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Implementation of Solar-Powered Submersible Pump Technology (PSTSP) to Increase Rainfed Rice Field Production

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Abstract: *Waninggap Miraf is one of the villages with its main source of income being rice cultivation. Rainfed rice fields are managed by relying on rainwater stored in reservoirs, requiring Alkon pumps to control and supply water. However, operational costs for irrigating the fields have increased due to using oil-based fuels in the Alkon pumps. The implementation of Portable Solar-Powered Submersible Pump Technology (PSTSP) is expected to solve the challenges farmers face. The method utilized is harnessing solar energy as an alternative to oil-based fuels. The dissemination of this technology aims to optimize operational costs and enhance farmers' knowledge of utilizing renewable energy in agriculture. The implementation of this community-driven project involves the participation of the local community in the process of socialization, planning, design, training, and technology application. Based on trial results, this project has successfully increased farmers' knowledge and reduced operational costs by sustaining for up to 4 hours, supplying approximately 12,000 liters of water per hour.*

Introduction

The village of Waninggap Miraf is one of the villages located in the Tanah Miring District, Merauke Regency, Papua Province. The Tanah Miring District is the largest producer of rice in Merauke Regency, Papua Province, with a total rice production reaching 90,600.16 tons and a planting area of 15,784 hectares. [1] The main source of income in Waninggap Miraf village is rice cultivation. The graph of rice production growth over the years has been continuously increasing with the expansion of new land openings.[2] Nearly 95% of the rice fields in Merauke Regency are rainfed, relying on

[1] Badan Pusat Statistik, "Kabupaten Merauke Dalam Angka," BPS - Statistics Indonesia, 2021, https://meraukekab.bps.go.id/publication/2021/02/26/97ca4325f867c3604c247b8c/kabupaten-merauke-dalam-angka-2021.html.

[2] BPS, "Kecamatan Tanah Miring Dalam Angka 2019," Energy BPS-Statistics Indonesia, 2019, https://meraukekab.bps.go.id/publication/2019/09/27/6c6937b8d07186983a7ac2fa/kecamatan-

water from rain stored in long storage (reservoirs or ponds). [3] Rainwater is collected in long storage for water supply after the rainy season. The elevation difference between the reservoir and the rice fields requires the water in the long storage to be pumped for irrigation. However, farmers have faced a problem in irrigating their rice fields. They use fuel-powered Alkon pumps to extract water from the long storage. The fuel consumption for irrigating 1 hectare is 60 liters of gasoline, costing around Rp. 4,200,000 per hectare. During the dry season, the water source from long storage starts to deplete, and sometimes even runs out. Farmers have to spend twice the amount to fetch water from distant long storages.

The implementation of the Portable Solar-Powered Submersible Pump technology offers a new and renewable solution to reduce production costs for farmers, particularly the fuel expenses for water pumping. This technology has been developed through various research starting from 2014, exploring electric wind-powered pumps for agricultural irrigation. However, the uneven distribution of wind throughout the day led to unstable charging of the battery, which took a relatively long time to reach the nominal voltage of 12 Volt-DC.[4] In 2015, the concept of Hybrid Solar Cell - Wind Power Application to Support Agricultural Irrigation Provision (Case Study: 1600 m2 Rice Field) was developed, resulting in promising outcomes.[5] In 2020, a study on the potential of renewable energy in Merauke Regency revealed that solar energy has enormous potential, with an average power intensity of 5.38 kWh m-2d-1 per year.[6] Further research by Parenden and Hariyanto tested the solar cell concentration, showing that the output power is significantly affected by solar intensity and the operational temperature of the solar cell. Rusdi et al. conducted research on inverters for power electronic devices that convert DC electrical energy into AC.[7] Several studies

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tanah-miring-dalam-angka-2019.html.

