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Installation and Testing of Electric Generators in Civil Engineering Structures for Microhydro Power Plants in Nagari Kamang Hilia Agam

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ABSTRACT

This community service program, conducted by Universitas Negeri Padang in Nagari Kamang Hilia, Agam Regency, focused on the planning, construction, and utilization of a micro-hydro power plant to support local agricultural activities. The program began with coordination with the Nagari government and community to identify challenges and beneficiaries, followed by technical surveys including water discharge mapping, hydraulic head measurement, and land suitability analysis using GIS and UAV-based mapping. Based on these data, detailed engineering designs were prepared for the turbulence-based intake structure, inlet channel, and powerhouse. The project then advanced to the construction of civil works, the installation of turbines, generators, and control panels, and the testing of the operational system. With an installed capacity of up to 5 kW, the plant now provides renewable electricity for agricultural use and street lighting, helping reduce dependence on costly diesel engines. Training and counseling were also delivered to ensure that the community can operate and maintain the system independently. The program demonstrates how micro-hydro technology can be effectively applied to foster rural electrification, empower local farmers, and contribute to sustainable development goals.

Keywords: *Microhydro; Environmentally Friendly; Turbelence; Renewable Energy; Electrification.*

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INTRODUCTION

Agriculture remains a cornerstone of West Sumatra's economy, contributing roughly a quarter of provincial gross regional domestic product over the past five years and absorbing about 37 to 41% of total employment in the province.[1] A key enabler of agricultural performance is the reliable availability of irrigation water for paddy fields and dryland farming, together with dependable electrical energy to sustain post-harvest processing and the local agro industry. In rural Indonesian contexts, micro hydropower has been shown to provide cost-effective, low-carbon, and community-appropriate electricity, particularly under low-head conditions and run-of-river schemes, thereby improving service continuity for productive end uses in agriculture. Building on this rationale, our community engagement program focuses on planning and implementing a turbulence-inducing water-capture civil structure to drive a micro-hydropower unit that supports agricultural needs in Nagari Kamang Hilia, Agam Regency, West Sumatra. The system is engineered to deliver stable, environmentally benign electricity by modifying the intake channel and civil works to promote controlled turbulence, thus enhancing the fluid impulse on the turbine runner and improving shaft power for local loads.[3]-[6]

Nagari Kamang Hilia covers approximately 16.31 km² and comprises 17 jorong or hamlets, namely Koto Panjang, Dangau Baru, Dalam Koto, Batu Baraguang, Bancah, IV Kampuang, V Kampuang, Pintu Koto, Nan VII, Balai Panjang, Koto Kaciak, Koto Nan Gadang, Guguak Rang Pisang, Binu, Ladang Darek, Solok, and Joho, with a total population of 4,941 consisting of 2,451 males and 2,490 females.[1] The Nagari's economy is anchored by smallholders cultivating chili and shallots, as well as by its role as a regional rice granary. Consistent with the broader profile of Agam Regency, agriculture, especially food crops, plays a pivotal role in local economic activity. Prioritizing reliable on-farm water and productive electricity access is therefore integral to sustaining yields and post-harvest value addition.[1] In line with recent Indonesian case studies, decentralized micro hydropower tailored to very-low-head settings can be integrated with simple civil works to enhance agricultural productivity and off-grid reliability at the village scale[3]-[6].

Table 1. Area of Harvest, Production, and Productivity of Rice Fields in Agam District in 2012-2016

Year	Harvest Area (ha)	Production (ton)	Productivity (ton/ha)
2012	56.989	66.151	5,34
2013	57.946	306.410	5,29
2014	58.511	322.621	5,51
2015	60.998	327.567	5,37
2016	66.151	367.535	5,56

