# Promoting Green Energy in Fisheries Activities:
## a simulation study on water pump systems in fish landing site

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The fishery supply chain is facing challenges due to rising fuel costs and sharp declines in marine resources. Thus, it is imperative to establish a low-cost, hygienic, and greener fishery supply chain with the goals of lowering poverty, securing food, promoting gender equality, and mitigating the effects of climate change to achieve sustainability by 2030. In response to the profound implications of climate change, the United Nations has prioritized achieving net-zero carbon emissions in the near future. Thailand, as part of this global effort, has developed a comprehensive plan to reduce greenhouse gas emissions at 20–25 percent by 2030 based on current conditions. In this regard, the Training Department (TD) of SEAFDEC also supports the use of low-carbon emissions, energy-efficient technologies, and alternative energy sources to minimize greenhouse gas emissions from the fisheries sector to fulfill the Resolution on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2030, specifically *Resolution No. 9. Support the efforts to promote low carbon development technologies by minimizing the contribution of the fisheries sector to greenhouse gas emissions, with emphasis on promoting the use of energy-efficient equipment and alternative energy sources*.

The fisheries industry in many countries generates significant revenue from the export of fish and fishery products. However, recently, importers have begun to demand stricter sanitary standards throughout the fisheries value chain. Fish landing sites, which are crucial components of the fisheries value chain, require substantial amounts of water for cleaning tools, workspaces, and equipment, leading to increased operational costs for water and electrical systems. Additionally, growing concerns about greenhouse gas emissions, particularly carbon dioxide, are raising public awareness of the consequences of global warming.

It is widely acknowledged that sunlight represents an inexhaustible energy resource with versatile applications, including the generation of heat and light. The technology converting sunlight into electricity is commonly referred to as a photovoltaic cell or solar cell. These cells are typically integrated into panels, wherein multiple individual cells are combined to enhance the overall power output (Raza *et al.*, 2015). When sunlight impinges on the photovoltaic cells, the solar panel generates electrical energy. The amount of electricity produced varies throughout the day, contingent upon the availability of light. Typically, solar electricity

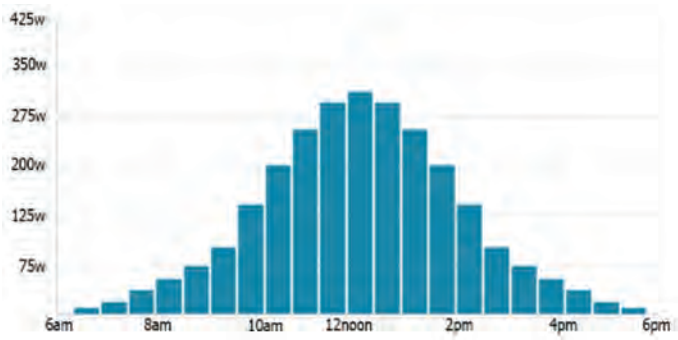


**Figure 1.** Electrical power generation of a 350-watt solar panel (Mclnerney, 2023)

generation exhibits a pattern characterized by increasing output in the morning, reaching its peak around midday due to the maximum intensity of sunlight, and subsequently declining. **Figure 1** illustrates the power generation profile of a specific 350-watt solar panel over a day, assuming ideal conditions of clear skies and no interference on the surface of the solar panels (Mclnerney, 2023). The incorporation of this power generation profile within a controlled setting enables an estimation of the overall electricity production achievable by solar panels.

Since solar energy is a clean and unlimited energy source, systems for producing electricity from solar cells are used in many sectors, including agriculture and fisheries. Previous research have shown that solar-powered water pump systems are attractive technology and are widely used for irrigation in the agricultural, industrial, and domestic sectors. In the capture fisheries sub-sector, some solar energy system applications include charging batteries onboard small-scale fishing vessels, cool rooms, and water pumps. Typically, fish landing sites utilize two types of water pump systems, namely: a) electric water pumps in areas with electric service and b) diesel water pumps in areas without electric service. Nevertheless, studies have shown that solar water pumps have several benefits over diesel or electric water pumps, in terms of cost-effectiveness, environmental friendliness through the absence of greenhouse gas emissions, low maintenance costs, and suitability for use in hybrid on/off-grid or remote areas (Korpal *et al.*, 2016; Ibrahim, 2017; Zhou & Abdullah, 2017; Imjai *et al.*, 2020; Nelson, 2021; Raza *et al.*, 2015; Schnetzer & Pluschke, 2017).

