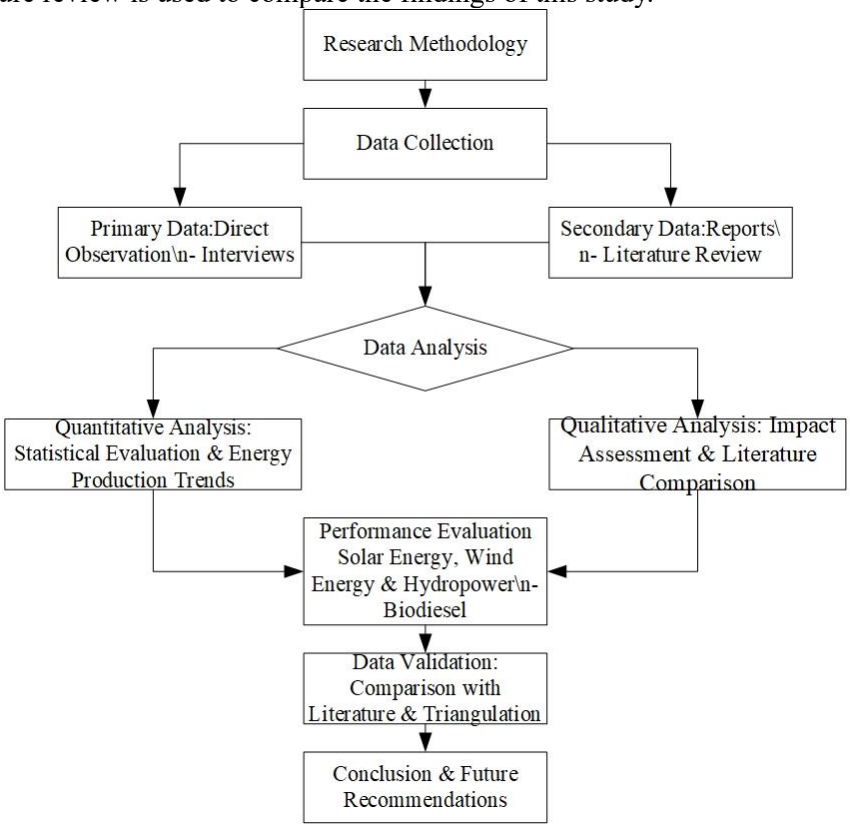

Figure 1: Flowchart of Research Methodology for Renewable Energy Implementation at UMPSA

Renewable Energy System Performance Evaluation.

a. For solar power systems, the analysis is based on the installation capacity (kWp), annual energy production (kWh), and contribution to campus electricity consumption.
b. Wind turbine evaluation is carried out by considering the average wind speed at the installation location and the efficiency of the power produced.
c. The performance of the micro hydro system is analyzed based on water discharge and electrical energy conversion.
d. Biodiesel efficiency is reviewed based on the raw materials and energy produced.

Data Validation

To ensure the data's validity, the energy production calculation results are compared with historical data and literature related to the implementation of renewable energy in other educational institutions. In addition, method triangulation is carried out by comparing the results of interviews, field observations, and quantitative data analysis.

3. Result & Discussion

The increasing global energy demand and environmental concerns have driven universities to adopt renewable energy solutions as part of their sustainability strategies. Universities are vital in promoting green energy adoption by integrating renewable technologies into campus operations, research, and education. The transition to renewable energy on university campuses contributes to reducing carbon footprint, saving energy, and creating a sustainable learning environment. Renewable energy adoption is essential for reducing carbon emissions and mitigating the adverse effects of climate change. UMPSA has been at the forefront of this movement since 2016, implementing a wide range of renewable energy

sources across its campuses in Pekan and Gambang. This paper reviews UMPSA's efforts, emphasizing its contribution to Malaysia's goal of achieving carbon neutrality by 2050.

