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SOLAR PANEL APPLICATION IN KOI SPAWNING PONDS FOR IMPROVED FISH FARMING PRODUCTIVITY IN TULUNGAGUNG

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Abstract
The Community Service (CS) program took place in Sumberingin Kidul Village, Ngunut District, Tulungagung Regency, approximately 100 km southwest of Malang City. The target group for this program includes small and medium enterprises (SMEs) engaged in koi fish spawning. Our partners face several challenges, primarily the reliance on aeration pumps powered by the national electricity grid (PLN) to supply oxygen to the ponds. The program aimed to install a 100 Wp solar panel system to generate clean energy for a low-voltage aeration pump, helping to maintain optimal oxygen levels in the pond and supporting healthy fish growth. The program successfully implemented this solar-powered aerator pump system in the pond area, providing an innovative, sustainable solution that empowers the community by integrating science and technology into fisheries. It is hoped that this program will inspire other fish farmers in Tulungagung and surrounding areas to adopt similar sustainable practices.
Keywords: Aeration Pump, Cultivation, Koi Spawning, Solar Panel, Tulungagung Regency

INTRODUCTION

Sumberingin Kidul Village is known for its significant livestock industry, which includes a diverse range of animals such as laying hens, broiler chickens, Arabic chickens, quails, cows, Etawah (*Jamnapari*) goats, and various types of fish, including gourami, catfish, and ornamental fish. According to data from the Tulungagung Regency Fisheries and Livestock Agency (DKP Kab. Tulungagung, 2024), this district is renowned as a major centre for freshwater fish farming, catering to both consumption and ornamental fish markets. Remarkably, the ornamental fish industry in this area supplies nearly 90% of Indonesia's demand and has even extended exports to neighbouring countries.

The target beneficiaries of this community service are small and medium-sized enterprises (SMEs) involved in ornamental fish farming, specifically Koi fish farming. Our partner has been in this business for 10 years. The partner manages a facility that includes six permanent cement ponds, each measuring 20 metres by 6 metres with a depth of 1.25 metres, dedicated to Koi spawning. In addition, a circular tarpaulin pond complements their aquaculture operations. Figure 1 shows a stationary concrete-lined pond used for spawning

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Koi fish, owned by the partner. Meanwhile, Figure 2 shows a portable circular pond made from tarpaulin.

Figure 1. The spawning pond for the Koi fish

Figure 2. A circular tarpaulin pond used to breed Koi

The Community Service Partners started cultivating Koi fish in 2015, after previously using the pond for catfish farming. Initially, they suffered losses due to lack of experience and knowledge. However, they began to see positive results. In the last two years, they have consistently made a profit from the harvest. The main challenge faced by the partners is the significant amount of electricity required to run the pond equipment, particularly the aeration pumps. This often results in minimal lighting at night, leading to murky and stagnant water conditions that can hinder fish growth. The current aeration system, consisting of two standard aerators distributed throughout the pond via a simple branched hose system, is insufficient to maintain optimum oxygen levels. As a result, prolonged power outages can lead to mass fish mortality, as shown in Figure 3, which shows Koi that have perished due to a malfunctioning aerator.

Figure 3. The koi fish died due to a lack of oxygen caused by malfunctioning aerators

In a turbid pond, Koi fish mortality due to oxygen depletion is the result of several biological and environmental processes that are exacerbated when aeration is interrupted. Cloudy water often contains high levels of organic matter such as algae, food waste and fish waste. This organic matter serves as a nutrient source for aerobic bacteria that break down the matter, consuming dissolved oxygen (DO) in the process. As these bacteria thrive in turbid water, oxygen levels are depleted more rapidly, especially in stagnant conditions where natural oxygen replenishment is limited.

In ponds, oxygen is typically produced by algae and aquatic plants through photosynthesis during the day. However, at night, both plants and animals in the pond consume oxygen through respiration rather than producing it. If the aerator fails, this natural oxygen supply is insufficient, and DO levels can fall sharply, particularly in the early morning when no photosynthetic oxygen production has occurred overnight (Sutanto et al., 2023). In warmer climates (pond locations), water temperatures are higher, which reduces the water's capacity to hold dissolved oxygen. As the pond temperature rises, the effects of oxygen depletion worsen, particularly in warm, turbid ponds. This issue is common in stagnant or shallow ponds where water temperature increases quickly without circulation. Additionally, Koi fish are highly active and have a high metabolic rate, requiring significant amounts of oxygen. When aerators fail, especially overnight, oxygen levels can plummet, leading to hypoxia. Prolonged exposure to low oxygen levels can cause physiological stress and, ultimately, death (Budiman, 2022).