In 2022, the Training Department (TD) of SEAFDEC applied a 20-kW hybrid solar energy system with a budget of USD 20,000. Solar panels were installed on the rooftop of one of the office buildings of TD (**Figure 2**). Between 8:00 and 16:00, approximately 70 % of the electricity was generated from the solar panel while around 30% was generated from the electric power line (**Figure 3**) (SEAFDEC, 2022). After 1.5 years of installation, the hybrid solar energy system had the capacity to generate an average of 13 kW of electricity per day (**Figure 4**). This consistent performance was achieved through uninterrupted daily operation, devoid of errors and minimal maintenance. The maintenance routine primarily involved monthly cleaning of the solar panels with minimal costs. Taking into consideration the monthly savings in electricity costs, which ranged from USD 267 to USD 450 depending on the recent electric utility rate, the payback period of the hybrid solar energy system is estimated to be 5–6 years.

**Figure 2.** Solar panels installed on the rooftop of one of the SEAFDEC/TD office buildings in 2022

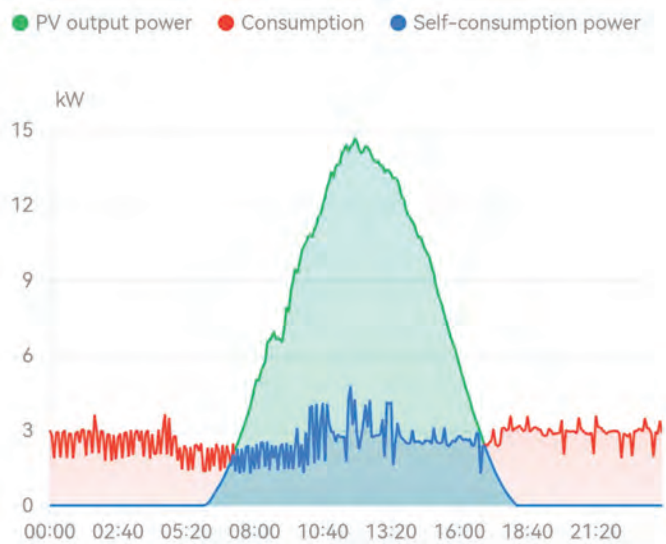


**Figure 3.** Electricity generated by a 20-kW hybrid solar energy system (70 % solar and 30 % electricity) installed at SEAFDEC/TD in 2022


**Figure 4.** Power generation of the 20-kW hybrid solar energy system applied by SEAFDEC/TD in 2022–2023

## Comparing the four water pump systems

The successful operation of the hybrid solar energy system applied by SEAFDEC/TD demonstrated stability and suitability for practical utilization of such system in fish landing sites that necessitate electricity cost reduction. Therefore, TD conducted a simulation study to compare the cost-benefit analysis and carbon emissions of four water pump systems powered by diesel fuel, electricity, solar energy, and hybrid solar energy (70 % solar and 30 % electric). The simulated scenario for the four water pump systems was at a 100 m2 fish landing site with the postulation that they operate under optimal maintenance conditions and are free from any breakdowns or efficiency reductions based on an 8-hr operation per day, representing the typical working hours in a fish landing site.

The diesel (**Figure 5a**) and electric (**Figure 5b**) water pump systems required only a single set of installations, and the key factors to consider were size and flow rate. In this context, a motor power or engine capacity of 4 kW can deliver water at a maximum flow rate of 600 L/min. On the other hand, the solar (**Figure 5c**) and hybrid solar (**Figure 5d**) water pump systems required the installation of three parallel panels of solar cells with a peak voltage of 45 Vp. Since the peak solar radiation occurs at noon, when the maximum power output reaches 9,900 watts, utilizing a 4,000-watt water pump in such circumstances would result in excessive production of electricity. Therefore, the installation of three parallel panels was crucial to accommodate the highest range of power generation. Moreover, the operations of the solar and hybrid solar water pump systems were under unobstructed sunlight and clear sky, thereby mitigating any potential external influences that could adversely affect their optimal performance.

