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Determination of Cost Savings and Energy Efficiency in Solar-Powered Water Pump Systems for Aquaponic Operation

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Abstract

Solar-powered water pump systems (SPWPS) allow sustainable practice for aquaponic operations that combine aquaculture and hydroponics, relying heavily on efficient water circulation, which is typically powered by conventional energy sources. This study focuses on installing solar panels to power the water pumps and evaluates cost savings compared to conventional energy sources, while assessing energy efficiency in maintaining water circulation. A Nutrient Film Technique (NFT) aquaponics system was designed and fabricated, using a 12V 9W polycrystalline solar panel with a DC submersible water pump capable of a maximum flow rate of 240 liters per hour. Performance testing was methodologically conducted under different weather conditions, along with a comparative analysis of operational costs between solar-powered and conventional-powered systems. The study identified that the solar energy system not only reduced operational costs but also improved energy efficiency compared to a conventional-powered system. The initial investment cost in solar technology is higher, but it is balanced by the cost savings on electricity bills and the environmental impact, as the use of renewable energy also contributes to a reduction of greenhouse gas emissions. The use of a solar-powered system displayed high energy efficiency in efficiently converting the solar energy to electrical power to maintain the water circulation needed in aquaponic operations. The availability of sunlight and the efficiency of the component were found to be key factors that affect system reliability. This approach is giving benefits for small-scale farmers and communities, particularly in rural areas where accessibility to electricity may be limited.

1. Introduction

The growing global demand for sustainable agricultural practices has driven interest in innovative solutions like aquaponics, which utilizes significantly less water and energy compared to traditional farming methods. Aquaponics is a synergistic system that combines aquaculture (raising aquatic animals) and hydroponics (cultivating plants in water) in a closed-loop environment [1]. One of the critical components are water pump, which ensures the continuous circulation of water from the sump tank between the fish tank for aquaculture cultivation and the plant bed for plant cultivation. This method is always used by farmers and can further facilitate their work, typically reliant on conventional power sources. However, some places cannot supply sufficient electricity to run these aquaponic systems and land limitations for cultivation. Thus, the integration of solar power into aquaponic systems is proposed in this study, and this is particularly appealing in more disadvantaged regions for persons with limited resources. By using this method, solar-powered water pumps harness renewable energy from the sun, offering a cost-effective and eco-friendly solution for maintaining the necessary water flow in aquaponic operations [2].

This study aims to replace that dependency with solar energy through SPWPS. The use of solar energy not only reduces operational costs but also enhances the energy efficiency of the system, contributing to the overall sustainability of the aquaponic operation [3]. Hence, the generation of solar energy is said to be eco-friendly and has no pollution to the environment, also promotes sustainability [4]. Malaysia's high sunlight availability supports the viability of solar-powered alternatives. This paper evaluates the cost savings and the energy efficiency of SPWPS for small-scale operations compared to conventional energy sources.

2. Methodology

In this study, the development of a solar-powered water pump for aquaponic operation was carried out at home. Data were collected for 31 days under different weather conditions. Parameters such as flow rate, pump runtime, power consumption, efficiency and cost analysis were recorded and compared against the firsthand information on the operational and maintenance costs, as well as the performance and challenges of using conventional water pump systems.

2.1. Experimental Setup

A Nutrient Film Technique (NFT) system is selected as the design for this experiment due to its efficient water usage and simplicity, making it ideal for small-scale aquaponic operations. NFT aquaponics setup was designed using a 12V 9W solar panel powering a DC Submersible Pump. The experiment used the NFT system with poly fish tank and PVC grow beds. The diagrammatic representation of a solar-powered water pump that can be used in this experiment is shown in Figure 1.