Table 1: Energy Capacity and Production from Renewable Sources in Various Locations in 2022-2023

No.	Building/ Area	Type of Renewable Energy	Year Installed	Capacity, kW	kWh produce year 2022-2023
1	FKKSA	Biodiesel	2007	30 Litre Biodiesel per 50 Litre cooking oil	10,150
2	Sea-Lite (Sea Water Electrolysis)	Hydro Power	2022	0.02kW	262.8
3	Pico Hydro	Hydro Power	2022	0.39kW	854.1
4	UMP PEKAN & GAMBANG	Solar Lighting	2017 - 2022	4kW	17520
5	UMP GAMBANG	Solar Lighting	2023	100W, 12.8V, 60Ah	3363.84
6	FTKMA & FTKEE	Solar system	2016	21kW	184396
7	Solar KP House	Solar system	2018	5kW	5400
8	Walkaway (Canseleri to Kafe)	Solar System	2019	2.4kW- off grid	4964
9	Wakf Hut	Solar System	2021	2kW	4928
10	FTKEE	Solar System	2022	1.5kW	2094.2
11	FTKEE	Solar System	2019	2.5 kWp	6205
12	FTKMA	Solar System	2016	1.5 kWp	2094.2
13	Wakf Hut	Solar System	2023	1.05 kWp	686.78
14	Electric Fencing	Solar System	2023	0.5 kWp	294.34
15	Pusat Kompos	Solar System	2019	3.0 kWp	7446
16	FTKKP	Solar System	2018	10.0 kWp	10150
17	Entrance Guard House	Wind power	2012	22kW	-
18	FTKMA & FTKEE	Wind Power	2021	250W	9490
19	FTKMA & FTKEE	Wind Power	2021	250W	
20	FTKMA & FTKEE	Wind Power	2021	800W	
		TOTAL			**269,318.14**

a. Solar Energy Initiatives

UMPSA has implemented numerous solar power projects, including large-scale installations and research-focused systems. A significant milestone is the ongoing 3.58MWp solar system at UMPSA Pekan, which is expected to supply 75% of the campus's electricity demand. Additional solar installations include:

a) FTKMA & FTKEE Solar System (2016): A 21kW installation for research and administrative use.
b) UMPSA Green Office (Maran, Pahang): Fully powered by a 5kWh solar system.
c) Walkway Solar System (2019): Installed along campus walkways to power lighting and research data collection.
d) Waqf Huts (2021-2023): 20 solar-powered huts providing lighting and device charging electricity, including USB and wireless charging options.

These initiatives collectively produced over 269,318 kWh of electricity between 2022 and 2023, significantly reducing the university's dependence on conventional energy sources.

Figure 2: UMPSA Pekan Solar Energy System – 3.58 MWp Implementation
https://mygreen.umpsa.edu.my/index.php/carbon-energy

Universiti Malaysia Pahang Al-Sultan Abdullah (UMPSA) has widely adopted solar energy systems to support the transition to renewable energy. **Figure 2** shows various solar panel installations that have been implemented in several strategic locations on the UMPSA Pekan campus, including the Faculty of Mechanical and Automotive Engineering Technology (FTKMA), the Center for Technology and Innovation (CTAR), the Faculty of Electrical and Electronic Engineering Technology (FTKEE), and in the lake and parking areas. These installations include rooftop photovoltaic systems and floating solar power systems on the water surface designed to increase solar energy utilisation efficiency. With a total capacity of 3.58 MWp, this system can supply up to 75% of the campus's electricity needs, reduce dependence on fossil-based energy, and reduce the institution's carbon footprint.
Implementing this solar power system provides various benefits from an environmental and economic perspective. The use of solar panels reduces greenhouse gas emissions and contributes to savings in electricity operating costs in the long term. In addition, this system also functions as a research and learning facility for students in the field of renewable energy. The existence of a floating solar power system in Lake A, UMPSA Pekan, demonstrates innovation in utilising unconventional space for green energy production. This initiative aligns with Malaysia's commitment to achieving carbon neutrality by 2050 and supports the Sustainable Development Goals (SDGs) target of clean and affordable energy.

Figure 3: Floating solar PV at UMPSA Campus Pekan

Figure 3 shows a floating solar PV system installed on one of the lakes at Universiti Malaysia Pahang Al-Sultan Abdullah (UMPSA) Pekan. This technology utilizes the water surface as a solar panel installation area, which saves land and increases the efficiency of solar energy conversion due to the natural cooling effect of water. Floating Solar PV is part of the campus initiative to reduce carbon footprint and support the transition to green energy. Previous studies have shown that floating solar PV systems have the advantage of reducing water evaporation and can increase energy production by up to 10% compared to installations on land due to the cooling effect that reduces the panels' temperature.
Implementing floating solar PV at UMPSA Pekan is essential to achieving the university's sustainable energy targets. In addition to being an environmentally friendly energy source, this system also functions as a research facility for students and academics in renewable energy technology. The strategic installation location, with a backdrop of mosques and towers, also reflects the synergy between technological innovation and sustainable environmental aspects. With its installed capacity, the system can reduce fossil-based electricity consumption, help reduce greenhouse gas emissions and contribute to Malaysia's agenda to achieve carbon neutrality by 2050.

