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TECHNICAL TRAINING AND FEASIBILITY ANALYSIS FOR THE IMPLEMENTATION OF RENEWABLE ENERGY SOURCES FOR SMALL RURAL PRODUCERS

CAPACITAÇÃO TÉCNICA E ANÁLISE DE VIABILIDADE DE IMPLANTAÇÃO DE FONTE DE ENERGIA RENOVÁVEL PARA PEQUENOS PRODUTORES RURAIS

CAPACITACIÓN TÉCNICA Y ANÁLISIS DE VIABILIDAD PARA LA IMPLEMENTACIÓN DE FUENTES DE ENERGÍA RENOVABLE PARA PEQUEÑOS PRODUCTORES RURALES

Celso Souza
Universidade Anhanguera Uniderp
ORCID: https://orcid.org/0000-0002-2689-8264
Vinícius Henrique
Universidade Federal da Grande Dourados
ORCID: https://orcid.org/0009-0006-9056-5938
Giovane Silvestrim
Universidade Federal da Grande Dourados
ORCID: https://orcid.org/0009-0001-1907-0928
Luiz Eduardo Simon
Universidade Federal da Grande Dourados
ORCID: https://orcid.org/0009-0005-4112-7408
Orlando Moreira Júnior
Universidade Federal da Grande Dourados
ORCID: https://orcid.org/0000-0002-6232-7100
Pedro Henrique Alves
Universidade Federal da Grande Dourados
ORCID: https://orcid.org/0009-0002-4874-4378
Vitor da Cruz Silva
Universidade Federal da Grande Dourados
ORCID: https://orcid.org/0009-0002-4852-5087
Daniel Frainer
Universidade Estadual de Mato Grosso do Sul
ORCID: https://orcid.org/0000-0003-0813-214X

[1] Corresponding author: vinicius.moreira370@academico.ufgd.edu.br

Abstract: This article presents the results of an extension project developed in the Lagoa Grande Settlement, in Dourados-MS, whose initial objective was to evaluate the feasibility of implementing Micro Hydroelectric Power Plants (MHPs) using Pumps Operating as Turbines (PATs). Diagnostic visits to the settlement revealed insufficient water resources for the implementation of the technology on a community scale, which resulted in the reorientation of extension activities towards photovoltaic solar energy, aligning with local demands. Simultaneously, an experimental PAT test rig was assembled in a laboratory environment to characterize the equipment's performance. Field activities involved training courses, field days, the creation of educational booklets, the development of a microlearning module , and a feasibility study for the implementation of a solar system for the community well. The results indicate significant social, technical, and educational impacts, reinforcing the importance of university extension as an instrument of transformation.
Keywords: Family farming; BFT; Solar energy; University extension; Sustainability.

Resumo: Este artigo apresenta os resultados de um projeto de extensão desenvolvido no Assentamento Lagoa Grande, em Dourados–MS, cujo objetivo inicial consistiu na avaliação da viabilidade de implantação de Micro Centrais Hidrelétricas (MCHs) utilizando Bombas Funcionando como Turbinas (BFTs). As visitas de diagnóstico realizadas no assentamento evidenciaram a insuficiência hídrica para a implantação da tecnologia em escala comunitária, o que resultou na reorientação das ações de extensão para a energia solar fotovoltaica, alinhando-se às demandas locais. Em paralelo, no ambiente laboratorial, foi concluída a montagem de uma bancada experimental de BFTs, destinada à caracterização de desempenho desses equipamentos. As ações de campo envolveram cursos de capacitação, dias de campo, elaboração de cartilhas, desenvolvimento de um módulo de microlearning e realização de um estudo de viabilidade de implantação de um sistema solar para o poço comunitário. Os resultados apontam impactos sociais, técnicos e educacionais significativos, reforçando a importância da extensão universitária como instrumento de transformação.
Palavras-chave: Agricultura familiar; BFT; Energia solar; Extensão universitária; Sustentabilidade.