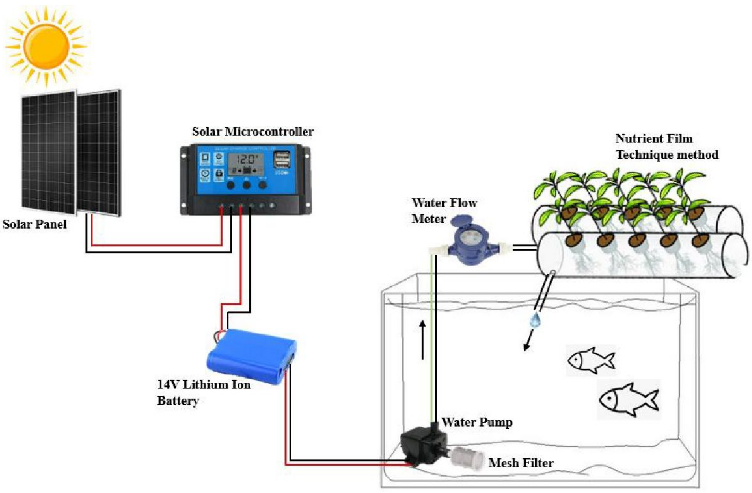

Fig. 1 *Schematic diagram of solar-powered water pump*

For the seeding, small seeds were initially placed in a net pot filled with cotton as the growing medium. Net pots are neatly arranged for seeds to germinate and grow. After 4 to 7 days, once the small seedlings begin to appear, the net pots used to support the seedlings during the early stages will be placed inside the NFT plant bed so that the plant roots will be allowed to grow into the nutrient solution flowing through the system. Figure 2: (a) Germination Stage 1: Imbibition of Pak Choi Seeds (b) Germination Stage 2: Emergence of Radicle in Pak Choi (c) Germination Stage 3: Seedling Emergence of Pak Choi that shows the germination stage.

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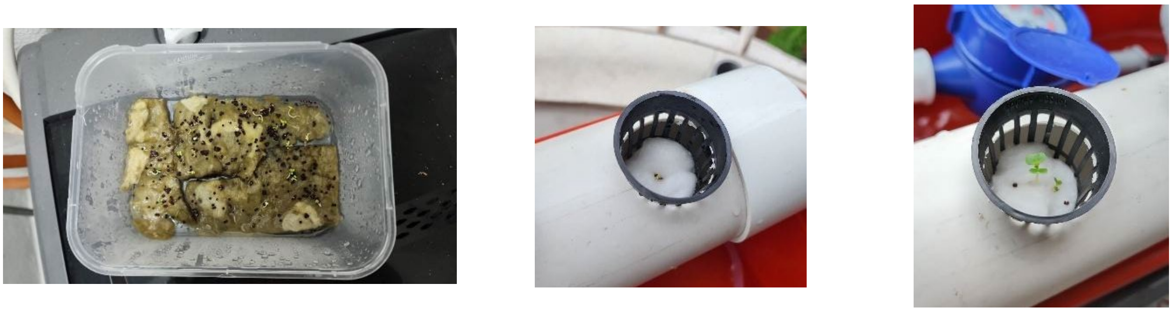

(a) **(b)** **(c)**

Fig. 2 *Germination Stage* ***(a)*** *Germination Stage 1: Imbibition of Pak Choi Seeds* ***(b)*** *Germination Stage 2: Emergence of Radicle in Pak Choi* ***(c)*** *Germination Stage 3: Seedling Emergence of Pak Choi*

2.2. Data Collection

Throughout the study, the aquaponics operation will be conducted for 1 month (4 weeks). There are 3 groups of data that will be collected, where we will focus on the performance of solar water pumps, cost analysis, and energy efficiency assessment.

2.3. Evaluation of the water flow rate

A mechanical cold-water meter (DN15), typically being used for household water supply lines, is installed near the outlet of the water pipe. Flow rate measurements will be collected multiple times daily to account for changes in pump operation due to sunlight intensity.

This water flow meter has an arbitrary rotation function, which is convenient for meter reading. The flow meter provided readings in cubic meters per hour (m^3/h), which will be converted to liters per hour (L/hr) for analysis. Figure 3 shows the DN15 Cold Water Meter.

Fig. 3 *DN15 Cold Water Meter*

2.4. Evaluation of the Pump Operational Hours

The pump's operational hours were recorded daily using a stopwatch and compared across different weather conditions.