In Indonesia, research on solar panel technology has been widely applied in various community service projects over the past five years (Asrori et al., 2021; Witono et al., 2023), particularly in sectors such as agriculture, fisheries, and livestock (Asrori et al., 2023; Candra et al., 2024). In the fisheries sector, solar energy applications have been implemented in multiple research studies and community service initiatives. For example, Nofriadi (2021) developed a solar-powered LED lighting system for fish ponds, designed to deter predators at night while reducing energy consumption. Both on-grid and off-grid solar systems have been proposed for fish farming ponds, with land-based installations recommended for larger operations (Ramadhan et al., 2021). In catfish farming, solar-powered bio floc ponds have demonstrated increased production capacity and economic benefits, especially during the COVID-19 pandemic (Nurhadi et al., 2021).

Solar energy offers a sustainable solution for powering koi fish ponds. By integrating solar power systems, fish farmers can enhance aeration, filtration, and overall pond management. Asrori et al. (2022) demonstrated this by installing a 600 Wp solar power system to address high electricity costs and outages. This system, consisting of solar panels, an inverter, and a battery, generates approximately 2.5 kWh of electricity daily, powering filtration pumps and aerators. This not only reduces costs but also improves water quality and fish health, contributing to the sustainability and profitability of koi fish farming.

Nisrina et al. (2024) also studied the application of solar panels in fish farming, focusing on the use of solar energy to power water pumps in fish ponds. This system supports the oxygenation and water circulation necessary for fish survival. Solar panels provide an alternative to grid electricity, reducing dependence on conventional energy sources and lowering operating costs. By installing two 100WP solar panels, the study aimed to reduce operating costs and improve fish health. The system generated an average of 24.48 watts per 30 minutes, even in less than ideal weather conditions, demonstrating the potential of solar energy for fish farming.

Currently, one of the major challenges in aquaculture is its energy-intensive nature, often relying on traditional, costly and environmentally unsustainable sources of electricity. The integration of solar panels into Koi spawning ponds offers a sustainable solution that uses renewable energy to power essential components of the fish farming system, helping to address these challenges. Therefore, based on the background provided, the objectives of this project are to develop a 100 Wp solar module system that can be effectively assembled to operate a pond aeration. In addition, a short training programme will be offered to facilitate technology transfer to fish farmers.

IMPLEMENTATION METHOD

The efficacy of a community service (CS) project is contingent upon the implementation of effective and sustainable strategies. It is of the utmost importance that a well-defined implementation methodology, tailored to the specific solutions proposed by the team, be in place. Detailed technical specifications must accompany the methodology to ensure seamless project execution.

The initial phase comprises a series of pivotal stages. (i) Internal team coordination: The coordination of lecturers, technicians, and students is essential for the reinforcement of the program structure and the guarantee of organized and focused activities. (ii) Partner coordination: Collaborating with partners to finalize the plan for installing solar panel systems and their equipment. (iii) Site assessment: Reviewing the pond location and identifying strategic points for equipment placement. (iv) Material procurement: Acquiring necessary tools and materials, including solar panels, battery controllers, batteries, aerator pumps, and supporting components. (v) Local workforce coordination: Local laborers were engaged to provide installation assistance.

Additionally, the implementation of CS activities follows the sequence outlined in the flow diagram shown in Figure 4.