[3] A. R. Dungu and E. U. K. Retang, "FAKTOR-FAKTOR YANG MEMPENGARUHI PRODUKSI PADI SAWAH TADAH HUJAN DI DESA UMBU PABAL KECAMATAN UMBU RATU NGGAY BARAT KABUPATEN SUMBA TENGAH," *Jurnl Pertanian Agros* 25, no. 1 (2023): 714–723, http://www.e-journal.janabadra.ac.id/index.php/JA/article/view/2501/1669; M. Maliano, E. Yurisinthae, and A. Suharyani, "KINERJA USAHATANI PADI SAWAH TADAH HUJAN DI KECAMATAN SUNGAI KAKAP KABUPATEN KUBU RAYA," *Jurnal Ekonomi Pertanian Dan Agribisnis (JEPA)* 6, no. 4 (2022): 1271–1280,

[4] Jayadi and D. Hardiantono, "Desain Modul Pengukuran Potensi Pompa Listrik Tenaga Angin (Studi Kasus Ptl-Angin Kapasitas 100 Watt)," *Jurnal Ilmiah Mustek Anim Ha 3*, no. 3 (2014): 239–247.

[5] J. Jayadi, M. Alahudin, and U. Untari, "Aplikasi Hibrid Solar Cell - Wind Power Untuk Mendukung Penyediaan Irigasi Pertanian (Studi Kasus Lahan Sawah 1600 M2)," *Seminar Nasionar Industrialisasi Madura (SNIRA)* 2015 (2015): 257–262.

[6] H. Hariyanto, D. Parenden, Z. Vincēviča-Gaile, and P. Gamawati Adinurani, "Potential of New and Renewable Energy in Merauke Regency as the Future Energy," *E3S Web of Conferences 190* (2020): 00012, https://doi.org/10.1051/e3sconf/202019000012.

[7] M. Rusdi, F. A. Samman, and R. S. Sadjad, "FPGA-based electronic pulse generator for single-phase DC/AC inverter," in 2019 *International Conference on Information and Communications Technology, ICOIACT* 2019 (2019): 756–760, https://doi.org/10.1109/ICOIACT46704.2019.8938571.; M. Rusdi, F. A. Samman, R. S. Sadjad, A. E. U. Salam, and C. MacHbub, "Standalone Single Phase DC-AC Inverter with FPGA-based Pulse Modulated Generator Unit," in Proceedings - 2020 *International Seminar on Intelligent Technology and Its Application: Humanification of Reliable Intelligent Systems, ISITIA 2020* (2020): 7–12, https://doi.org/10.1109/ISITIA49792.2020.9163770.

on using submersible pumps with application as per the requirement have been carried out.[8]

The use of submersible pumps requires electrical energy as the power source for the pump. In this community engagement, renewable solar energy is utilized as the energy source by converting sunlight into electrical energy using solar cells. However, the electrical energy produced by solar cells is in the form of direct current (DC). Therefore, additional power electronic devices are needed to convert the DC electrical energy into alternating current (AC) electrical energy required by the submersible pump. The DC/AC converter, also known as an inverter, is the power electronic device responsible for this conversion. All the devices, including the pump, solar cells, and inverter, have been integrated into one portable unit inside a cart that can be easily pushed, making it convenient for the farmers. This technology is known as the Portable Solar-Powered Submersible Pump (PSTSP).

This Community Partnership Program aims to improve the farmers' economic and productive conditions and promote the utilization of affordable and environmentally friendly renewable energy. In this program, the partner community is the Mulya Business Farmer Group located in Waninggap Miraf Village, Tanah Miring District, Merauke Regency, South Papua Province. The solution offered through this Community Partnership Program is the dissemination of the technology product and the implementation of the Portable Solar-Powered Submersible Pump technology. The partner farmers will be equipped with workshops on designing and using the Portable Solar-Powered Submersible Pump technology to understand its operation and proper maintenance. Implementing this program is expected to help farmers reduce production costs, especially the expenses for purchasing fuel to irrigate the rice fields, thus improving their economic conditions.