2.5. Evaluation of the Power Consumption

To control battery charging and secure all components of the solar-powered water pump system, Figure 4 shows that a solar microcontroller or solar charge controller has been integrated into the system. The controller employs a 3-stage Pulse Width Modulation (PWM) charging process to optimize battery charging efficiency and extend battery life. In addition to prevent overcharging, over-discharging, and reverse polarity connections, it also manages load connection and disconnection based on battery voltage, providing protection for both the battery and the water pump.

Fig. 4 *Solar Charge Controller*

2.6. Cost Analysis

The cost analysis for the solar-powered system is measured using Capital Expenditure (CAPEX) where the initial cost of purchasing and installing the SPWPS includes the items, quantity, price per unit, and total cost. Additionally, Operational Expenditure (OPEX) where the ongoing costs of operating and maintaining the SPWPS including activity/items, frequency, cost per occurrence, and the total cost will be collected. Lastly, the monthly cost savings will be achieved through the use of solar energy and will be calculated to estimate the payback period, expressed as:

$$Payback\ Period\ (months) = \frac{Initial\ Investment}{Monthly\ Cost\ Savings} \quad (1)$$

Secondary data for the conventional water pump system will be collected through literature review, case studies, and interviews. The interviews will involve aquaponic operators to gather firsthand information on the operational and maintenance costs, as well as the performance and challenges of using conventional water pump systems. The data will be used to compare the cost-effectiveness and energy efficiency of the solar-powered system against the traditional system.

2.7. Energy Efficiency Analysis

Energy efficiency will be evaluated by comparing the estimated energy input from the solar system to the useful energy output that is delivered as water flow. Since DC measurement is not taken in this experiment, the energy input will be estimated based on the rated power of the pump and its recorded runtime using the formula:

$$Energy\ input\ (Wh) = Pump\ rated\ power\ (W) \times Runtime\ (hours) \quad (2)$$

While the energy output should be determined based on the flow rate and the height of water lifted, the hydraulic power formula is calculated as follows:

$$Hydraulic\ Power\ (W) = \frac{Flow\ rate\ (L/s) \times Head\ (m) \times Gravity\ (9.81\ m/s^2)}{1000} \quad (3)$$

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The hydraulic energy output is then:

$$Hydraulic\ Energy\ (Wh) = Hydraulic\ Power\ (W) \times Runtime\ (hours) \quad (4)$$

The ratio of the system's energy efficiency, where the formula for calculating the energy efficiency is:

$$Energy\ Efficiency, \eta = \frac{Hydraulic\ Energy\ (Wh)}{Energy\ input\ (Wh)} \times 100\% \quad (5)$$

3. Result and Discussion

3.1. Performance of the SPWPS

This experiment was conducted for 4 weeks, from 17 May 2025 until 16 June 2025. The Nutrient Film Technique (NFT) system was placed outdoor and was observed twice a day at 7.00am and 9.30pm everyday throughout this one-month period. Figure 5 shows the experimental setup used in this study. In this study, the performance of the Solar-Powered Water Pump System (SPWPS) was examined based on key parameters, including water flow rate, pump operational hours, and power consumption on the solar charge controller.

Fig. 5 *The SPWPS and aquaponics setup*

3.2. Water Flow Rate

The difference in meter readings over a known time interval was used to calculate the flow rate in liters per hour (L/h) using the formula:

$$Flow\ Rate\ (L/h) = \frac{Volume\ (L)}{Time\ (h)} \quad (6)$$

The data revealed that the system produced good performance, particularly during periods of extended sunlight. It was observed that the system operated at near-optimal flow rates during sunny and partly cloudy days, while performance dropped slightly during rainy or overcast conditions. Table 1 presents the measured flow rates throughout the 4 weeks experiment, along with corresponding weather conditions and temperature readings.

