Socioeconomic Impacts of Hybrid Pico Hydro-Solar Generation System Implementation in Sitio Singawan, Barangay Umiray, Municipality of Dingalan, Aurora, Philippines

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Abstract

This paper introduces a research and extension program focused on the promotion, transfer, and adoption of the Hybrid Pico Hydro-Solar Generation System in Sitio Singawan, Barangay Umiray, Municipality of Dingalan, Aurora, Philippines, to explore the significant socioeconomic impacts of implementing renewable energy systems in rural areas. Spearheaded by the Technological University of the Philippines' College of Engineering, led by former Dean Benedicto Fortaleza as the project leader, and involving the crucial contributions of the Civil Engineering (CE), Electrical Engineering (EE), Electronics Engineering (ECE), and Mechanical Engineering (ME) departments, the program addresses the absence of electricity in the community and strives to enhance the livelihoods of the Dumagat constituents. This paper outlines the methodology employed, encompassing benchmark surveys, needs assessments, the development and installation of the Hybrid Pico Hydro-Solar Generation System, and details regarding the return on investment. The results demonstrate the successful generation of electricity, shedding light on the challenges encountered in power distribution to the community and system maintenance. This study's findings are relevant for similar rural electrification initiatives, offering valuable insights into the social impact and economic viability of incorporating renewable energy technologies.

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Social impact

Implementing the Hybrid Pico Hydro Solar Generation System in Sitio Singawan has brought about significant social impact, transforming the lives of community members in various ways [1]. The availability of electricity has profoundly affected their daily activities and overall well-being.

First and foremost, introducing electricity has greatly improved lighting conditions within households. Previously, community members relied on kerosene lamps or candles, which provided limited and dim lighting. With the Hybrid Pico Hydro-Solar Generation System, households can now access brighter and more reliable lighting, extending their productive hours into the evening. Children can study at night, adults can engage in income-generating activities, and overall productivity and efficiency have increased.

Moreover, the ability to operate essential appliances such as televisions, radios, and electric fans has transformed the community. Access to information and entertainment through these appliances has expanded, connecting community members with the outside world and broadening their horizons. Electric fans have also provided much-needed relief during hot weather, improving the overall comfort and well-being of the residents.

Additionally, implementing the Hybrid Pico Hydro-Solar Generation System has enhanced the safety and security of the community. The improved lighting has significantly reduced the risk of accidents and criminal activities at night. Community members feel safer walking around their village, and households can implement better security measures, fostering a sense of security and peace of mind.

The social impact of the Hybrid Pico Hydro-Solar Generation System extends beyond individual households. The availability of electricity has positively affected public spaces and communal facilities such as community centers, schools, and healthcare facilities. These spaces can now function effectively with a reliable electricity supply, improving access to education, healthcare services, and communal activities. This has strengthened social cohesion, community development, and a sense of belonging.

Furthermore, introducing electricity has opened up new economic opportunities for the community. Small-scale enterprises and entrepreneurial ventures have emerged, utilizing the newfound energy to start businesses and generate income. This economic empowerment has contributed to poverty reduction and the overall improvement of livelihoods within the community.

Methodology

Benchmark and Needs Assessment Survey

A benchmark survey and needs assessment were conducted to gather data and insights regarding the community's electricity requirements and socioeconomic conditions [2]. Interviews, questionnaires, and participant observation were

utilized as data collection methods. Geophysical data and census information were also collected from the Municipal Comprehensive Land Use Plan and CBMS Census. Livelihood, socioeconomic, and load profile data were obtained through questionnaires and personal interviews with key informants, including officials from the Municipal Mayor's Office, National Commission on Indigenous Peoples (NCIP) Dingalan Community Service Center, Municipal Engineer's Office, and Barangay officials.

Development of the Pico Hydro Generation System

Based on the findings of the benchmark survey, a Pico Hydro Generation System was designed and constructed[3]. The Pelton turbine was initially chosen. However, the system utilized a Banki- Crossflow turbine, chosen for its suitability in low-head and medium-flow hydropower sites. Parameters such as turbine power, side disk diameter, blade length, angle of attack, and blade angles were determined based on the desired head and flow. Site inspections were conducted to identify the optimal location for the system's installation, considering factors such as accessibility, slope, and water flow rate. The Pico Hydro Generation System comprised a dam for water embankment, 6-inch diameter penstock pipes, and a Banki-Crossflow turbine coupled with a low-speed generator. Automatic Generation Controller (AGC) for the Pico Hydro Generation System was used to regulate voltage and frequency output in pico-hydro power systems [4]. By utilizing sensors and an Arduino Uno, the AGC adjusts water flow in the turbine to maintain standard voltage and frequency levels. ANFIS was chosen as the control algorithm due to its reliability, speed, and efficiency.

Development of the Solar Generation System

Three Solar Generation Systems, each consisting of a 50W solar panel and a charge controller, were installed in every residential house [5]. A Fuzzy-based Maximum Power Point Tracking Solar Battery Charge Controller with a backup standby AC generator was also developed [6]. A fuzzy logic algorithm for maximum power point tracking battery charge control in isolated areas utilizing solar panels and AC generators was implemented in the charge controller. The hardware includes a switched-mode power supply, source switching circuit, buck-boost converter, and diversion load controller.