**Economic analysis**

The associated costs of the four water pump systems were assumed to remain constant throughout the 5th year and 15th year duration (**Table 1**). The operational requirements of the diesel water pump system and electric water pump system necessitate a consistent provision of diesel fuel and electricity, respectively; resulting in continuous expenditures. As the duration of their usage increases, these expenses also tend to escalate with both the diesel and electric motor pumps necessitating replacement every five years. The diesel and electric water pump systems are specifically designed for nocturnal operations, utilizing off-peak electricity between 00:00 and 08:00. Consequently, the attributed variable costs demonstrate a negative trend for the diesel engine water pump system at about USD -4,161.00 per year, while the electric water pump system at USD -836.30 per year (**Table 2**).

For the solar water pump system and hybrid solar water pump system, the water pump and inverter require replacement every five years, solar panels every fifteen years, and water tanks every fifteen years for the solar water pump system (**Table 1**). Nonetheless, the solar water pump system and hybrid solar water pump system provide an opportunity for income generation or reduction in electricity expenses with estimated values of USD 2,027.00 per year and USD 1,419.00 per year, respectively (**Table 2**). Typically, the investment cycle of the solar water pump system and hybrid solar water pump

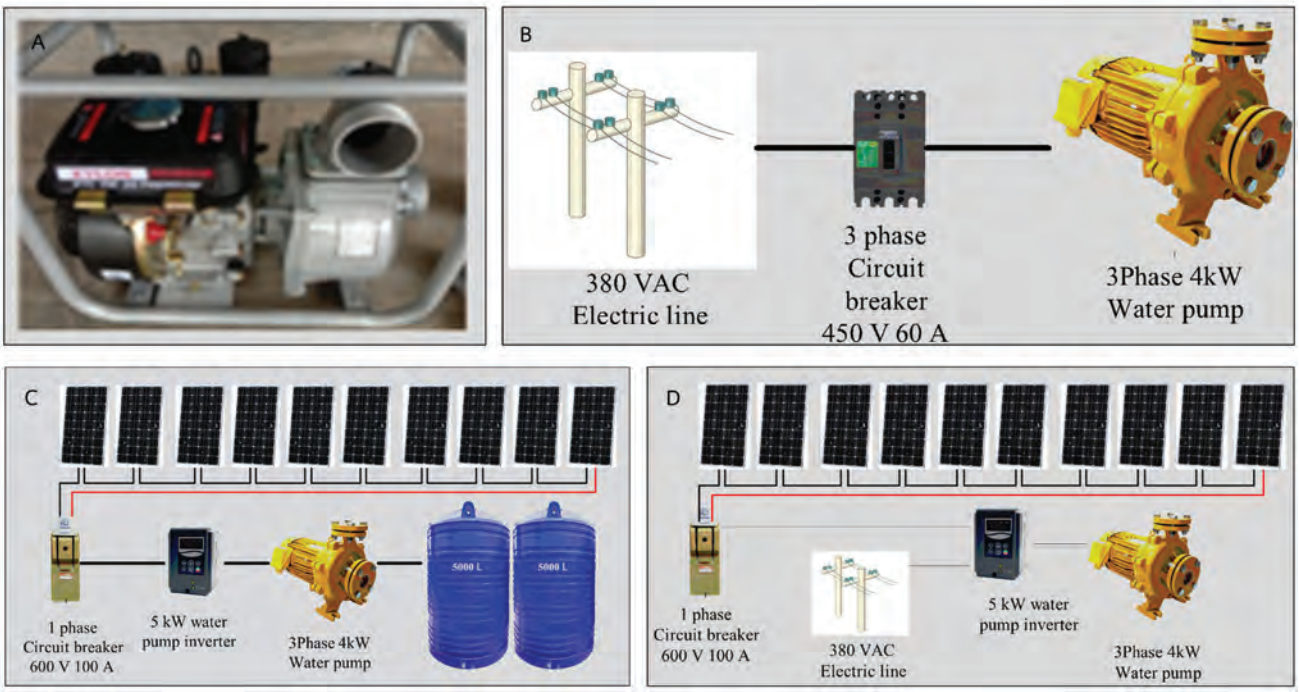


**Figure 5.** Components of each water pump system *(A: diesel, B: electric, C: solar, and D: hybrid solar)* for the simulation study conducted by SEAFDEC/TD