Table 1 *Water Flow Rate under different weather conditions*

Day	Weather Condition (°C)		Measured Flow Rate (L/h)	Remarks
	Day	Night		
1	35	27	150	Mostly Clear
2	34	24	148.72	Mostly Clear
3	33	25	128.57	Showers
4	33	24	107.14	Scattered Thunderstorms
5	31	25	98.56	Thunderstorms
6	33	25	135.71	Partly Cloudy
7	34	26	142.86	Partly Cloudy
8	36	26	136.71	Partly Cloudy
9	35	26	135.85	Partly Cloudy
10	36	26	136.72	Partly Cloudy
11	36	27	136.9	Partly Cloudy
12	36	26	136.77	Partly Cloudy
13	29	25	121.43	Scattered Thunderstorms
14	35	26	145.91	Partly Cloudy
15	34	25	144.88	Partly Cloudy
16	37	26	146.25	Partly Cloudy
17	36	26	136.15	Partly Cloudy
18	35	26	130.12	Scattered Thunderstorms
19	34	26	131.67	Scattered Thunderstorms
20	33	25	135.1	Partly Cloudy
21	33	25	133.61	Scattered Thunderstorms
22	33	24	133.97	Scattered Showers
23	34	25	142.88	Partly Cloudy
24	35	24	135.85	Partly Cloudy
25	32	25	108.32	Showers
26	35	25	135.93	Partly Cloudy
27	36	26	136.17	Partly Cloudy
28	36	26	136.2	Partly Cloudy
29	35	26	128.57	Showers
30	35	24	132.59	Scattered Thunderstorms
31	32	24	103.86	Thunderstorms

In Figure 6, days with higher flow rates (above 140 L/h) typically align with clearer weather, such as clear and partly cloudy days. This shows the performance of the SWPS can operate efficiently when sufficient sunlight is available. While, on Day 5 and Day 31, a significant drop in flow rate which aligns with reported thunderstorms during those days. This is due to less energy being obtained by solar panels to generate electricity and making the water pump performance inefficient. Next, between Day 6 and Day 20, the flow rate remained stable, with minor variations, under partly cloudy conditions.

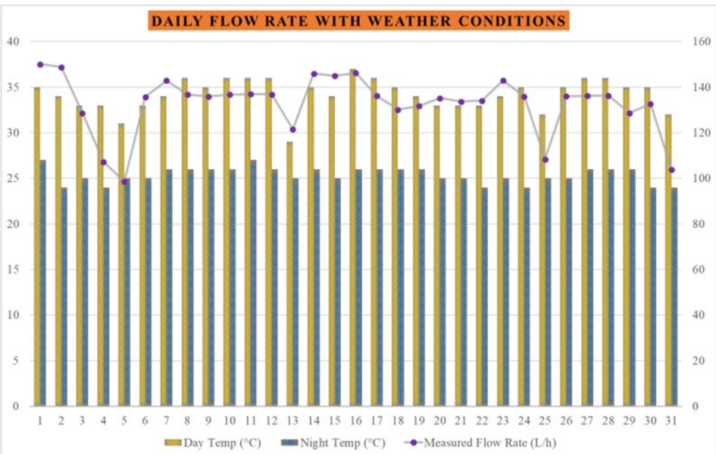

Fig. 6 *Daily Flow Rate with weather conditions*

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3.3.Pump Operational Hours

From my observation, the battery takes 10 hours to fully charge when connected the charger. And when connected in SPWPS, the combination of solar energy that gets charged under the strong sun and the fully charged battery, it can work for 16 hours continuously. The results indicated that the pump operated for longer periods on sunny days compared to cloudy or overcast conditions. The recorded data as in Table 2 shows the water pump runtime depending on the weather conditions and sunrays received by the solar panel on that day. Figure 7 shows the graph of daily pump runtime for 31-days period.

Table 2 *Pump operational hours under different weather conditions*

Day	Weather Condition	Pump Runtime (hours)
1	Mostly Clear	16
2	Mostly Clear	10
3	Showers	6
4	Scattered Thunderstorms	8.5
5	Thunderstorms	6
6	Partly Cloudy	11
7	Partly Cloudy	12
8	Partly Cloudy	10
9	Partly Cloudy	10
10	Partly Cloudy	10.5
11	Partly Cloudy	12
12	Partly Cloudy	11.5
13	Scattered Thunderstorms	8
14	Partly Cloudy	9
15	Partly Cloudy	8.5
16	Partly Cloudy	9
17	Partly Cloudy	11
18	Scattered Thunderstorms	10
19	Scattered Thunderstorms	11
20	Partly Cloudy	8
21	Scattered Thunderstorms	9.5
22	Scattered Showers	9
23	Partly Cloudy	10.5
24	Partly Cloudy	10
25	Showers	10.5
26	Partly Cloudy	9
27	Partly Cloudy	8
28	Partly Cloudy	9
29	Showers	6.5
30	Scattered Thunderstorms	9
31	Thunderstorms	7