Based on the data presented above, harvested area, total production, and paddy productivity in Agam Regency have shown a generally upward trajectory year by year. The largest harvested area was 66,151 ha in 2016, compared with the lowest, 56,989 ha, in 2012. The highest recorded paddy production reached 367,535 tons (reported for 2018), whereas the lowest was 304,321 tons in 2012. Likewise, productivity peaked at 5.56 tons/ha in 2016 and was lowest at 5.34 tons/ha in 2012. In practice, harvested paddy is channeled to rice-milling enterprises that convert it into milled rice and by-products for local markets. In Tilatang Kamang Sub-district, two principal business models are observed among rice mills: (i) integrated mills that purchase paddy directly from farmers and then perform milling and retail sales, thereby internalizing ownership of milled rice and all by-products; and (ii) custom-hire mills that provide milling services to households or aggregators, where payment is commonly made as a percentage deduction from the milled output. These organizational forms are consistent with the broader Indonesian and Southeast Asian rice value chain, where small and medium mills play a pivotal role in linking farm production to downstream markets and stabilizing post-harvest processing capacity.[7]-[10] Within Nagari Kamang Hilia, there are currently two operating rice mills; one of these has been identified as the focal partner for the community-engagement program, with initial field surveys already documenting partner constraints and outlining a preliminary set of technical and managerial solutions aligned with village-level agricultural needs.[7]-[11]


Figure 1: Irrigation Water Control Structure


Figure 2: Nagari Rice Milling Business

Nagari Kamang Hilia has strong potential for livelihoods and economic growth due to its vast rice fields. As Nagari is located far from the end of Tilatang Kamang District, where a continuous supply of electricity is essential for rice milling businesses to operate consistently, it is crucial to have access to an affordable, hygienic rice milling service. One of the pillars of the agricultural sector's success is the availability of water for irrigating rice fields and plantations, and of electrical energy to support the processing of agricultural production. To support the availability of continuous, environmentally friendly electricity, this community service activity focuses on planning and implementing Turbulence Water Capture Civil Buildings for Microhydro Power plants to meet Community Agricultural Needs in Kenagarian Kamang Hilia, Agam Regency, West Sumatra.

RESEARCH METHODS

The program was implemented through targeted technical and expert assistance, structured training and counseling, and the empowerment of the local community in Nagari Kamang Hilia, Tilatang Kamang District. Activities covered site selection, hydraulic and electrical calculations, and the engineering design of a turbulence-based water-capture civil structure for a micro-hydropower plant to support community agricultural needs in Nagari Kamang Hilia, Agam Regency, West Sumatra.

The implementation of community service activities in Nagari Kamang Hilia, Tilatang Kamang District, was carried out through technical assistance, expert guidance, structured training, and community empowerment. The activities began with site selection, hydraulic and structural calculations, and the design of a turbulence-based intake structure as part of the civil works for a micro-hydropower plant intended to meet the community's agricultural energy needs in Agam Regency, West Sumatra. Mapping of potential water sources was conducted by the UNP team, together with civil engineering students and the local farmers' group, through field surveys of irrigation and drainage channels to identify intake locations. UAV-based aerial mapping (DJI Phantom 3 with Pix4D) produced orthomosaics and digital surface models that informed hydraulic screening and final site selection. Land suitability analysis using GIS, AutoCAD Map 3D, and hydrographic surveys resulted in a Land Suitability Map to guide engineering design. Following this analysis, the team, together with experts, developed detailed engineering designs, 2D and 3D drawings, and cost budget calculations. Importantly, the program moved beyond planning to actual construction of the civil works, including the intake structure, inlet channel, and powerhouse, followed by the installation and testing of turbines, generators, and electrical systems. The micro-hydro plant has since been fully constructed and is now in operation, providing renewable electricity for community agricultural activities and street lighting. In addition, the UNP team conducted training and counseling for the local community on renewable energy, plant operation, and maintenance, ensuring that the system can be managed sustainably.