Method

The implementation of this program is located in Waninggap Miraf Village, Merauke Regency, Papua (Figure 1). The partners involved in the implementation are the Mulya Business Farmer Group and the Village Government of Waninggap Miraf.

[8] H. Budiyanto, P. Tutuko, A. B. Setiawan, R. Mas, and B. Jati, "Listrik Tenaga Surya untuk Pompa Submersible pada Greenhouse Hidroganik di Kabupaten Malang," *ABDIMAS: Jurnal Pengabdian Masyarakat Universitas Merdeka Malang* 6, August 2021, 336–346.; A. Bukhori, I. N. Setiawan, and I. W. A. Wijaya, "TENAGA SURYA SEBAGAI SUPLAI DAYA POMPA AIR SUBMERSIBLE INOTO 2 HP DI DUSUN LERAN," *Jurnal SPEKTRUM* 8, no. 4 (2021): 117–125.

Figure 1. Location of Waninggap Miraf Village in Merauke Regency, Papua

Implementing this Community Partnership Program adopts the Community Development (CD) method, involving direct participation of the community in the activities. The CD method in this community engagement aims to develop and enhance the community's understanding of technology application in agriculture. It also encourages and promotes utilizing local resources to improve the community's well-being. Implementing the activities involves several stages, including situation analysis, technology dissemination, planning and design of the technology, training on technology usage, and monitoring and evaluation (Figure 2).

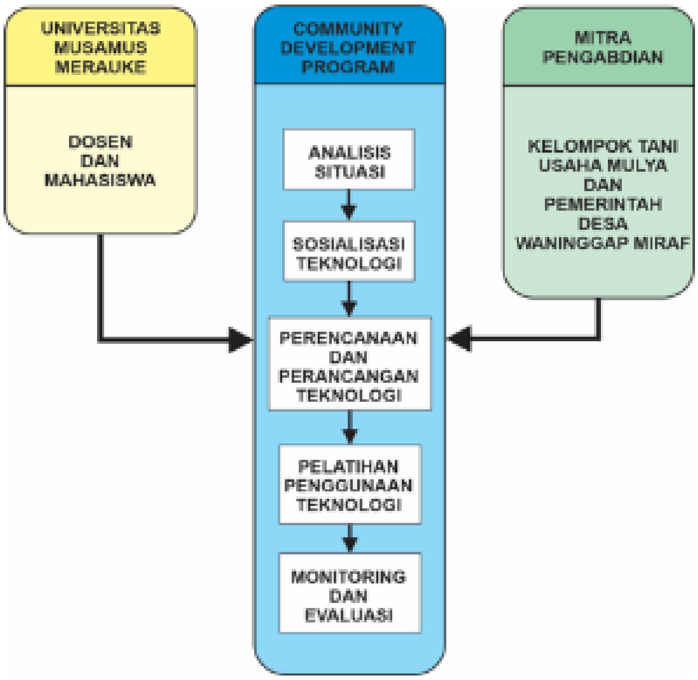

Figure 2. Flowchart of Community Partnership Implementation

Situation Analysis: The engagement team conducts interviews with the partners to gather information about their challenges and conducts on-site visits to the engagement location.

Technology Dissemination: This stage aims to inform the partners about the importance of the technology product, specifically the Portable Solar-Powered Submersible Pump, in addressing their production cost issues. The partners actively participate in providing input during the planning and design of the technology, tailored to the specific conditions at the engagement site.

Planning & Design of Technology: This stage involves the design and construction of the Portable Solar-Powered Submersible Pump over a period of 2 months. It includes preparing the necessary tools and materials, fabricating the framework, welding, painting, and assembling the pump with other components until completion.

Technology Usage Training: This stage aims to provide training on the operation of the Portable Solar-Powered Submersible Pump. A workshop on pump operation aims to impart understanding to the farmers about the importance of operating and maintaining the pump in accordance with standard operational procedures.

Monitoring and Evaluation: Regular monitoring and evaluation are conducted every month for 6 months to assess the performance and maintenance of the Portable Solar-Powered Submersible Pump.