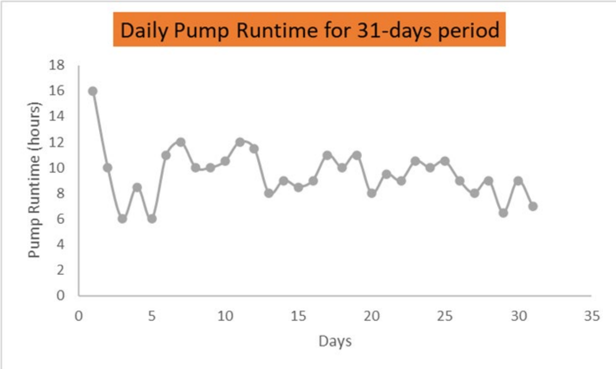

Fig. 7 *Graph of Daily Pump Runtime for 31-days period*

3.4. System Power Consumption

The power consumption behavior of the system was monitored using the voltage readings from the solar charge controller display. During sunny conditions, the system voltage typically ranges between 12.2V and 12.4V, showing the battery charge is sufficient when the pump was turned on. On cloudy and overcast days, the voltage reading drops over time, reaching values as low as 11.2V as the battery discharges during continuous operation without sufficient energy input. The power consumption for each day can be seen from Table 3 that showing the weather forecast, discharge voltage, and water pump run time. Figure 8 shows the graph of maximum discharge voltage vs the pump runtime by days.

Table 3 *System power consumption under different weather conditions*

Day	Weather Condition	Maximum Discharge Voltage (Volt)	Pump Runtime (hours)
1	Mostly Clear	11.9	16
2	Mostly Clear	12.2	10
3	Showers	12.2	6
4	Scattered Thunderstorms	11.6	8.5
5	Thunderstorms	11.0	6
6	Partly Cloudy	12.1	11
7	Partly Cloudy	12.2	12
8	Partly Cloudy	12.2	10
9	Partly Cloudy	12.3	10
10	Partly Cloudy	12.1	10.5
11	Partly Cloudy	12.3	12
12	Partly Cloudy	12.3	11.5
13	Scattered Thunderstorms	11.8	8
14	Partly Cloudy	12.1	9
15	Partly Cloudy	12.1	8.5
16	Partly Cloudy	12.2	9
17	Partly Cloudy	12.1	11
18	Scattered Thunderstorms	12.0	10
19	Scattered Thunderstorms	11.9	11
20	Partly Cloudy	12.2	8
21	Scattered Thunderstorms	12.1	9.5
22	Scattered Showers	11.8	9
23	Partly Cloudy	11.9	10.5
24	Partly Cloudy	11.2	10
25	Showers	11.7	10.5
26	Partly Cloudy	11.3	9
27	Partly Cloudy	11.2	8
28	Partly Cloudy	12.0	9
29	Showers	12.1	6.5
30	Scattered Thunderstorms	12.2	9
31	Thunderstorms	12.2	7