**Table 1.** Investment costs for diesel, electric, solar, and hybrid solar water pump systems

| Components | Power rate (kW; Hp) | Lifespan (years) | Quantity | Cost/unit (USD) | Initial investment (USD) | 5th year investment (USD) | 15th year investment (USD) |
|---|---|---|---|---|---|---|---|
| **Diesel water pump system** | | | | | | | |
| Diesel engine model:178FE | 4.0; 5.5 | 5 | 1 | 333.33 | 333.33 | 333.33 | |
| Water pump brand: XYLON (Model XY-30DE) | | | | | | | |
| Installation cost | | | | | 166.67 | | |
| **Total investment** | | | | | **500.00** | | |
| **Electric water pump system** | | | | | | | |
| Water pump | 4.0; 5.5 | 5 | 1 | 400.00 | 400.00 | 400.00 | |
| Installation | | | | | 1,333.33 | | |
| **Total investment** | | | | | **1,733.33** | | |
| **Solar water pump system** | | | | | | | |
| Solar cell (W) | 0.35 | 25 | 30 | 100.00 | 3,000.00 | | 3,000.00 |
| Water pump power | 4.0; 5.5 | 5 | 3 | 400.00 | 1,200.00 | 1,200.00 | |
| Inverter | 5.0; 6.75 | 5 | 3 | 400.00 | 1,200.00 | 1,200.00 | |
| 5 $m^3$ water tank cost | | 15 | 2 | 500.00 | 1,000.00 | | 1,000.00 |
| Installation | | | | | 4,000.00 | | |
| **Total investment** | | | | | **10,400.00** | | |
| **Hybrid solar water pump system** | | | | | | | |
| Solar cell (W) | 0.35 | 25 | 30 | 100.00 | 3,000.00 | | 3,000.00 |
| Water pump power | 4.0; 5.5 | 5 | 3 | 400.00 | 1,200.00 | 1,200.00 | |
| Inverter | 5.0; 6.75 | 5 | 3 | 400.00 | 1,200.00 | 1,200.00 | |
| Installation | | | | | 3,333.00 | | |
| **Total investment** | | | | | **8,733.00** | | |

**Table 2.** Variable costs for diesel, electric, solar, and hybrid solar water pump systems

| | |
|---|---|
| **Diesel water pump system** | |
| Fuel consumption (g/kWh) | 285.60 |
| Fuel consumption (L/h) | 1.63 |
| Operation period (hr/day) | 8 |
| Operation period (days/year) | 365 |
| Fuel consumption (L/day) | 13.06 |
| Diesel oil price (USD/L) | 0.86 |
| Lubricating oil (USD/year) | 80.00 |
| Total fuel cost (USD/year) | -4,161.00 |
| **Electric water pump system** | |
| Electric utility rate (USD/kWh) | |
| On-peak period (09:00–22:00) | 0.15 |
| Off-peak period (22:00–09:00) | 0.07 |
| Operation period (hr/day) | 8 |
| Operation period (days/year) | 365 |
| Total electricity consumption (unit/year) | 11,680.00 |
| Annual electricity savings during 00:00–08:00 (USD) | -836.30 |
| **Solar water pump system** | |
| Annual electricity savings during 8:00–16:00 (USD) | 2,027.00 |
| **Hybrid solar water pump system** | |
| Annual electricity savings during 8:00–16:00 (USD) | 1,419.00 |

system is based on the 15-year warranty of the solar panels, and multiple rounds of investment could result in higher cumulative profits from lower electrical costs. Considering the duration of the solar panel warranty, the payback period for the solar water pump system is seven years while the hybrid solar water pump system is eight years.

### $CO_2$ emission analysis

In Thailand, the existing electric generating process of the Electric Generating Authority of Thailand (EGAT) is reliant on multifuel sources. Based on the consumption and $CO_2$ emissions of each type of fuel, the weighted average specific $CO_2$ emission from all types of fuel is roughly 0.18 kg $CO_2$ per kWh (**Table 3**). Comparing the specific $CO_2$ emissions of different fuels, the carbon footprint of each water pump system is illustrated in **Figure 6**. The diesel water pump system and electric water pump system emit a significant quantity of $CO_2$ into the environment when in use. But since solar energy is a green technology, the solar water pump system does not release into the environment, the hybrid solar water pump system releases some $CO_2$ from its electric source.