Resumen: Este artículo presenta los resultados de un proyecto de extensión desarrollado en el asentamiento Lagoa Grande, en Dourados (Mato Grosso do Sul), cuyo objetivo inicial consistía en evaluar la viabilidad de implantar microcentrales hidroeléctricas (MCH) utilizando bombas

que funcionan como turbinas (BFT). Las visitas de diagnóstico realizadas en el asentamiento pusieron de manifiesto la insuficiencia hídrica para la implantación de la tecnología a escala comunitaria, lo que dio lugar a la reorientación de las acciones de extensión hacia la energía solar fotovoltaica, en consonancia con las demandas locales. Paralelamente, en el entorno del laboratorio, se completó el montaje de un banco experimental de BFT, destinado a caracterizar el rendimiento de estos equipos. Las acciones de campo incluyeron cursos de capacitación, jornadas de campo, elaboración de folletos, desarrollo de un módulo de microaprendizaje y realización de un estudio de viabilidad para la implementación de un sistema solar para el pozo comunitario. Los resultados apuntan a impactos sociales, técnicos y educativos significativos, lo que refuerza la importancia de la extensión universitaria como instrumento de transformación.
Palabras clave: Agricultura familiar; BFT; Energía solar; Extensión universitaria; Sostenibilidad.

INTRODUCTION

Brazil's energy matrix, although largely supported by renewable sources, still presents structural inequalities in access to quality electricity, especially in rural areas. Small producers, fundamental to national food security, face high costs, unstable supply, and technological limitations that compromise both their productive activities and the quality of life in the countryside.

In the Itahum district of Dourados, Mato Grosso do Sul, this scenario is evident. The community, comprising approximately 300 families, has a prominent family farming profile yet lacks technological solutions for productive modernization and energy cost reduction. During the initial diagnostic survey, it was identified that electricity consumption associated with pumping water from the community well is one of the main local challenges.

The initial proposal for this extension project involved training in decentralized micro-hydroelectric generation technologies, focusing on Pumps Operating as Turbines (PFTs). However, field assessments indicated that the water resources (flow and elevation difference) available in the settlement were insufficient for the implementation of Micro Hydroelectric Power Plants (MHPs). Thus, the extension activities were redirected towards photovoltaic solar energy, while the laboratory research remained focused on the development of the experimental PFT bench.

THEORETICAL FOUNDATION

Micro hydroelectric power plants (MCHs) are small-scale renewable energy systems capable of supplying energy to isolated communities, although their use is limited by the high cost of custom-designed turbines (RAMALHO et al., 2025). In this context, Pump-Turbine Systems (PAT systems) emerge as a lower-cost alternative, utilizing commercial centrifugal pumps operating in reverse to generate energy with good efficiency and simple maintenance (FONTANELLA et al., 2020; CRESPO et al., 2019).

The reverse operation of PATs depends on adequate hydraulic conditions, since the flow drives the rotor in the opposite direction to pumping, requiring flow rates and heads higher than nominal conditions for better performance (YANG et al., 2022). Due to the changes in hydraulic and mechanical dynamics caused by this operation, experimental tests are fundamental to determine efficiency curves, operational limits, and points of maximum efficiency (ZŁOTY; PASIKOWSKI, 2019).

Meanwhile, solar photovoltaic energy has established itself as a clean and low-maintenance solution, standing out for its energy autonomy, cost reduction, and security of supply to rural properties. Its growth in the Brazilian agricultural sector in recent years has been significant, driven by technological accessibility and incentive policies (CNA, 2021; BRAZILIAN GOVERNMENT, 2025).

MATERIALS AND METHODS

The project was developed directly with family farmers from the Lagoa Grande Settlement, located in the Ithaum district of Dourados, Mato Grosso do Sul, an area founded in 1997 that totals 4,111 hectares and is home to approximately 300 families distributed across 151 rural plots, ranging from 18 to 75 hectares. The location, characterized by gentle terrain, and the community, which predominantly uses artesian wells to meet its water needs and is heavily dependent on electricity for its productive activities, have different production profiles but share common challenges in accessing energy technologies, managing consumption, and the availability of technical knowledge to optimize processes and add value to their products.

The proposed methodology was based on the union of Teaching, Research, and Extension. In practice, it sought a synergy between the generation of technical-scientific knowledge (Research), the training of students (Teaching), and the application of this knowledge within the community (Extension). The approach involved the knowledge sharing between academic team and rural producers, using methodologies to solve real problems that emerged from field diagnosis and dialogue with the settlers.

Field activities included gathering data on water availability through flow measurements in streams and reservoirs; analyzing existing infrastructure, such as terrain and access to plots; and community engagement through meetings with settlers to present the project's objectives, understand local energy demands, and schedule visits to the properties.

In parallel with these field activities, the assembly of the BFT test bench at the UFGD Flow Machines Laboratory was completed, intended for conducting tests to evaluate the performance of the pumps in different operating regimes.