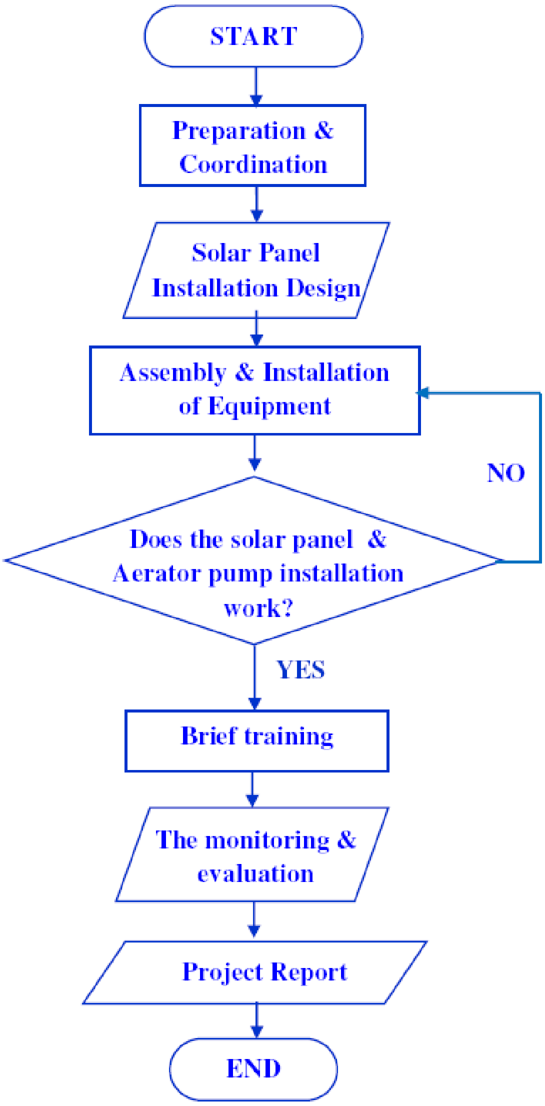

Figure 4. Flowchart of community service implementation

This community service project utilized technology selected based on findings from previous research (Asrori et al., 2022b; Susilo et al., 2021; Yuhanandri, 2023). Solar panels were identified as a suitable energy source to fulfil the electricity needs of community businesses. The system included 100 Wp Monocrystalline-PV modules, a 10A/12V PWM solar charge controller, a 50 Ah/12V VRLA battery, a 25W/12V DC aerator pump, a mounting frame, and essential installation components, such as cables, panel boxes, switches, connectors, and DC lights. Figure 5 shows the schematic diagram of the solar-powered aeration system, illustrating the components and their connections in detail.

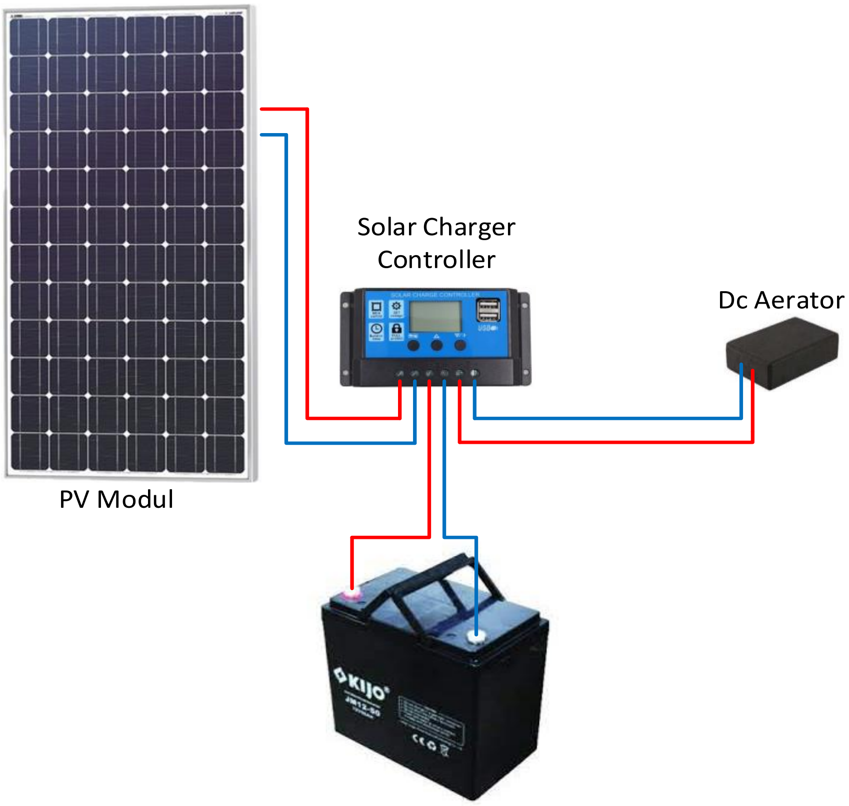

Figure 5. The schematic diagram of the solar-powered aeration system

The diagram (Figure 5) illustrates a solar-powered aeration system, consisting of a PV module, solar charge controller, battery, and DC aerator. The PV module (solar panel) captures sunlight and converts it into electricity, which then flows to the solar charge controller. The charge controller regulates the current to prevent overcharging and manages the flow of electricity from the PV module to the battery and aerator.

The battery, rated at 50 Ah, stores the electricity generated by the PV module for later use, ensuring that the aerator has a consistent power supply even when sunlight is unavailable. The DC aerator is connected to the battery via the charge controller, providing aeration to the pond as needed. Red and blue lines indicate positive and negative connections, respectively, showing the flow of electricity through each component in the system.

