Study on the Application of Solar Energy and Hydropower for Fish Farming to Generate Electricity

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Abstract

The objective of this research is to study and develop an energy-efficient fish farming box with dimensions of 0.30m x 0.60m x 0.38m to provide a simple, efficient, energy-saving, cost-effective, designed for remote rural areas. But conventional fish farming boxes require electricity to power various devices, such as bright light bulbs and oxygenators. In this study, solar energy and hydropower were employed as alternative sources of electricity to replace the conventional household electricity, a natural resource that can be harnessed without limitations, free from fuel production costs, and environmentally friendly. Over the course of 8 days of experimentation, the average electricity output was found to be 110.37 W, with the maximum current reaching 8.30 A at 12:00 PM. When compared to regular fish farming boxes, this energy-efficient fish farming box can save approximately 1,938.53 Baht/year in electricity costs. Over 10 years of use, the total electricity cost savings amount to approximately 19,385.28 Baht, which is about seven times higher than those of conventional fish farming boxes. It was found that the average DO value in the energy-efficient fish tank using the waterwheel was 7.18 mg/l, while the average DO value in the regular water was 4.08 mg/l. This indicates a difference of 3.10 mg/l in the DO values between the two conditions.

Keywords: Solar energy, Hydropower, Solar panels, Fish farming box, Electricity generation

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1. Introduction

Currently, fish farming has become a popular activity that provides income for some families. Some people raise fish in ponds or fish farming boxes for aesthetic purposes and for selling. To achieve this, they need to use household electricity to power various devices, such as light bulbs for illumination and oxygenators for the fish tanks. However, in remote rural areas where access to electricity is limited, such activities cannot be easily carried out. To address this issue, research has been conducted to explore the use of alternative energy sources to generate electricity for household activities and also to enable fish farming. In this study, the chosen primary energy source is solar energy, a natural resource that can be harnessed without limitations, free from fuel production costs, and environmentally friendly. The electricity generation from solar energy utilizes devices called solar cells, which convert solar energy into electrical power

From previous research, it has been found that the production of electricity from solar energy and hydropower has been extensively studied and researched, particularly in Asia, Europe, and Africa. For instance, Lima et al. (2024) studied the feasibility of integrating hydro and solar power with a Hydrogen-based Electrical Energy Storage System (H_2EESS) at the Serra da Mesa hydroelectric Brazilian power plant. The integration of hydro and solar power with H_2EESS resulted in an 11.10% increase in energy production compared to conventional hydroelectric generation, with H_2EESS providing 36.06% of this increase. Additionally, there was a 9.71% utilization increase in substation capacity. Additionally, Mbasso et al. (2023) evaluated the suitability of the Hybrid Optimization Model for Electric Renewable (HOMER) program. The study investigated the optimal energy generation mix for sustaining the fish farming industry and fulfilling the energy requirements of the chosen

building. Examining the specifics, the study attains an impressive renewable fraction (RF) of 92.5% and a Deficit of Power Supply Probability (DPSP) of 0%. Furthermore, the production of 50 kg of O_2 and the emission of 1.69 kg of carbon annually prove acceptable for constructing a reliable and environmentally sound energy system. Moreover, Ratchapakdee and Geendoung (2019) developed an air diffuser system powered by solar energy for fish farming in fish tanks. Their research revealed that the minimum dissolved oxygen concentration in the fish tank without the air diffuser was 1.70 mg/L, while the maximum was 5.05 mg/L. In contrast, the fish tank with the air diffuser had a minimum dissolved oxygen concentration of 1.78 mg/L and a maximum of 8.42 mg/L, resulting in increased oxygen levels. Furthermore, the use of the air diffuser helped reduce electricity costs. Similarly, Noilublao (2012) developed a solar-powered wastewater treatment system for pond usage. The research showed that the wastewater treatment system increased oxygen levels by 2.25 milligrams per liter, or approximately 56.82%. The project's total cost was 227,000 Baht. Additionally, Mahamai et al. (2014) designed and developed a small paddle-wheel aerator that was used in a 20 m^2 earthen pond to boost the amount of dissolved oxygen (DO). The highlight of this aerator was that it relied on solar cells and electrical power from turbine-driven mechanical energy. It was tested for 8 hours, with DO measurement every 2 hours from both the aerated pond and the non-aerated pond. According to the test results, it was found that the amount of DO increased by 1.537 ml/L on average per hour. The electrical power from the solar cell was 51 watts on average, and the electrical power from the power conditioning unit was 4.9 watts on average. Besides, Polizelli et al. (2003) obtained data on pressure drop in stainless steel sanitary fittings and valves during laminar and turbulent flow of aqueous solutions of sucrose and xanthan gum, which were selected as model fluids and determined the rheological properties of these solutions. The results showed that power-law model provided the best fit for the experimental data. Additionally, friction losses were measured in fully and partially open butterfly valves, plug valves, bends, and unions. Likewise, Pathi, Pankong, and Phoomkittipich (2010) designed a system for generating electricity using both hydropower and solar cells for a remote school building. Their research demonstrated that the combined system was capable of providing electricity to the school building continuously for 24 hours, with a total power output of approximately 3 kW from both energy sources. In the research conducted by Saniso, a study was carried out on mini hydropower generation. When installing the electricity-generating set at a river location, it was found that the mini hydropower system could provide an average electrical voltage of 217.43 ± 2.70 V and a frequency of 47.52 ± 2.12 Hz (Saniso, 2010). Furthermore, Laodee et al. investigated the usage of 19 mini hydroelectric generators by the villagers in Tapaen village. The research revealed that these generators altogether provided a total power output of 22 kW (Laodee et al., 2005). Additionally, Pangteerasukmai studied hydroelectric turbines to enhance electricity production. The research involved modifying the turbines to improve their efficiency, resulting in electricity generation of 3-5 A, with a budget of approximately 6,900 Baht for the project (Pangteerasukmai, 2011). In another study, Thanasin et al. designed and developed a prototype for electricity production using water energy. The research involved designing a cup-shaped turbine to efficiently capture energy from water impact. The experimental results showed that the system was capable of producing 4 A of electric current (Thanasin et al., 2018). Furthermore, Petrasathien et al. designed and created a hydroelectric power plant set for electricity production using water energy. From the experiments conducted, it was found that the electrical voltage obtained from the tests ranged from 6 to 8.35 V, with a project cost of 12,135 Baht (Petrasathien et al., 2018).