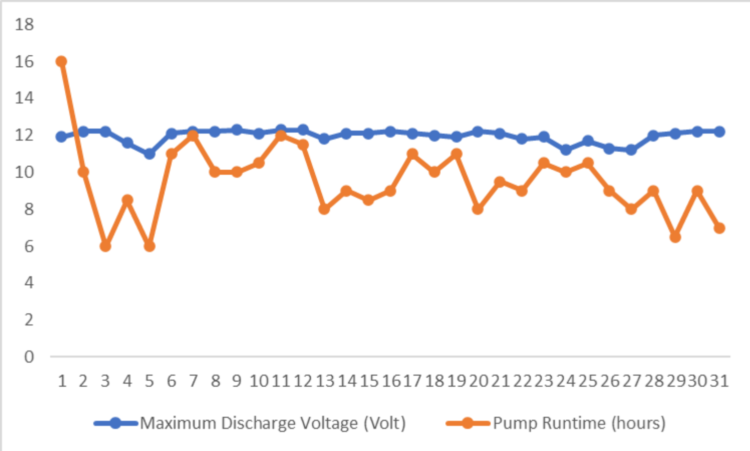

Fig. 8 *Graph of maximum discharge voltage vs the pump runtime*

3.5. Energy Efficiency Analysis

This study was conducted under real operating time and conditions across different weather conditions to evaluate the overall system performance and responsiveness to environmental changes. Since the DC (amperage) readings were not recorded in this experiment, the energy input was calculated based on the rated power of the pump which operates at 12V 3.6W and operational runtime. On the other hands, the useful energy output was calculated from the water flow rate and head height (vertical distance the water is lifted) of the system. Then, the result of hydraulic power was used to calculate the hydraulic energy output. Finally, the energy efficiency of the system was calculated as the ratio of the hydraulic energy output to the calculated energy input across different environmental conditions, reflecting the typical performance of small-scale DC water pumps. Table 4 shows the Energy Efficiency analysis of the SPWPS.

Table 4 *Energy Efficiency Analysis of SPWPS*

Day	Energy Input (Wh)	Hydraulic Power (W)	Hydraulic Energy (Wh)	Efficiency (%)
1	57.6	8.59×10^{-5}	1.37×10^{-3}	0.0024
2	36.0	8.51×10^{-5}	8.51×10^{-4}	0.0024
3	21.6	7.35×10^{-5}	4.41×10^{-4}	0.002
4	30.6	6.14×10^{-5}	5.22×10^{-4}	0.0017
5	21.6	5.64×10^{-5}	3.38×10^{-4}	0.0016
6	39.6	7.77×10^{-5}	8.55×10^{-4}	0.0022
7	43.2	8.18×10^{-5}	9.82×10^{-4}	0.0023
8	36.0	7.83×10^{-5}	7.83×10^{-4}	0.0022
9	36.0	8.18×10^{-5}	8.18×10^{-4}	0.0023
10	37.8	7.83×10^{-5}	8.22×10^{-4}	0.0022
11	43.2	7.83×10^{-5}	9.4×10^{-4}	0.0022
12	41.4	7.83×10^{-5}	9×10^{-4}	0.0022
13	28.8	6.94×10^{-5}	5.55×10^{-4}	0.0019
14	32.4	8.34×10^{-5}	7.51×10^{-4}	0.0023
15	30.6	8.28×10^{-5}	7.04×10^{-4}	0.0023
16	32.4	8.36×10^{-5}	7.52×10^{-4}	0.0023
17	39.6	7.79×10^{-5}	8.57×10^{-4}	0.0022
18	36.0	7.44×10^{-5}	7.44×10^{-4}	0.0021
19	39.6	7.54×10^{-5}	8.29×10^{-4}	0.0021
20	28.8	7.73×10^{-5}	6.18×10^{-4}	0.0021
21	34.2	7.64×10^{-5}	7.26×10^{-4}	0.0021
22	32.4	7.66×10^{-5}	6.89×10^{-4}	0.0021

23	37.8	8.18×10^{-5}	8.59×10^{-4}	0.0023
24	36.0	7.77×10^{-5}	7.77×10^{-4}	0.0022
25	37.8	6.2×10^{-5}	6.51×10^{-4}	0.0017
26	32.4	7.79×10^{-5}	7.01×10^{-4}	0.0022
27	28.8	7.79×10^{-5}	6.23×10^{-4}	0.0022
28	32.4	7.79×10^{-5}	7.01×10^{-4}	0.0022
29	23.4	7.35×10^{-5}	4.78×10^{-4}	0.002
30	32.4	7.58×10^{-5}	6.82×10^{-4}	0.0021
31	25.2	5.95×10^{-5}	4.17×10^{-4}	0.0017

For Day 1 (16 hours) and Day 2 (10 hours), the SPWPS operated consistently throughout the day until the night, the solar input powering directly during the day and by the battery bank during low sunlight conditions. This shows that, in favorable weather, the solar panels and battery capacity are capable of maintaining continuous operation. The calculated energy input for both of these days were 57.6Wh and 36Wh, respectively, resulted in hydraulic energy outputs that were comparatively higher than those recorded on stormy or overcast days.