RESULTS AND DISCUSSION

The implementation of devotion to the community of the Construction Nagari Development Program is carried out in accordance with the planning of the implementation of devotion as follows:

1. Coordination of the activity agenda with the Nagari government

The initial step undertaken by the UNP community service team was to coordinate with the Nagari government and local community through communication and consultation. These discussions aimed to identify key issues and gather baseline data to determine suitable locations for beneficiary facilities, including partner farmer groups, rice mills, and the proposed civil structures for water intake. Field consultations revealed that one of the main challenges faced by the community was the dependence on middlemen and traders from neighboring regions, such as Payakumbuh Municipality and Tanah Datar Regency, who often purchased grain directly from farmers. In response, stakeholders expressed strong expectations that the program could provide free or low-cost electricity to local partners. This support would help reduce rice milling costs, making services more affordable and attractive to local farmers while strengthening the agricultural economy of Nagari Kamang Hilia.

2. Mapping potential water sources that will be the source of the turbine drive

Figure 3: Measurement of Hydraulic Head

At this stage, the Community Service Team carried out mapping and discharge measurements to assess potential water sources for turbine operation. Using a current meter, the river flow velocity was measured at an average of 2 m/s, which demonstrates sufficient hydraulic potential for small-scale power generation. While theoretical calculations suggest the river could support higher capacities under ideal conditions, the micro-hydro installation in Kamang

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Hilia was designed to produce up to 5 kW. In practice, however, the available discharge and site conditions indicate that the actual generated capacity is lower than this maximum, yet still adequate to support local agricultural activities and street lighting.