From all the research reports mentioned above, both solar energy and hydropower have proven to be highly advantageous in electricity generation. As a result, the researchers are interested in studying the application of both energy sources for fish farming boxes to produce electricity in remote rural areas. The main aim is to have a simultaneous supply of electricity while also maintaining aesthetically pleasing and enjoyable fish farming boxes for families.

2. Materials and Methods
2.1 Fish farming box for electricity generation
In the design and construction of the fish farming box for electricity generation, both hydropower (utilizing the principle of gravity) and solar energy (using solar panels) were employed. The selection of materials and equipment prioritized locally available and cost-effective options. Refer to Figure 1, Figure 2, and Table 1 for details.

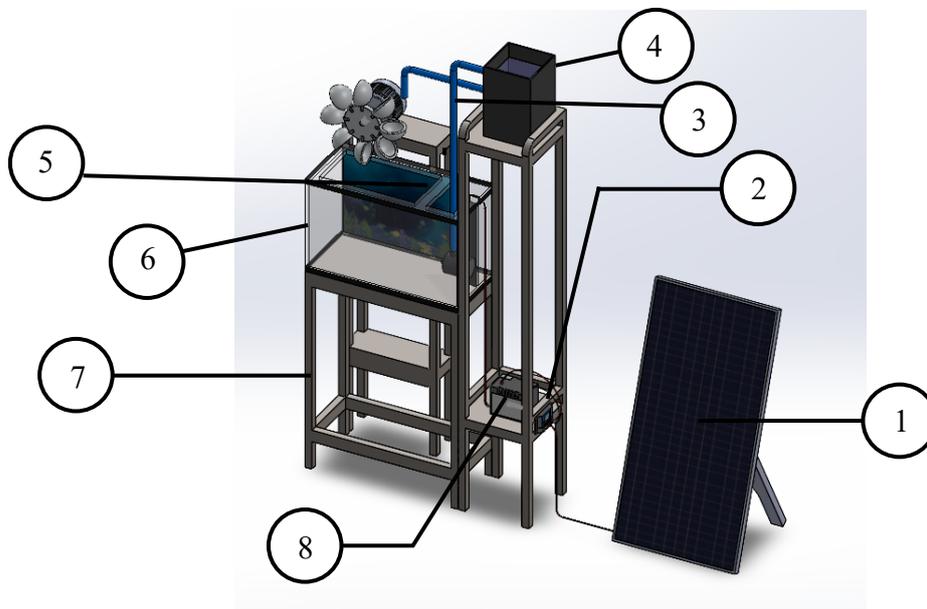**Figure 1.** Components of the fish farming box for electricity generation.

Figure 2. Experimental device setup.

Table 1. List of materials and equipment corresponding to the numbers in Figure 2.

No.	Equipment List
1	Polycrystalline Solar Cells
2	Solar Charger
3	PVC Pipe
4	Water tank
5	Light Bulbs
6	Fish Farming Box (0.30m x 0.60m x 0.38m in size)
7	Steel Box
8	Battery

2.1.1 The detailed list of materials and equipment, see Figure 2.

2.1.1.1 180 W.,18 V. Polycrystalline Solar Cells (No. 1): This type of solar cell employs crystalline silicon. Liquid silicon was set into a square mold before being cut into thin sheets. Thus, the shape of each particular cell was

square, with an edge that was not cut. The color of the cells was blue, but not very dark. The advantages included a simple and unsophisticated production process, efficient operation under high temperatures, and low cost. See Figure 3.

Figure 3. Polycrystalline solar cell.

2.1.1.2 Solar Charger (No. 2): We used a PWM (Pulse Width Modulation), whose function was to control the solar cell-generated electric frequency to maintain digital system stability, saving energy and controlling charging the battery efficiently, consequently retarded degradation. There were pilot lamps connected to other devices, e.g., solar cell functions, battery storage levels (Full, moderate, low), DC power supply to connected DC electrical appliances. An auto-power cutoff system was also provided in case the battery energy level was low to prevent degradation due to overload. See Figure 4.

Figure 4. PWM solar charger (Pulse Width Modulation).

2.1.1.3 PVC Pipe (No. 3): Blue ½ inch polyvinyl chloride (PVC) piping, size ½ inch, was used for water transmission, e.g., plumbing, piping, or drainage. For the general structure, it is fundamentally a long and straight plastic cylinder with smooth texture, light weight, low cost, and long lifespan. See Figure 5.

Figure 5. ½" blue PVC pipe.

2.1.1.4 Water tank (No. 4): This research used a 21L opaque white bucket, as in Figure 6. Instead of a square tank, a plastic bucket was used because it was locally available and inexpensive.