Management of Technology Transfer and Adoption

The Technology Promotion, Transfer, and Adoption of the Hybrid Pico Hydro-Solar Generation System was facilitated through close coordination between the Technological University of the Philippines (TUP) and the community of Sitio Singawan. Community engagements, workshops, and training sessions were conducted to introduce the technology, educate the community members, and enhance their skills in operating and maintaining the generation system. Participants underwent comprehensive training on the system's assembly, installation, operation, and maintenance. To ensure the sustainable management of the system, a local committee was established to oversee its management, monitoring, and maintenance.

Results and Implications

Implementing the Pico Hydro Generation System in Sitio Singawan yielded positive results and several implications for a diverse audience. The system successfully generated electricity, meeting the power demands of approximately 40 households in the community.

A return on investment (ROI) analysis was conducted to evaluate the project's economic viability. The total expenses incurred while implementing the Hybrid Pico Hydro Solar Generation System in Sitio Singawan amounted to Php 319,000.00. These expenses included costs for site survey and needs assessment (Php 33,840.00), technology promotion, transfer, and adoption (Php 34,560.00), the first and second phases of technology monitoring, visitation, evaluation, and live demos (Php 29,600.00 and Php 21,000.00, respectively), development of the solar intelligent distribution system for rural areas (Php 65,000.00), and construction materials, maintenance, and miscellaneous expenses (Php 135,000.00).

The income or revenue generated from the Hybrid Pico Hydro Solar Generation System was calculated as follows: 0.76kW x 24 hours x 365 days x P9.82/kW-hr = P65,377.63 per year. The minimum payout period (MPP) was determined by dividing the total cost by the total revenue: MPP = P319,000/P65,377.63 = 4.88 years. The rate of return or return on investment was calculated as 20.49%.

The findings of this study indicate that implementing the Hybrid Pico Hydro Solar Generation System in Sitio Singawan had a significant social impact, improving the livelihoods of the community members through enhanced access to electricity. However, challenges were encountered in power distribution and system maintenance. The study highlights the need for a well-designed distribution system tailored to the community's needs. It emphasizes the importance of community empowerment and capacity building for effective technology adoption and long-term maintenance. Table 1 summarizes the positive social, economic, educational, and environmental changes the Hybrid Pico Hydro Solar Generation System brought about in Dingalan, Aurora.

Table I. Positive social, economic, educational, and environmental changes brought about by the Hybrid Pico Hydro Solar Generation System in Dingalan, Aurora

Impacts	Implications
Improved Access to Electricity	Implementing the Pico Hydro Generation System provided the Sitio Singawan community with electricity access. This significantly impacted the daily lives of community members, enabling them to have reliable and affordable electricity for lighting and operating essential appliances.
Socioeconomic Development	Access to electricity positively influenced the socioeconomic conditions of the community. It enhanced productivity and economic activities, allowing community members to engage in income- generating activities during the evening hours. It also facilitated using electrical equipment and tools, contributing to improved livelihoods and potential business opportunities.
Enhanced Education	The availability of electricity enabled students in Sitio Singawan to study and do their homework in well-lit conditions. It created opportunities for educational advancements, as students could now utilize electric devices such as computers and laptops for research and learning purposes.
Health and Safety Improvements	With electricity, community members no longer had to rely on kerosene lamps or candles for lighting, reducing the risk of fire accidents and indoor air pollution. Access to electricity also allowed for the use of electric fans and other cooling devices, improving comfort levels, particularly during hot and humid weather conditions.
Environmental Benefits	The Pico Hydro Generation System utilizes renewable energy from flowing water, reducing the reliance on fossil fuel-based energy sources. This contributes to reducing greenhouse gas emissions and helps mitigate climate change. Additionally, the system has a minimal ecological footprint compared to large- scale hydropower projects, minimizing potential adverse impacts on the surrounding environment.
Capacity Building and Empowerment	Through workshops, training sessions, and community engagements, the project facilitated the transfer and adoption of the Pico Hydro Generation System. It enhanced the skills and knowledge of community members in operating and maintaining the system, empowering them to take ownership and responsibility for its management. A local committee was established to oversee system maintenance, ensuring sustainability and community involvement.

The economic analysis demonstrated the project's viability, with a return on investment of 20.49%. These results showcase the economic potential of implementing renewable energy technologies in rural areas and contribute to the broader understanding of the social impact and economic viability of rural electrification initiatives.

In conclusion, the research and extension program, centered on implementing the Hybrid Pico Hydro-Solar Generation System in Sitio Singawan, not only successfully addressed the community's electricity deficiency but also brought about significant social impact and improved livelihoods. The methodology, including benchmark surveys, needs assessments, technology development, and transfer activities, emphasized the importance of well-designed power distribution systems, community empowerment, and economic viability for achieving sustainable rural electrification. These insights offer valuable guidance for future initiatives seeking to harness renewable energy sources and empower rural communities for sustainable development. The initiative's success was not a stroke of luck; it resulted from meticulous planning and active

community participation. The technology was customized to meet Sitio Singawan's unique requirements through close collaboration between the university and the community. The sustainable pico hydro system, tailored without infringing on local culture, was met with acceptance, supported by the Dumagat community's consent obtained from their elders, as evident in the positive outcome of the impact assessment and acceptability survey.

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