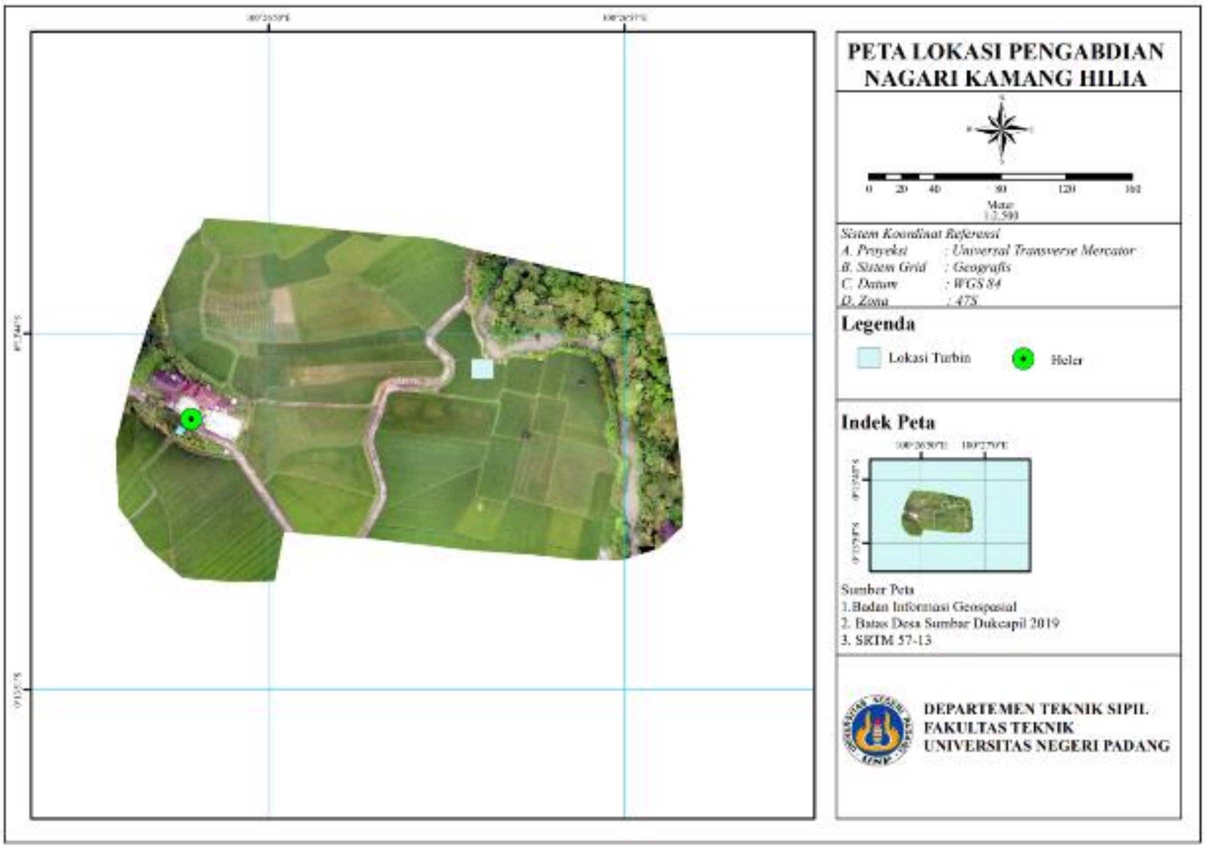

Figure 4: Map of Nagari Binaan Community Service Location, Kamang Hilia

For field mapping, the Community Service Team uses drones and a theodolite. The results of drone scans are 3-dimensional maps of the area around rice fields and rice mills in the Kamang Hilia Kenagarian area. Here are the results of the drone mapping.

3. Analysis of the suitability of Nagari Kamang Hilia land and the location for civil buildings needed for the location of microhydro electricity treatment installation

The land suitability analysis was carried out along the Jorong Binu–Ladang Darek river, identified as the prospective site for the turbulence-based intake structure. Field surveys showed that the river has an average flow velocity of 2 m/s, which is sufficient to support the installation of a micro-hydro intake. The civil structure is designed in a relatively simple form, with essential micro-hydro components expected to deliver a minimum output capacity of approximately 5 kW. A key advantage of the turbulence-based design is its ability to optimize energy conversion even under fluctuating water levels and low discharges, as the induced turbulent flow increases the impact momentum on the turbine runner, thereby enhancing overall energy-generation efficiency.

4. Design of civil buildings, water catchers, and microhydro power plants

The civil works design focused on developing a turbulence-based water intake structure, inlet channel, and powerhouse as the core components of the micro-hydro power plant. Field measurements and hydraulic analyses were used to determine flow characteristics, available head, and structural dimensions required for reliable operation. The turbulence water-catcher design was chosen to maximize energy transfer efficiency, improve turbine performance, and extend the service life of turbine bearings. A sluice gate was integrated into the design to regulate water discharge, allowing the incoming flow to be adjusted to meet the desired electrical power output. The final design was presented as detailed engineering drawings and a cost budget plan, which guided subsequent construction and implementation in Kamang Hilia.