Although the actual data for current was not recorded to refine real-time power consumption, but the system operated efficiently within the expected range, especially on days with clear sunlight. In days with lower voltages, there are some losses of efficiency due to cloudy or stormy weather, where battery usage was higher and pump runtime could not be sustained for long time. These effects can be seen on Day 5, 25 and 31 where the runtime and efficiency dropped.

However, even with those effects, the system still maintained a functional flow rate that sufficient for small-scale aquaponic needs. The Daily Energy Efficiency of SPWPS for 31-Days period could be concluded in Figure 9.

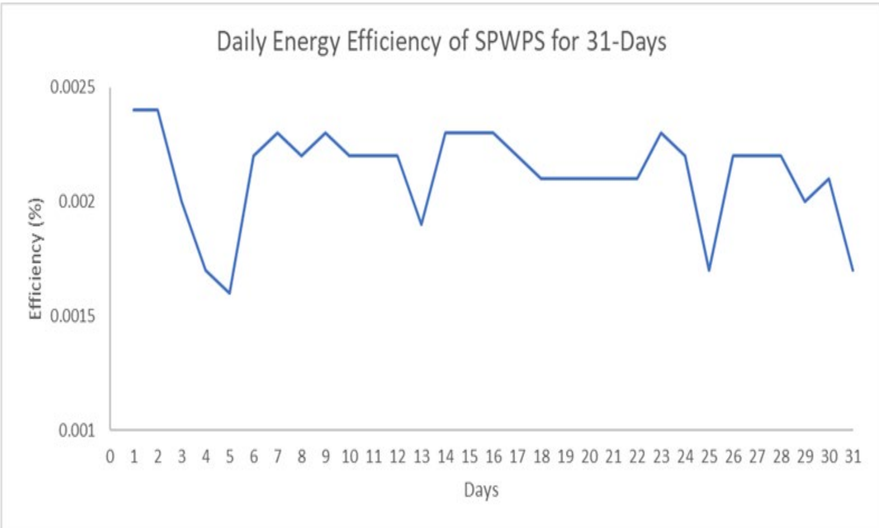

Fig. 9 *Daily Energy Efficiency of SPWPS for 31-Days period*

Even the calculated energy efficiency values were low, ranging from 0.0016% to 0.0024% or less than 1%, this is considered normal for small-scale solar-powered systems especially with low wattage DC pumps. The low efficiency percentages are a result of the minimal energy input (3.6W) and relatively small hydraulic output caused by a low head height and limited water flow rate. Additionally, some energy loss is expected due to factors such as heat dissipation, friction within the piping system, and conversion losses between the solar panel, battery, and pump. Even with the low numerical value, the SPWPS successfully delivered a constant and sufficient water flow to the aquaponic setup, especially on days with stable sunlight.

3.6. Energy Efficiency Analysis

Overall, the total cost used was RM 401.23 from the total CAPEX and OPEX calculation, as can be seen from Table 5 for the Capital Expenditure (CAPEX) of SPWPS and Table 6 for the Operational Expenditure (OPEX) of SPWPS.

Table 5 *The Capital Expenditure (CAPEX) of SPWPS*

Item	Quantity	Unit Price	Total Cost
Solar Panel	2	-	RM 153.90
Lithium-Ion Batteries	6		
Brushless DC Submersible Pump	1		
3-meter Pipe	1		
Solar Charge Controller	1	RM 9.60	RM 9.60
DN15 Water Flow Meter	1	RM 22.51	RM 22.51
Aquaponic Budget Set - PVC Pipe - UPVC Pipe - 45L Transparent Box - Joiner pipe - Net pot	1	-	RM 156.00
Cotton	1	RM 3.50	RM 3.50
Vegetable Seeds	1	RM 2.00	RM 2.00
PVC Fittings	2	RM 1.00	RM 2.00
Total CAPEX			**RM 349.51**