Figure 6. 21L opaque white bucket.

2.1.1.5 Light Bulbs (No. 5): As in Figure 7, a 27cm light bulb with a charging cable was connected to the battery to illuminate and beautify the fish farming box.

Figure 7. 27cm light bulb with charging cable.

2.1.1.6 Fish Farming Box (No. 6): This 55L transparent glass box is 0.30m x 0.60m x 0.38m and 5 mm thick. Its sides are sealed with waterproof, clear silicone. It was used for fish raising and aquatic animals, aqua-scaping, etc. See Figure 8.

Figure 8. 55L transparent glass box, size 0.30m x 0.60m x 0.38m, 5 mm thick.

2.1.1.7 Steel Box (No. 7): Its size was 1.1/2 × 1.1/2 2 mm. 2 mm. thick, as in Figure 9. It was used for cutting, connecting, and assembling the bucket bearing structure, the fish farming box, and the battery, etc.

Figure 9. The steel box is cut, connected, and assembled into the research structure.

2.1.1.8 Battery (No. 8): Used to store electricity and able to supply electricity directly, with a capacity of 12 V, as in Figure 10. The battery in this research was for electricity storage only, not for generating.

Figure 10. 12V battery.

2.1.2 Fish farming box construction process
2.1.2.1 The length of the steel for the box was measured (Size 1.1/2 × 1.1/2mm, thickness of 2 mm). The cutting spot was marked.

Figure 11. The cutting distance measurement and the correct lengths are marked.

2.1.2.2 Cutting.

Figure 12. Cutting the steel for the box with a metal cutting machine.

2.1.2.3 After cutting, the cut pieces were assembled into the structure.

Figure 13. Assembling the steel pieces into the structure.

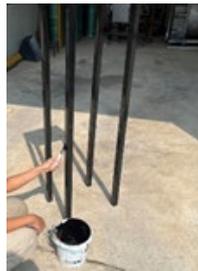2.1.2.4 The structure was examined and painted black.

Figure 14. Painting the structure black.

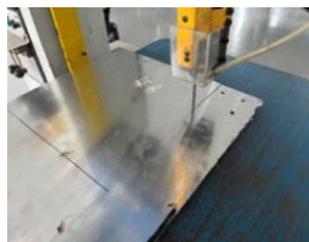2.1.2.5 An aluminum sheet was cut to as the structure bed to bear the bucket, the fish farming box, and the battery.

Figure 15. Cutting the aluminum sheet.

2.1.2.6 The PVC pipe was cut as per the layout. The pipe was connected to joints and elbows.

Figure 16. Cutting the PVC and connecting joints and elbows.

2.1.2.7 The bucket was perforated and connected to the cut PVC.

Figure 17. Perforating the bucket.

2.1.2.8 Parts were assembled, e.g., bucket stand, fish farming box stand, battery stand, and all the other devices required in the research, as in Figure 1.

2.2 Experiment
2.2.1 Install a 180 W solar panel with a voltage of 18 V, facing both north and south directions, as in Figure 18.

Figure 18. Installing the solar panel, oriented toward the north and south directions.

2.2.2 Connect the solar panel's positive and negative terminals with wires, then connect the wires to the solar charger, as in Figure 19.

Figure 19. Connecting the cables to the solar poles.

2.2.3 Connect the battery and the water pump in a DC circuit with the solar charger, as in Figure 20.

Figure 20. Connecting the battery cables and pump cables to the solar charger.

2.2.4 Finally, set up the operational system as shown in the process diagram of the fish farming box for electricity generation using solar and hydropower, as depicted in Figure 21.
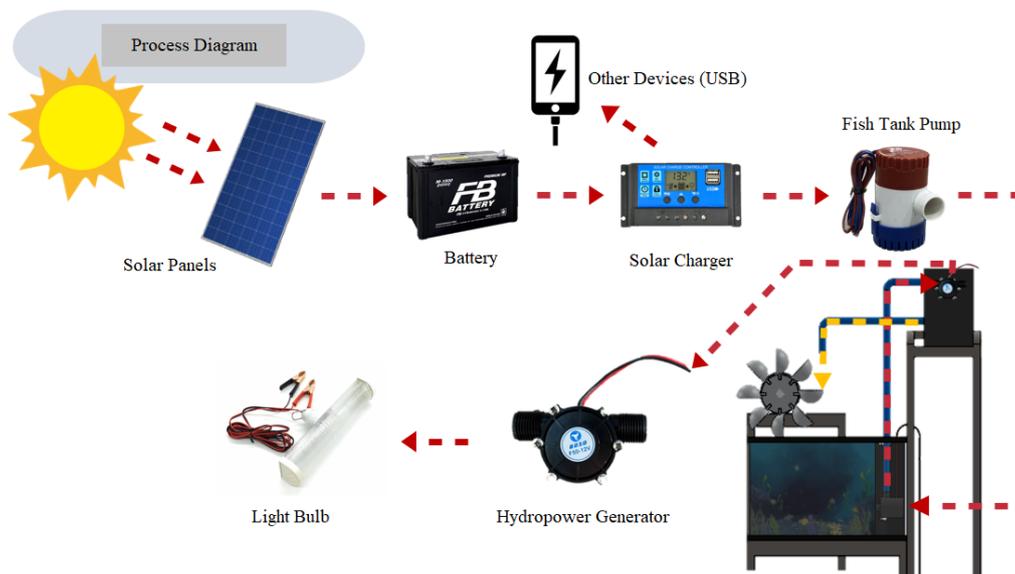
Figure 21. Process diagram of the fish farming box for electricity generation using solar and hydropower.