In a second phase of the project, during the analysis of field data for the community, the technical infeasibility of applying small hydroelectric plants (SHPs) within the settlement was encountered due to insufficient water resources. Based on the projected demand from the producers, a new approach was initiated, this time focused on photovoltaic energy. This involved gathering historical consumption data from properties and community artesian wells through energy bills, as well as analyzing the region's solar irradiation potential to support new feasibility studies.

The final phase of the project focused on transferring the generated and adapted knowledge to the settlement community. To this end, two courses were developed and delivered to the producers: the first on fundamental concepts of renewable energies (wind, photovoltaic, and hydroelectric) and the second focused on the practical sizing of small photovoltaic energy generation systems, with an economic feasibility analysis.

Finally, three "Field Days" were held, practical and immersive events in which 53 producers and representatives of community groups participated in sizing simulations for their properties. Educational materials were distributed at these events, such as printed booklets (also available online through the project's LinkedIn page) and a microlearning module .

RESULTS

Development of the BFT Bench

The experimental test rig was the project's primary research output, designed as a versatile system to simulate the full operating cycle of a Micro Hydroelectric Power Plant (MHP). The physical assembly employed industrial equipment, with the central element being the THEBE TH-50/250 MANCA Feed Pump (10 hp), responsible for drawing water from a 1,000-liter reservoir and pressurizing it in the hydraulic circuit. The pressurized flow can be directed to four IMBIL Turbine-Operating Pumps (BFTs), with nominal powers between 2 and

10 hp, which, when operating in reverse, functioned as hydraulic turbines, transmitting mechanical energy to a three-phase alternator for electricity generation.

The system was controlled using the WEG CFW-08 frequency inverter, which allowed for adjustments to rotation speed, flow rate, and pressure, enabling simulations of multiple operating conditions.

Figure 1 - Overview of the BFT Bench and Reservoir in the Laboratory
Source: Author (2025).

During preliminary tests, excessive vibrations were identified in the bench structure at certain rotation speeds. Computer modeling in AutoCAD and SolidWorks, with static and dynamic analyses, allowed the identification of critical points of structural stress. Metal reinforcements were added to the most susceptible regions, and dynamic balancing of the drive shaft was performed.

In complementary tests, using the Global Sensor Technology vibration analysis software, a significant reduction in vibrations was confirmed after the interventions, ensuring greater operational stability of the workbench. These results led to a scientific article to be submitted to the Journal. of the Brazilian Society of Mechanical Sciences and Engineering.

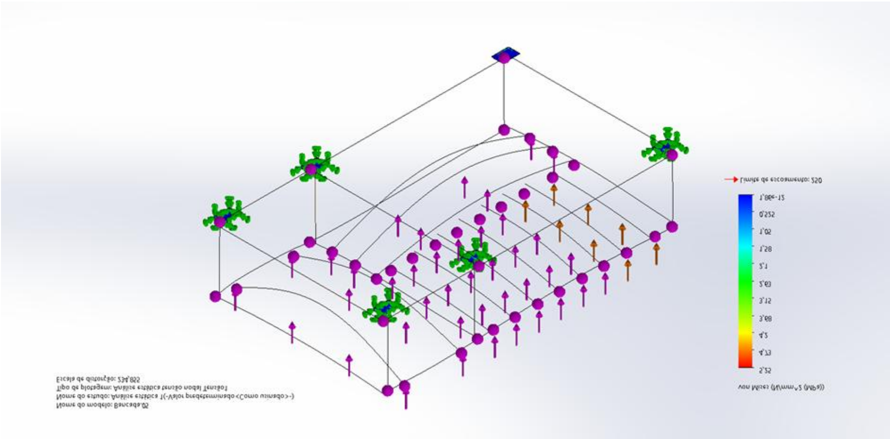

Figure 2 - Computational Stress Analysis in the Structure of the BFT Bench
Source: Author (2025).

With structural stabilization completed, the experimental phase began to characterize the performance of the BFTs under different operating conditions. Varying the inverter frequency allowed for the control of flow rate and pressure, while data on flow velocity (CAM-3000H), shaft rotation, inlet pressure, and generated electrical voltage were obtained. These measurements enabled the construction of tables and graphs essential for determining efficiency curves and points of maximum efficiency.