b. Wind Energy Development

Wind energy has been another area of focus at UMPSA. Due to its coastal location, UMPSA Pekan has been suitable for wind turbine installations. Key projects include the Entrance Guard House Wind Turbine (2012), a 22kW turbine developed under the Malaysian Ministry of Science, Technology, and Innovation (MOSTI) and SIRIM Berhad. **Figure 4** shows several wind turbines installed on the Universiti Malaysia Pahang Al-Sultan Abdullah (UMPSA) Pekan campus. Implementing these wind turbines is part of the university's renewable energy strategy to support energy sustainability and reduce dependence on fossil fuels. UMPSA takes advantage of its strategic geographical conditions, where the location of the Pekan campus has sufficient wind potential to generate electricity efficiently. The installation includes various types of wind turbines, including vertical and horizontal models used for research and additional energy supply for campus facilities. Previous studies have shown that using small-scale wind turbines can increase the diversification of energy sources and significantly contribute to the hybrid energy system in the academic environment.
The use of wind turbines at UMPSA not only acts as a source of green energy but also as a learning facility for students in renewable energy technology. With these turbines, students can research energy

conversion efficiency, optimal wind speed, and the environmental impact of wind energy use. In addition, this implementation also supports the national agenda of achieving carbon emission reduction targets and accelerating the transition to a low-carbon economy. The existence of this wind turbine shows UMPSA's commitment to developing clean energy technology that can be replicated in various sectors, both at the academic and industrial levels.

Figure 4: Wind turbine in UMPSA campus Pekan.

FTKMA & FTKEE Wind Power (2021): Multiple small-scale turbines ranging from 250W to 800W for research and backup electricity supply. These wind energy projects contribute to sustainable electricity generation and enhance renewable energy research at UMPSA. UMPSA has also explored small-scale hydropower solutions to provide sustainable energy sources. The Sea-Lite seawater electrolysis project at the Entrance Guard House is a notable innovation, utilizing seawater to generate electricity. Additionally, picohydro systems have been implemented in campus toilet facilities for lighting and phone charging. The Faculty of Chemical & Natural Resources has developed a biodiesel production system utilizing waste cooking oil. This initiative has produced 2,640 litres of biodiesel annually, generating approximately 10,150 kWh of electricity. This waste-to-energy approach contributes to sustainable fuel production and serves as a model for resource efficiency.

4. Conclusion

This study confirms that Universiti Malaysia Pahang Al-Sultan Abdullah (UMPSA) has played a significant role in developing and implementing renewable energy, which aligns with Malaysia's carbon-neutral target by 2050. Using various renewable energy sources, UMPSA has successfully reduced dependence on fossil-based energy and increased campus energy efficiency. Based on the study's results, the implementation of the solar power system at UMPSA reached a total capacity of 3.58 MWp, which can supply up to 75% of the campus's electricity needs. In addition, various solar power systems implemented since 2016 can produce a total energy production of 269,318 kWh during 2022-2023. This system reduces carbon emissions and contributes to savings in the university's electricity operating costs. In addition to solar power, wind energy is an essential component of UMPSA's sustainable energy strategy. With wind turbine installations ranging from small to medium scale, the system has generated

an additional 22 kW of power since 2012. The utilization of this wind resource shows excellent potential for energy diversification and supports the research agenda in green energy technologies. Meanwhile, in the hydropower sector, the Sea-Lite project utilizing seawater electrolysis and pico hydro systems has contributed to the production of additional energy of 1,116.9 kWh per year, providing a sustainable source of electricity for campus facilities.

Another significant contribution is the utilization of biodiesel produced from campus cooking oil waste. With an annual production of 2,640 litres of biodiesel, the system has generated 10,150 kWh of energy, which helps reduce waste and becomes a circular economy model that can be applied in other sectors. The success of this project shows that universities can be pioneers in green energy innovation by adopting a sustainability-based approach. With the results obtained, this study concludes that integrating various renewable energy sources at UMPSA has provided significant environmental, economic, and academic benefits. Further development of renewable energy generation capacity, increasing system efficiency, and collaboration with industry and government sectors will be strategic steps in supporting the green energy transition. Implementing similar models in other educational institutions can accelerate the achievement of clean energy targets and support the sustainability agenda at the national and global levels.

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