2.2.5 Use a multimeter to record the electrical current and voltage values obtained from the solar panel from 08:00 AM to 4:45 PM., as in Figure 22.

Figure 22. Measuring electricity and voltage with a multimeter.

calculate the electrical power using the formula:

$$E = I \times V \tag{1}$$

Where:

E is the electrical power (Watt or W),

I is the electrical current (Ampere or A), and

V is the voltage (Volts or V).

2.2.6 Take water samples from the fish farming box and measure the dissolved oxygen (DO) levels using a DO meter. Record the results, as in Figure 23.

Figure 23. Measuring the O_2 in the water with a DO meter.

3. Results and Discussion

3.1 Experimental results

From the graphs showing the average values of electrical current and voltage obtained from the 180W solar panel with an 18V output from 8:00 AM to 4:45 PM over an 8-day period (as shown in Table 2), it was observed that during the time interval of approximately 8:00 AM to 9:00 AM, which marked the beginning of the testing, the electrical current ranged from 3 to 5 A, and the voltage ranged from 18 to 19 V. As time passed, both the electrical current and voltage gradually increased, reaching their peak values between 11:30 AM and 1:00 PM. After 1:00 PM, the electrical current and voltage from the solar panel began to decrease as shown in Figure 24 and Figure 25, respectively.

Table 2. Average electrical current and voltage measured from the 180W solar panel from 8:00 AM to 4:45 PM over an 8-day period.

| Experimental Results Recording Electrical Current (Amp) and Voltage (Volt)											
Average Electrical Current and Voltage over an 8-Day Period											
8:00		8:15		8:30		8:45		9:00		9:15	
Amp	Volt	Amp	Volt	Amp	Volt	Amp	Volt	Amp	Volt	Amp	Volt
3.15	18.62	3.43	18.71	3.70	18.76	4.16	19.01	4.45	19.06	5.06	19.22
9:30		9:45		10:00		10:15		10:30		10:45	
Amp	Volt	Amp	Volt	Amp	Volt	Amp	Volt	Amp	Volt	Amp	Volt
5.40	19.27	5.03	19.16	6.01	19.34	6.69	19.52	6.39	19.43	7.18	19.62
11:00		11:15		11:30		11:45		12:00		12:15	
Amp	Volt	Amp	Volt	Amp	Volt	Amp	Volt	Amp	Volt	Amp	Volt
7.43	19.72	6.67	19.62	7.35	19.82	7.42	19.87	7.61	19.93	7.50	19.87
12:30		12:45		13:00		13:15		13:30		13:45	
Amp	Volt	Amp	Volt	Amp	Volt	Amp	Volt	Amp	Volt	Amp	Volt
7.8	19.90	7.52	19.79	7.41	19.73	6.91	19.61	6.75	19.55	6.28	19.45
14:00		14:15		14:30		14:45		15:00		15:15	
Amp	Volt	Amp	Volt	Amp	Volt	Amp	Volt	Amp	Volt	Amp	Volt
6.86	19.55	6.60	19.49	6.34	19.43	6.16	19.39	5.86	19.30	5.17	19.18
15:30		15:45		16:00		16:15		16:30		16:45	
Amp	Volt	Amp	Volt	Amp	Volt	Amp	Volt	Amp	Volt	Amp	Volt
4.92	19.13	4.27	19.05	3.87	18.92	3.34	18.78	2.78	18.65	1.98	18.53
Average Electrical Current and Voltage Received during the 8-Day Period				Average Electrical Current				5.71 A			
				Average Voltage				19.33 V			
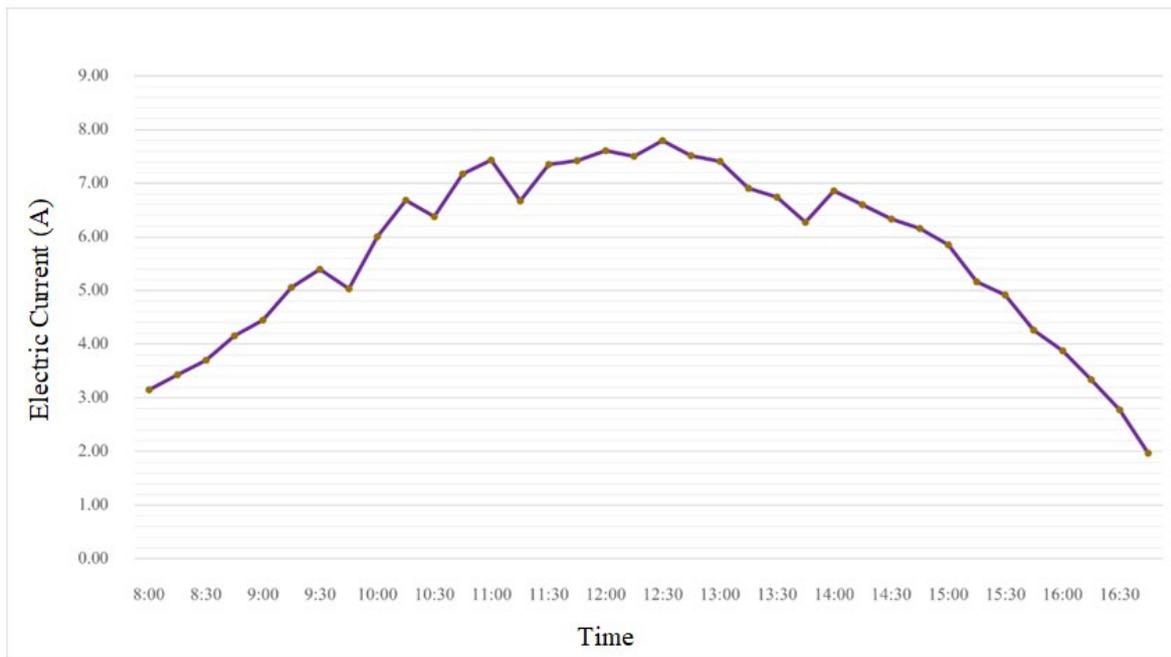
Figure 24. Graph showing the average electrical current obtained from the 180W solar panel over an 8-day period.
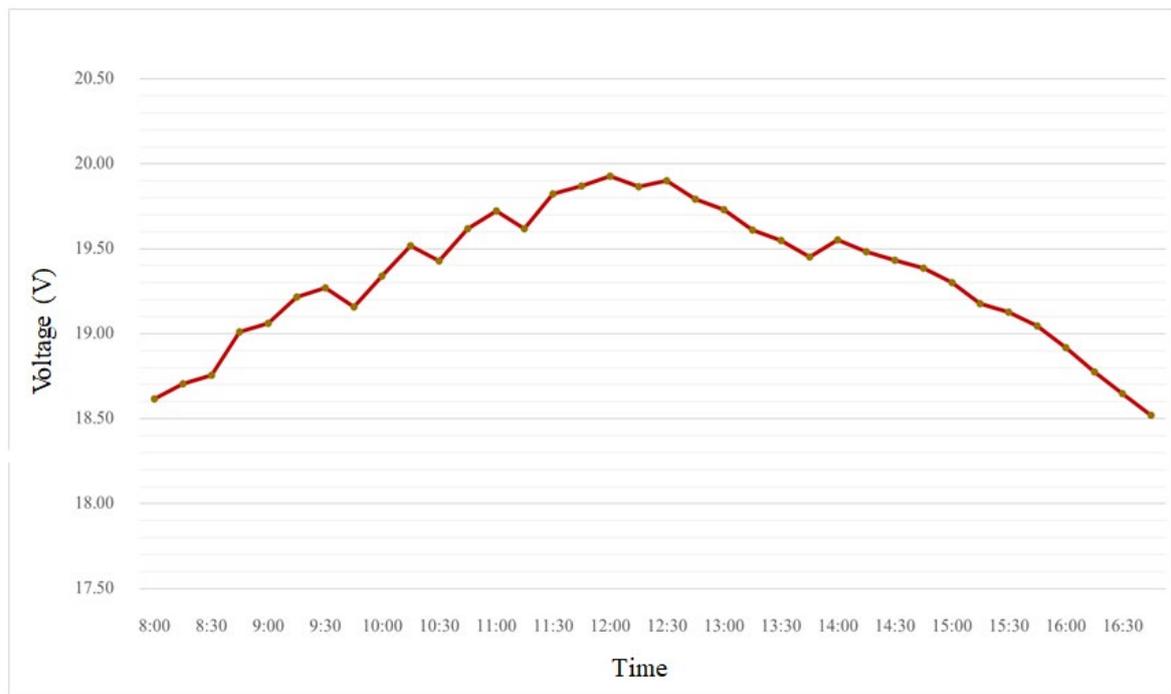