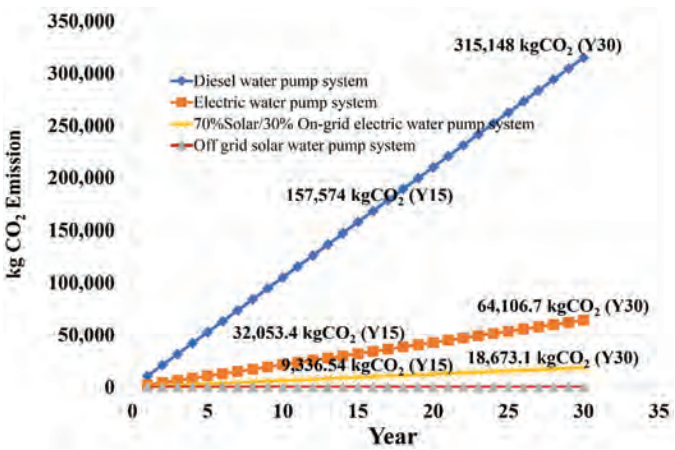


**Figure 6.** Simulated $CO_2$ emissions (kg) of diesel, electric, solar, and hybrid solar water pump systems

**Table 3.** Electric-grid generation by fuel type of Thailand (EGAT, 2021) and specific $CO_2$ emission of each type of fuel (Engineering ToolBox, 2009)

| Fuel type | Thailand electric-grid generation (January-August 2021) | | Specific $CO_2$ emission | | |
|---|---|---|---|---|---|
| | Unit (MWh) | % | $kgCO_2$/kgfuel | $kgCO_2$/kWh | Weighted average |
| Compressed natural gas | 75,552.61 | 57.55 | 2.75 | 0.185 | 10.65 |
| Diesel | 185.42 | 0.14 | 3.15 | 0.25 | 0.04 |
| Coal (lignite) | 30,499.15 | 23.23 | 1.10 | 0.31 | 7.20 |
| Heavy oil | 341.32 | 0.26 | 3.11 | 0.27 | 0.07 |
| Wood | NA | NA | 1.83 | 0.41 | NA |
| Renewable energy (biogas, solar, wind, hydro, geothermal) | 23,185.60 | 17.66 | 0 | 0 | 0.00 |
| Others (Lao PDR, Malaysia, etc.) | 1,517.02 | 1.16 | NA | NA | 0.00 |
| **Total** | 131,281.12 | 100.00 | | | 0.18 |

## Conclusion and Way Forward

Taking into account the long-term operating costs and environmental impacts of the four water pump systems, it seemed that the solar water pump system provides the most advantages in terms of economic aspects and environmental impacts. However, the solar water pump system exhibits constraints with regard to energy source stability and storage space requirements, making it less optimal compared to the hybrid solar water pump system.

The use of solar energy is limited only during the day since solar cells require sunlight to generate electricity; thus, the solar water pump system and hybrid solar water pump system are exclusively operational during daylight hours and the water flow rate varies depending on light intensity. During low light intensity, the flow rate is low, but during four hours of midday when the light intensity is high, the flow rate is high. To ensure a consistent and adequate water flow rate during low light intensity, large-capacity water tanks are needed as water accumulators to store potential energy and water supply in a fish landing site. These storage tanks play a crucial role in maintaining the flow rate and increasing the potential pressure of water in the pipeline without depending on sunlight intensity. In contrast to the solar water pump system, the hybrid solar water pump system does not require water storage tanks, which are considered a significant cost in the initial investment and will require a lot of space which could be an issue for a fish landing site that has limited space. Although the hybrid solar water pump system needs a higher initial investment than the solar water pump system, its long-term investment is lower than those of diesel and electric water pump systems over time.

Considering the various benefits such as cheaper investment costs and lesser environmental impacts, the hybrid solar water pump system is ideal and could be a successful application in fish landing sites for reducing power costs and requiring less equipment. The results of this simulation study should not be confined to a 4-kW water pump system that can be scaled up or down to achieve similar outcomes. This innovation could be adopted by key stakeholders, thereby contributing to the promotion of sustainable and responsible fishing practices.

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