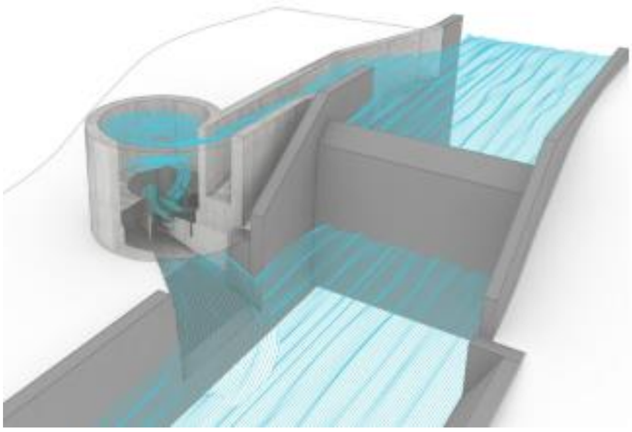

Figure 5: Turbine Installation Plan

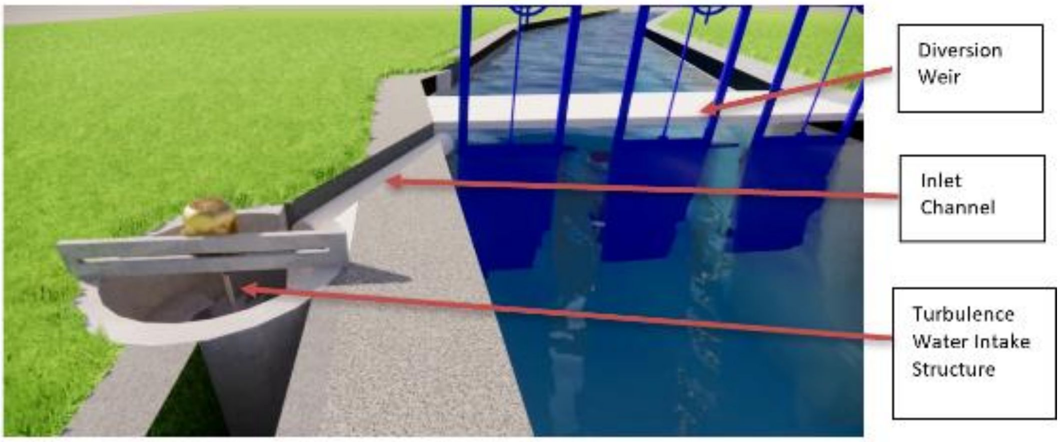

Figure 6: Design of Micro-Hydro Power Plant Water Resources Building

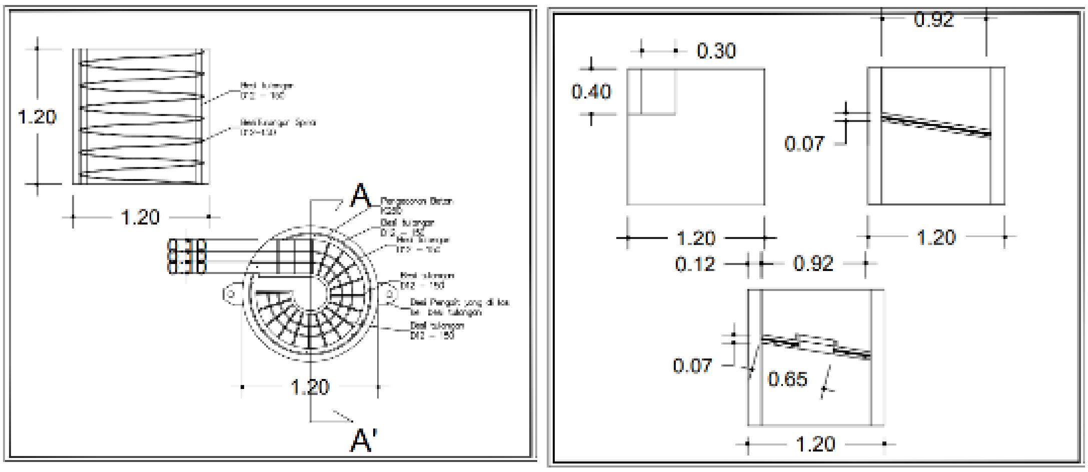

Figure 7: Construction Drawing of Turbulent Flow Intake Structure

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5. Electrical Design

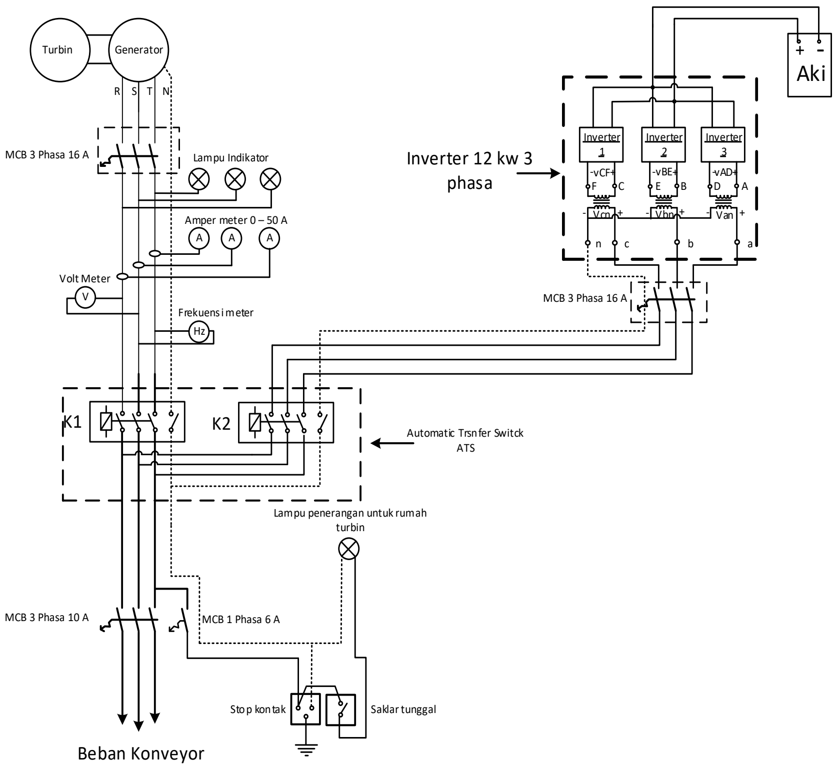

Figure 8: The circuit uses a battery backup

After completing the civil building design, the next stage is to prepare the electrical system. The UNP Assisted Nagari Service Team will design electrical panels and supporting instruments that function as the main control and distribution units. These systems will regulate the turbine's power output, ensuring the conversion of mechanical energy into stable, safe electrical energy. The design also integrates protection and monitoring devices to guarantee reliability, efficiency, and sustainability in energy distribution for the community.

6. Construction Process of the Micro-Hydro Power Plant

Figure 9: Assembly of Inlet and Outlet Pipes and Installation of Micro-Hydro Power Plant Water Resources Building

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Figure 10: Construction Process of the Micro-Hydro Power Plant

The construction phase began after the completion of site selection, hydraulic analysis, and engineering design. Civil works included the construction of a diversion weir to regulate and divert water, a turbulent-flow intake structure to optimize hydraulic energy capture, and an inlet (headrace) channel to guide water toward the powerhouse. Excavation, formwork, reinforcement, and concreting were carried out in accordance with the detailed design drawings. Careful attention was paid to structural stability and hydraulic performance, ensuring that the intake and channel could withstand seasonal flow variations. Subsequently, the powerhouse was constructed as a reinforced-concrete building to house the turbine, generator, and control systems. This stage was crucial for transforming design outputs into functional civil structures capable of supporting long-term plant operations.

7. Electrical Panel Installation