Figure 25. Graph showing the average voltage obtained from the 180W solar panel over an 8-day period.

In the measurements of electrical current and voltage from the 180W solar panel with an 18V output over an 8-day period, it was found that on March 21, 2023, the highest electrical current recorded was 8.30 A at 12:00 PM (as shown in Table 3). On March 25, 2023, the highest voltage obtained was 20.18 V at 11:45 AM (as shown in Table 4). It is worth noting that both of these days had clear and sunny weather conditions without clouds, indicating that weather conditions can influence the values of electrical current and voltage as per theoretical expectations. Comparing the average electrical current (Figure 24) with the average voltage (Figure 25), it was observed that when the electrical current increased, the voltage also increased, and vice versa. This demonstrates a direct relationship between electrical current and voltage, as expected.

Table 3. Weather data and electrical current information.

Date of Experiment	Weather Conditions	Maximum Electrical Current	Minimum Electrical Current	Current Difference (Maximum - Minimum)	Average Electrical Current Throughout the Day
20/03/2023	Clear Sky, Strong Sunlight, No Clouds	8.14 A	1.31 A	6.83 A	6.04 A
21/03/2023	Clear Sky, Strong Sunlight, No Clouds	8.30 A	1.87 A	6.43 A	6.01 A
22/03/2023	Clear Sky, Strong Sunlight, No Clouds	8.23 A	2.25 A	5.98 A	5.75 A
23/03/2023	Clear Sky, Strong Sunlight, No Clouds	8.02 A	1.63 A	6.39 A	5.43 A
25/03/2023	Clear Sky, Strong Sunlight, No Clouds	8.27 A	2.52 A	5.75 A	6.21 A
27/03/2023	Cloudy, there is some sunshine	7.89 A	1.73 A	6.16 A	5.21 A
01/04/2023	Cloudy, there is some sunshine	7.81 A	1.43 A	6.38 A	4.92 A
02/04/2023	Clear Sky, Strong Sunlight, No Clouds	8.16 A	2.48 A	5.68 A	6.08 A

Table 4. Weather data and voltage information.