Table 6 *The Operational Expenditure (OPEX) of SPWPS*

Item	Frequency	Unit Price	Total Cost/Month
Battery replacement	Only when damaged	RM 29.21	Estimate RM 2.43
Pump maintenance/cleaning	Monthly	Free	Free
Flow meter	Only when damaged	RM 22.51	Estimate RM 0.31
Total Estimated Monthly OPEX			**RM 2.74**

3.7. Comparison with Conventional System

According to Mr. Atiqullah, his current setup uses a 240V AC water pump and the power consumption of the pump for his current setup is 0.2kW, operates for 24 hours. This results in an estimated monthly energy consumption of 144 kWh and the average monthly electricity cost for running the pump is approximately RM 40.00. Additionally, he noted that occasional expenses are incurred for maintenance repair for every 6 months and the typical cost of repairs or part replacements are estimated RM 200.00, especially when the pump failed to operate due to a power overload.

In terms of the performance of the pump of his setup, the respondent earned their reliability under different weather conditions as moderately reliable. This shows that although the system is generally effective, its performance may be affected by certain factors such as inconsistent power supply or extreme weather conditions. The typical environmental conditions in which the pump runs in a temperature range of 26°C to 35°C, with humidity levels reaching 100% and exposure to rain estimated at 50%. These values highlighted the high-moisture outdoor environment, which may impose stress on the electrical components over time. In contrast, the SPWPS used in this study operates a 12V 3.6W DC pump powered by a 12V 9W solar panel that connected with a battery system. It came up to 16 hours of daily operation under optimal sunlight conditions with zero electricity cost. The initial investment cost of SPWPS is slightly higher, but it provides long-term savings, especially in rural or off-grid areas. Table 7 shows the comparison of the cost savings between the SPWPS and Conventional system.

Table 7 Comparison of the cost savings between the SPWPS and Conventional system

Parameter	SPWPS	Conventional	Difference (Savings)
Initial Investment (RM)	349.51	650	+300.49
Monthly Operational Cost (RM)	2.74	240	+237.26
Payback Period (months)	1.5	-	-

3.8. Environmental Considerations

The SPWPS was also interfered with by rain, direct sunlight, and changing temperatures. The solar system components, laid out and designed to withstand the weather, were enclosed in frames and put outside and sealed. The system is weatherproof, but prolonged exposure to heavy rain or moisture may reduce its performance, or the electrical components may be damaged unless properly sealed and kept dry.

The performance data showed that the system performed well during sunny days and partly cloudy days, when the water flow rate was also high. The flow rate in rainy days or cloudy days decreased slightly yet remained high to sustain the aquaponic system. The minimum flow rates occurred during heavy rain and thunderstorms, demonstrating the need for frequent maintenance and good waterproofing.

The fact that it uses solar power means that no greenhouse gases are emitted during use hence it is greener as compared to those powered electrically or using fuel. Sustainability is also promoted by rechargeable lithium-ion batteries, though their recycling should be handled properly to limit their environmental impact.

4. Conclusion

This study has demonstrated that integrating a Solar-Powered Water Pump System (SPWPS) provides a practicable, economically efficient, and environmentally sound solution for aquaponic operations, especially in countries with sufficient sunlight, such as Malaysia. The findings highlighted that the solar energy system not only reduced operational costs but also improved energy efficiency compared to conventional systems or, in particular, conventional energy-powered systems. Furthermore, the initial investment cost of solar technology is higher, but it is offset by savings on electricity bills and environmental benefits, as the use of renewable energy also reduces greenhouse gas emissions. Additionally, the use of a solar-powered system displayed high energy efficiency in efficiently converting the solar energy to electrical power to maintain the water circulation needed in aquaponic operations. This approach is providing benefits to small-scale farmers and communities, particularly in rural areas where access to electricity may be limited.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Xena Lennia Lau Ho Ping, Rosli Asmawi;* ***data collection:*** *Xena Lennia Lau Ho Ping;* ***analysis and interpretation of results:*** *Xena Lennia Lau Ho Ping, Rosli Asmawi, Zamri Noranai;* ***draft manuscript preparation:*** *Xena Lennia Lau Ho Ping, Rosli Asmawi. All authors reviewed the results and approved the final version of the manuscript.*

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