Following the completion of the civil structures, the mechanical and electrical systems were installed. The turbine and generator set were mounted inside the powerhouse, aligned with the penstock and outlet to ensure efficient energy transfer. The electrical control panel was then installed to regulate voltage, current, and frequency, providing safe and stable electricity output. The panel included protection devices, load controllers, and monitoring instruments to prevent overload or system failure. Test runs were conducted to verify performance, calibrate the control system, and confirm synchronization between mechanical input and electrical output. The installation of the panel marked the final step toward operational readiness, ensuring that the micro-hydro power plant could reliably supply renewable electricity to meet agricultural and public lighting needs in Nagari Kamang Hilia.

CONCLUSION

This community engagement program demonstrates the technical and socioeconomic feasibility of a turbulence-based micro hydropower solution to support the agricultural value chain in Nagari Kamang Hilia. Site reconnaissance, hydraulic measurements, and GIS-assisted land suitability analysis established a viable baseline (mean stream velocity of approximately 2 m/s) for a run-of-river installation, informing the detailed engineering design of the water-capture civil structure, turbine layout, and protective electrical architecture. The designed configuration targets a plant's near-term capacity with headroom for future upgrades to about 5 kW, while the electrical scheme, comprising control and distribution panels and ATS-based switching with optional battery-backup paths, prioritizes operational safety, reliability, and maintainability.

Under conservative weather-related efficiency assumptions, the site retains sufficient hydraulic potential to sustain the intended output. The turbulence-inducing intake and flow-conditioning elements are expected to improve drive efficiency and reduce mechanical wear, thereby lowering life-cycle costs for community rice milling operations. Collectively, these outcomes provide a practical pathway to stable, low-carbon electricity that can reduce milling costs, strengthen local processing capacity, and align with broader rural electrification objectives. The next phase, including civil works construction, equipment installation, commissioning, and operator training, should be accompanied by performance monitoring of power quality, seasonal flow variability, and distribution losses to validate assumptions and guide staged capacity enhancements.

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