Date of Experiment	Weather Conditions	Maximum Voltage	Minimum Voltage	Voltage Difference (Maximum - Minimum)	Average Voltage Throughout the Day
20/03/2023	Clear Sky, Strong Sunlight, No Clouds	20.07 V	18.47 V	1.60 V	19.39 V
21/03/2023	Clear Sky, Strong Sunlight, No Clouds	20.13 V	18.56 V	1.57 V	19.40 V
22/03/2023	Clear Sky, Strong Sunlight, No Clouds	20.09 V	18.54 V	1.55 V	19.34 V
23/03/2023	Clear Sky, Strong Sunlight, No Clouds	19.97 V	18.50 V	1.47 V	19.24 V
25/03/2023	Clear Sky, Strong Sunlight, No Clouds	20.18 V	18.46 V	1.72 V	19.50 V
27/03/2023	Cloudy, there is some sunshine	19.88 V	18.53 V	1.35 V	19.22 V
01/04/2023	Cloudy, there is some sunshine	19.76 V	18.37 V	1.39 V	19.14 V
02/04/2023	Clear Sky, Strong Sunlight, No Clouds	20.11 V	18.57 V	1.54 V	19.42 V

3.2 Comparison of expenses between conventional fish tanks and energy-efficient fish tanks

Based on the study of fish farming between conventional fish tanks and energy-efficient fish tanks, it was found that fish tanks incur expenses for electricity used by water pumps, oxygen pumps, and lighting, among others. Considering the electricity cost for a conventional fish tank, it would amount to approximately 161.544 baht per month (as shown in Table 5) or 1,938.53 baht per year (as shown in Table 6). However, upon analyzing the expense comparison between the two types of fish tanks (as shown in Table 7 and Figure 26), it was found that in the initial period, the energy-efficient fish tank incurred higher expenses compared to the conventional fish tank. But when it reaches the second year, the energy-efficient fish tank has lower expenses than the conventional one. Considering economic principles, utilizing the energy-efficient fish tank for a period of 2 years and 2 months will result in the recovery of investment costs. Moreover, if the energy-efficient fish tank is used beyond the 2 years and 2 months period, it will generate profits. Furthermore, over a 10-year period, the energy-efficient fish tank has the potential to save approximately 19,385.280 baht in expenses.

Table 5. Electricity costs from conventional fish tank per month.

Electric Appliances	Quantity of Appliances	Duration of Use (hours)	Electricity Consumption (Watts)	Electricity Cost per Month
Fish Tank Pump	1	24	35	25.2
Light bulb	2	8	20	8.4
Other devices (USB)	1	6	10	1.8
The conventional fish tank pays an electricity cost of 161.54 Baht per month				

Calculation of electricity units used per day

Calculate electricity units per day

$$= \frac{\text{Power (Watt) x Number of electrical appliances}}{1000} \text{ x Number of hours} \qquad (2)$$

Calculation of electricity units used per month

Calculate electricity units per month = Electricity units per day x 30 (3)

3.2.1 Calculation of the electricity cost of the fish tank pump

According to Equation 2

Calculation of electricity units used per day $= \frac{35 \text{ x } 1}{1000}$ x 24 = 0.840 units/day

According to Equation 3

Calculation of electricity units used per month = 0.456 x 30 = 25.2 units/month

3.2.2 Calculation of the electricity cost of the light bulb

According to Equation 2

Calculation of electricity units used per day $= \frac{20 \text{ x } 2}{1000}$ x 8 = 0.28 units/day

According to Equation 3

Calculation of electricity units used per month = 0.28 x 30 = 8.4 units/month

3.2.3 Calculation of the electricity cost of other devices (only those with USB)

According to Equation 2

Calculation of electricity units used per day $= \frac{10 \text{ x } 1}{1000}$ x 6 = 0.06 units/day

According to Equation 3

Calculation of electricity units used per month = 0.06 x 30 = 1.8 units/month

Total = 25.2 + 8.4 + 1.8 = 35.4 or approx. 36 units/month

3.2.4 Calculation of electricity consumption under the following conditions:

Unit 1-15 service charge = 2.347 baht/unit   2.347 x 15 = 35.23 baht

Unit 16-25 service charge = 2.988 baht/unit   2.988 x 10 = 29.88 baht

Unit 26-35 service charge = 3.241 baht/unit   3.241 x 10 = 32.41 baht

Unit 36-100 service charge = 3.624 baht/unit   3.624 x 1   =   3.624 baht

Thus, the total electricity consumption = 101.14 baht

3.2.5 Service charge = 24.62 baht

3.2.6 Fuel adjustment charge (FT) = The amount of electricity x F_t

FT = 36 x 0.9343

FT = 33.635

3.2.7 Calculation of VAT= (electricity consumption + 0.9343) x $\frac{7}{100}$

$= (101.14 + 0.9343) \text{ x } \frac{7}{100}$

= 7.145 baht

3.2.8 Total electricity cost = 101.14 + 24.62 + 33.635 + 7.145 = 166.54 baht

Government discount 3% = 166.54 - 3% = 161.54 baht/month

3.2.9 Thus, the fish tank/fish farming box can save 161.54 baht/month

Table 6. Electricity costs from conventional fish tank per year.