RESULTS AND DISCUSSION

A. Installation of Solar Power System

Figures 6 to 8 illustrate the steps involved in installing a 100 Wp solar panel to power a DC aerator pump for a koi pond. The initial step, shown in Figure 6, involves preparing the solar panel system by connecting the panel to supporting components like the charge controller and battery. This process requires measuring, cutting, and stripping cables to ensure proper connections. Before assembling the components, it's crucial to carefully review the electronic schematics and technical specifications to guarantee a precise and reliable installation.

Figure 6. Solar panel wiring and connection assembly

Figure 7 illustrates the results of installing a 100 Wp solar panel. To ensure optimal performance, several key factors must be considered: (i) Positioning of the Solar Panel: The placement of the solar panel is critical and requires careful attention. It is mounted on the roof in a position that maximizes sunlight exposure. Special consideration is given to the orientation and tilt angle, as the panel is installed on a sloped roof to enhance sunlight absorption and energy production. (ii) Cable Connections: The panel is connected to the solar charge controller (SCC) using MC4 connectors. These connectors are vital for maintaining a stable current flow and preventing short circuits. (iii) Environmental Factors: It is essential to evaluate the potential impact of nearby trees and plants on the panel's performance. Shading from these obstacles can significantly reduce the panel's efficiency when it comes to harnessing sunlight throughout the day.

Figure 7. Mounting solar panels on a sloped roof

Once the solar panels are properly connected, the next step is to install the necessary supporting equipment, as shown in Figure 8. This involves connecting the solar charge controller (SCC), batteries, and appropriate cables to the aeration system, including the pump and aerator.

Figure 8. Installation of solar power equipment

B. Installation of Aerator pump

A DC aerator pump is a device that extracts water from a pond, introduces oxygen into it, and then returns the oxygenated water to the pond. This process is of great consequence to the health of the fish, as it helps maintain optimal oxygen levels in the water, particularly during periods of low oxygen levels. Figure 9 shows the assembly process of an aerator pump connected to a battery source.

Figure 9. Pond aeration installation

C. Testing the pond aeration system

The final step involves testing the installed aerator to ensure optimal performance. This includes verifying sufficient oxygenation, detecting potential installation issues, and optimizing energy efficiency. Figures 10 and 11 illustrate the aerator and DC pump system in operation in the koi spawning pond.

Figure 10. Aerators function effectively by creating bubbles in the pond

Figure 11. The pump's functionality and the observable outcome of the water jet

Applying solar-powered aeration technology to the koi spawning pond in Tulungagung has proven effective in enhancing water quality and fish health, leading to higher yields and improved product quality. Furthermore, utilizing solar power can enhance the economic sustainability of aquaculture by decreasing electricity expenses, which subsequently boosts the profitability of fish farming operations. This method is particularly advantageous for small-scale farmers who may not have access to reliable grid electricity, making solar power a practical and appealing alternative.

D. Handing Over Appropriate Technology to Partners

The final stage of this community service activity is the handover process of appropriate technology (AT), as shown in Figures 12 and 13.

Figure 12. The handover process is conducted with the community service partners

Figure 13. The Polinema Community Service Team and their partners at the koi pond

The handover process is a crucial element in the sustainable use and adoption of appropriate technology (AT) within communities. The process serves to reinforce communities by cultivating a sense of ownership, promoting active involvement, and guaranteeing accountability for the upkeep of the technology. Furthermore, the process incorporates brief training sessions that equip partners with the requisite skills to operate, maintain, and troubleshoot AT independently, thereby reinforcing local technician expertise. Furthermore, the handover process fosters trust and transparency between the implementing organization and the community, reflecting a genuine commitment to their development. Furthermore, this structured approach allows for the collection of valuable feedback, which can then be used to inform improvements in future projects and, ultimately, to ensure the technology's lasting impact and sustainability.

CONCLUSION

The assembly of the 100 Wp off-grid solar panel system is relatively simple, with key components including solar panels, a solar charge controller, and batteries. The DC output is used directly to power aerators or water pumps for aerating a koi fish spawning pond. Installing a 100 Wp solar panel at the pond location can generate approximately 13.5 kWh per month, potentially saving around IDR 19,500 per month under ideal conditions. Additionally, brief training on the operation and maintenance of the 100 Wp solar power system is necessary to ensure safe, correct usage, thereby maximizing the equipment's lifespan.

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