Result

Existing Community Mapping

The engagement activities begin with an initial survey to gather information about the challenges the farmer group faces and the current field conditions. Based on the situation analysis and direct interviews with the Waninggap Miraf farmer group, it is found that their main source of income comes from rice cultivation. The type of rice fields cultivated by the community is mostly rainfed, relying on rainwater for irrigation. Rainwater is also collected in long storages (ponds) for water supply during the dry season. However, due to the elevation difference between the water source and the fields, water in the long storages needs to be pumped to irrigate the rice fields.

Design and Development of Technology

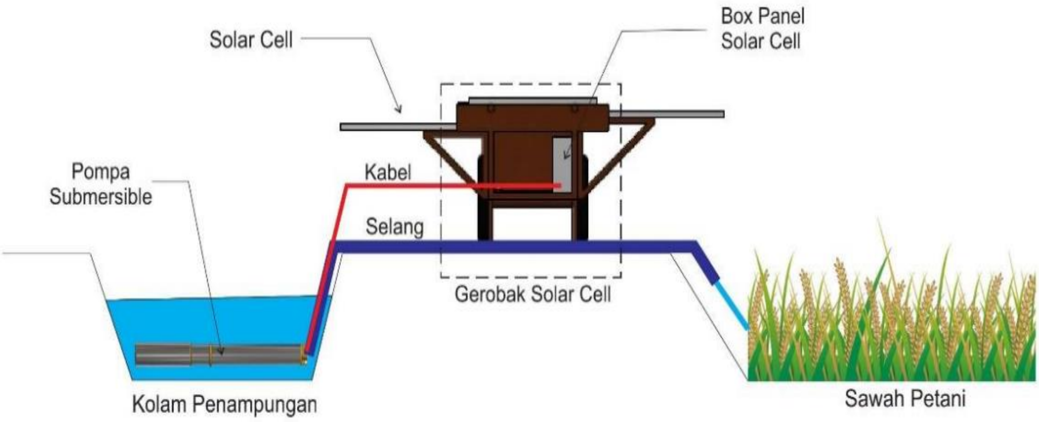

Figure 3. Illustration of Portable Solar-Powered Submersible Pump Technology

This technology is called the Portable Solar-Powered Submersible Pump (PSTSP), designed to meet the needs of farmers in pumping water to their fields in a cost-effective manner. The components of the pump, including a 500 W pump, 750 Wp solar cell, 1100VA inverter, 200Ah battery (accu), and BCU (Battery Charger Unit), are integrated into a portable cart to facilitate easy transportation for farmers, as shown in Figure 1. The working principle of the pump is that solar energy absorbed by the solar cell is directly converted into electrical energy. The electrical energy generated by the solar cell is in the form of direct current (DC). The DC current is stored in the battery (accu) using the BCU (Battery Charger Unit). The inverter functions to convert the DC electrical energy into alternating current (AC) electrical energy. The AC current from the inverter is then directed to the submersible pump installed in the water storage, which supplies water to the farmer's fields, as shown in Figure 3.

Figure 4. Design and Testing Process of Portable Solar-Powered Submersible Pump Technology

The next stage involves the design of the Portable Solar-Powered Submersible Pump Technology, which goes through several stages of work, starting with technology modeling to minimize errors during the technology development. The subsequent process involves the fabrication of the technology, including the construction of the cart and the installation of the solar-powered electrical system. The final step is the safety testing in operating the technology and collecting performance data before handing it over to the partners, as shown in Figure 4.

Operational Testing in the Assisted Community

The results of the operational testing and performance data collection can be seen in Table 1. The testing was conducted in Merauke Regency on November 1, 2021, from 10:50 AM to 3:00 PM local time. During the testing, the pump was continuously operated under cloudy weather conditions, resulting in suboptimal charging of the battery through the solar panels, with an average charging power of 235.974 W. Meanwhile, the average load power was 488.114 W, which reduced the pump's operating time to prevent battery damage.