Time Period (months)	Fish Tank Expenses (Baht)
1	161.54
2	323.09
3	484.63
4	646.18
5	807.72
6	969.26
7	1,130.81
8	1,292.35
9	1,453.90
10	1,615.44
11	1,776.98
12	1,938.53

Table 7. Comparison of expenditures between conventional fish tank and energy efficient fish tank over a 10-year period

| Time Period (years)	Electricity Costs from Conventional Fish Tank (Baht)	Electricity Costs from Energy-Efficient Fish Tank (Baht)
1	1,938.53	4,070.00
2	1,938.53+1,938.53 = 3,877.06	
3	3,877.06+1,938.53 = 5,815.58	
4	5,815.58+1,938.53 = 7,754.11	
5	7,754.11+1,938.53 = 9,692.64	
6	9,692.64+1,938.53 = 11,631.17	
7	11,631.17+1,938.53 =13,569.70	
8	13,569.70+1,938.53 = 15,508.22	
9	15,508.22+1,938.53 = 17,446.75	
10	17,446.75+1,938.53 = 19,385.28	
Total	19,385.28	4,070.00
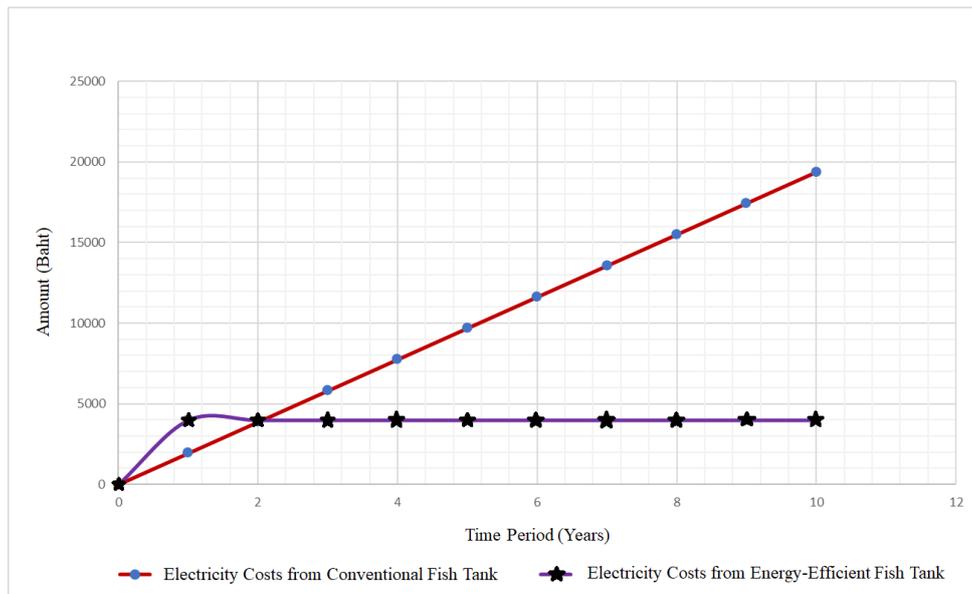
Figure 26. Graph comparing expenditures between conventional fish tank and energy efficient fish tank over a 10-year period

3.3 Results of dissolved oxygen (DO) measurement experiment

The experiment to measure the dissolved oxygen (DO) in the water was conducted by collecting water samples after the waterwheel had been operating for 30 minutes. The samples were then taken to the laboratory to measure the DO values. Each measurement was taken at intervals of 20 minutes (as shown in Table 8).

Table 8. Displays the average results of the dissolved oxygen measurement experiment conducted in 5 times.

Time	Temperature (°C)	Dissolved Oxygen in Regular Water, DO (mg/l)	Temperature (°C)	Dissolved Oxygen in Fish Tank with Waterwheel, DO (mg/l)
1	29.82	4.26	29.54	7.32
2	29.92	4.14	29.62	7.25
3	30.02	4.07	29.74	7.17
4	30.10	4.00	29.80	7.12
5	30.20	3.93	29.92	7.06
Average	30.01	4.08	29.72	7.18

It was found that the average DO value in the energy-efficient fish tank using the waterwheel was 7.18 mg/l, while the average DO value in the regular water was 4.08 mg/l. This indicates a difference of 3.10 mg/l in the DO values between the two conditions, as shown in Figure 27.
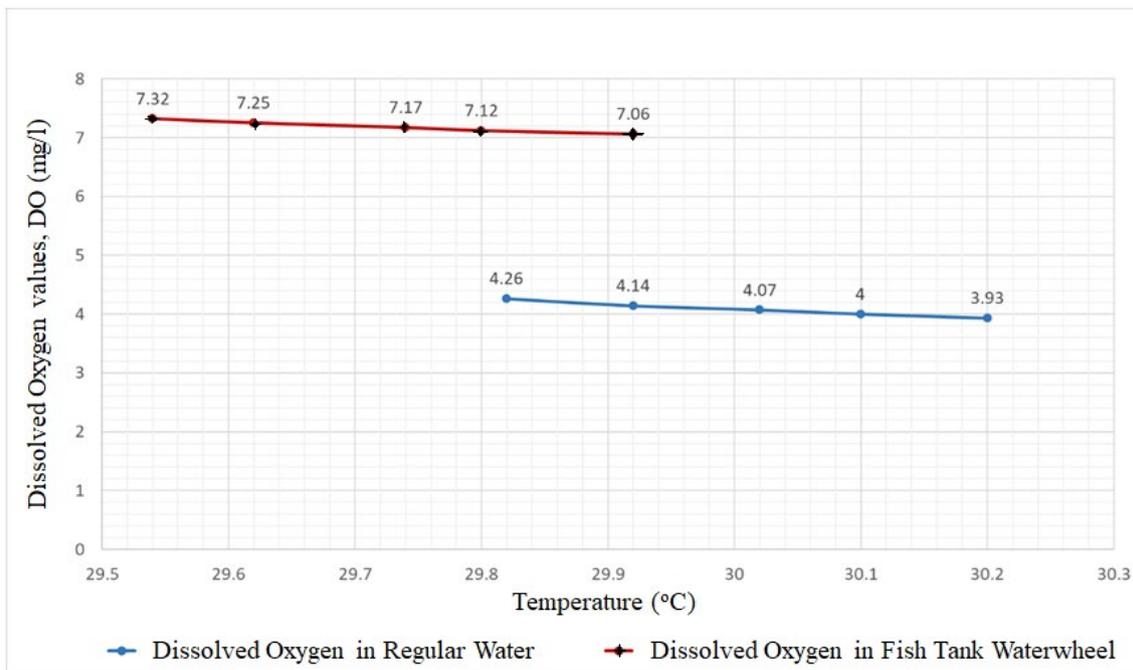
Figure 27. presents a graph comparing the average dissolved oxygen values between regular water and the water in the energy-efficient fish tank using the waterwheel.

4. Conclusions

The energy-efficient fish tank that utilizes solar and hydropower for electricity generation to operate fish farming equipment proved to be a cost-effective approach. The experiment involved measuring the electrical current and voltage obtained from a 180W solar panel with a voltage of 18V over an 8-day period. The maximum recorded electrical current was 8.30 A, and the highest voltage recorded was 20.18 V. Weather conditions significantly influenced the electrical current and voltage values, showing a gradual increase during the period from 8:00 AM to 12:00 PM and a subsequent decrease after 1:00 PM.

Regarding the dissolved oxygen (DO) measurement experiment, the fish tank with the waterwheel had higher DO levels compared to the regular water. Temperature was identified as a key factor affecting DO levels. The results indicated that as water temperature decreased, DO levels increased, and vice versa. This demonstrates an inverse relationship between water temperature and DO levels.

The overall cost of producing all the equipment was not substantial (approximately 4,070 Baht), resulting in electricity cost savings of 1,938.53 Baht per year when used for 10 years. Over the same 10-year period, the electricity cost savings compared to conventional fish tanks could reach up to 19,385.280 Baht, which is approximately 7 times more cost-effective. In the future, the fish tank's scale can be expanded to accommodate additional fish farming for generating additional income. For instance, constructing fish ponds for commercial fish farming can generate income, while also producing electricity for household use.

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References

Laodee, P., Ketjoy, N., & Rakwichian, W. (2005, May 11–13). *Pico hydro power generation: Case study of Ban Thapan, Luang PhaBang, LAO PDR*. The 1st Conference on Energy Network of Thailand, Cholburi.

Lima, G. M., Belchior, F. N., Villena, J. E. N., Domingos, J. L., Freitas, M. A. V., & Hunt, J. D. (2024). Hybrid electrical energy generation from hydropower, solar photovoltaic and hydrogen. *International Journal of Hydrogen Energy*, *53*, 602–612. https://doi.org/10.1016/j.ijhydene.2023.12.092

Mahamai, P., Viriyah, W., & Phechsuwan, P. (2014). The paddle wheels aerator used solar and backward energy for fish pound. *Naresuan Phayao Journal*, *7*(2), 142–150. https://li01.tci-thaijo.org/index.php/journalup/article/view/42776/35396

Mbasso, W. F., Naoussi, S. R. D., Molu, R. J. J., Saatong, K. T., & Kamel, S. (2023). Technical assessment of a stand-alone hybrid renewable system for energy and oxygen optimal production for fishes farming in a residential building using HOMER pro. *Cleaner Engineering and Technology*, *17*, 100688. https://doi.org/10.1016/j.clet.2023.100688

Noilublao, N. (2012). *Development of a wastewater treatment turbine using solar energy* [Thesis], Rajabhat Maha Sarakham University, Thailand. (in Thai)

Pangteerasukmai, P. (2011). *Hydro generator* [Thesis]. Faculty of Engineering, Rajamangala University of Technology PhraNakhon, Thailand. (in Thai)

Pathi, T., Pankong, N., & Phoomkittipich, K. (2010, December 15–17). *Design of 5 kW with hydro and photovoltaic power station.* Academic Symposium on Renewable Energy for Communities in Thailand, Rajamangala University of Technology Thanyaburi.

Petrasathien, T., Khongrit, S., & Ratnoomnoi, A. (2018). *Design's and taking hydroelectric power plant experimental*. Department of Mechanical and Automotive Engineering Technology, Faculty of Engineering and Technology, King Mongkut's University of Technology North Bangkok, Thailand. (in Thai)

Polizelli, M. A., Menegalli, F. C., Telis, V. R. N., & Telis-Romero, J. (2003). Friction losses in valves and fittings for power-law fluids. *Brazilian Journal of Chemical Engineering*, *20*(4), 455–463. https://doi.org/10.1590/S0104-66322003000400012

Ratchapakdee, P., & Geendoung, R. (2019). *Solar aerator for fish farm cage*. Faculty of Science and Technology, Rajamangala University of Technology Srivijaya, Thailand. (in Thai)

Saniso, E. (2010). Pico-hydropower generator. *The Journal of Industrial Technology*, *13*(1), 1–9.

Thanasin, K., Kumnerdjang, R., Phutthala., S., & Wanichayanan, C. (2018). Development of protypes for electricity generation using hydropower. *Advanced Science Journal*, *18*(2), 62–75.