Table 1. Data from Portable Solar-Powered Submersible Pump Technology Testing

Parameter	**Nilai**
Average solar radiation produced	712,6 W/m^2
Average power generated by solar cell	256,115 W
Average power for battery/accumulator charging	235,974 W
Average power of output load (Inverter + Submersible Pump)	488,114 W

Submersible pump water discharge rate	3,5 m^3/s atau 12.000 Liter/jam

Capacity Building of Community

The next step is for the engagement team to provide training on the operation and maintenance of the Portable Solar-Powered Submersible Pump technology to the partner, the Yasa Mulya Farmers' Group in Waninggap Miraf Village, Tanah Miring District, Merauke Papua. The technology is handed over to the partners during a workshop event, as shown in Figure 5. Additionally, the team prepares an operational guide sheet to facilitate the partners' understanding.

Figure 5. Workshop Activity and Technology Handover

Discussion

The use of a submersible pump requires electrical energy as the power source. In this engagement, solar energy is utilized as a renewable energy source and converted into electrical energy using solar cells.[9] However, the electrical energy produced by the solar cells is direct current (DC). Hence, additional power electronic devices, such as a DC/AC converter or inverter, are needed to convert the DC electrical energy into alternating current (AC), which is required for the submersible pump. [10] All the

[9] D. Parenden and H. Hariyanto, "Simulation of photovoltaic concentration with Fresnel lens using Simulink MATLAB," *European Journal of Electrical Engineering* 21, no. 2 (2019): 223–227, https://doi.org/10.18280/ejee.210214

[10] M. Rusdi, F. A. Samman, and R. S. Sadjad, "FPGA-based electronic pulse generator for single-phase DC/AC inverter," in *2019 International Conference on Information and Communications Technology, ICOIACT 2019* (2019): 756–760, https://doi.org/10.1109/ICOIACT46704.2019.8938571.

M. Rusdi, F. A. Samman, R. S. Sadjad, A. E. U. Salam, and C. MacHbub, "Standalone Single Phase DC-AC Inverter with FPGA-based Pulse Modulated Generator Unit," in *Proceedings - 2020 International Seminar on Intelligent Technology and Its Application: Humanification of Reliable Intelligent Systems, ISITIA 2020* (2020): 7–12, components, including the pump, solar cells, and inverter, are designed as a portable unit that can be easily assembled and disassembled within a cart, making it convenient for farmers.

The technology operation and performance data collection test results showed positive outcomes, even under overcast weather conditions. One of the advantages of this pump is its portability, allowing farmers to take it home and recharge it using electricity. This innovative technology significantly assists farmers in supplying water to their fields during the dry season. Farmers can independently develop and duplicate this technology and share their knowledge with other farmer groups.

The Yasa Mulya Farmers' Group in Waninggap Miraf Village, Tanah Miring District, Merauke Papua, which is a partner in the Community Partnership Program (PKM), played an active role and contributed throughout the implementation of the activities. They provided the venue for the technology dissemination, actively participated in discussions and question-and-answer sessions during the workshop, and participated in the evaluation phase. The benefits that the partners gained include: 1. Reducing agricultural production costs, especially for purchasing fuel (BBM) for irrigation; 2. Understanding the utilization of renewable energy; and 3. Operating the equipment and technology effectively.

Conclusion

The community engagement activity, which involved implementing solar-powered submersible pump technology to supply water to the rice fields, has been effectively carried out and utilized by our partners to reduce operational costs in the irrigation process. Furthermore, this community engagement activity can serve as a model and raise awareness among the community regarding using renewable energy in agriculture. Based on the evaluation results, the community's response to adopting renewable energy-based agricultural technology has been highly effective, with a positive response reaching up to 90%. Therefore, the support of the local government is essential in further developing renewable energy-based agricultural technology in synergy with universities and stakeholders to optimize the region’s agricultural potential.

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