To determine the instantaneous flow rate and fluid velocity in the hydraulic system, tests were performed using the CAM-3000H portable ultrasonic flow meter, a clamp-on type based on the transit time principle. The equipment allowed for non-invasive measurements without direct contact with the fluid. With the hydraulic system stabilized, instantaneous flow rate (m³/h) and fluid velocity (m/s) readings were recorded directly on the equipment's display. The measurements were repeated under different load and rotation conditions, allowing for a comparison between the hydraulic behavior of different BFT configurations tested, as shown in Table 1.

Table 1 – Data Collected During Bench Tests

Speed (m/s)	Voltage (V)	Rotation (RPM)	Inverter Frequency	Inlet pressure (kgf/cm²)	Outlet pressure (mca)
0.357	0	370.9	22.27	0.5	5
0.365	9.8	686.7	30	0.9	9
0.5978	100	900.5	40	1.64	16.4
0.6559	120	1051	45.76	1.83	18.3
0.6935	127	1073	46.57	1.9	19
0.6934	150	1180	50	1.98	19.8
0.7315	160	1300	56	2	20
0.7412	170	378	587	2.3	23
0.7782	190	1470	60	2.5	25
0.8203	202	1520	64	3.2	32
0.7843	220	1607	66	3.8	38

Source: Author (2025).

Extension Activities in the Lagoa Grande Settlement

In parallel with laboratory studies, the project was developed in the Lagoa Grande Settlement through field actions conducted in direct interaction with the local community. Technical visits were carried out to diagnose water resources, with the direct participation of four representatives from the community association, who guided the team regarding the history of water use and access to the sites. Flow and topography measurements confirmed that water availability was insufficient for the implementation of small hydroelectric plants , redirecting the focus of actions towards photovoltaic solar energy, in agreement with the residents.

Figure 3 – Diagnostic Visits to Water Resources and the Community Well
Source: Author (2025).

Furthermore, a Field Day on Renewable Energies was held on May 14, 2025, with an average attendance of 50 rural producers. The program included presentations on different renewable sources and a practical workshop on photovoltaic sizing using the settlers' own bills. Economic return (payback) simulations were also demonstrated, allowing for a personalized analysis of the financial return for each family.

Figure 4 – Training Activities During the Field Day
Source: Author (2025).

With the aim of ensuring continuous access to knowledge, two printed booklets ("Renewable Energies" and "Solar Energy Sizing") were produced, along with a Microlearning module containing infographics, videos, and podcasts, made available via LinkedIn.

Figure 5 – Brochures distributed to rural producers

Source: Author (2025).

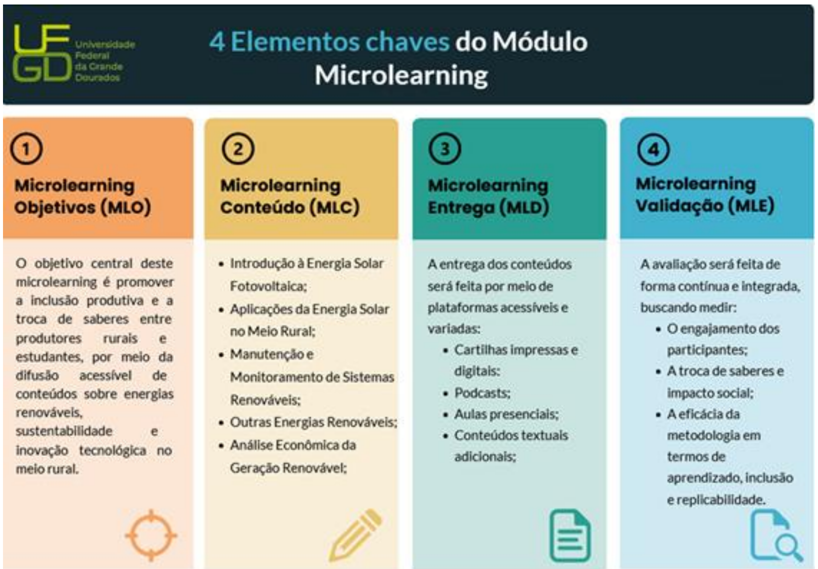

Figure 6 – Microlearning Module Structure

Source: Author (2025).

Case Study: Photovoltaic System for the Community Well

Applying the same methodology presented in the training sessions, a photovoltaic system was designed to supply the average consumption of 2,500 kWh/month from the community artesian well. The designed solution included 36 LR5-72HTH-575M modules (575 W), two 10 kW Growatt inverters and one 2 kW inverter, totaling an estimated cost of R$ 58,000.00. The financial analysis indicated an approximate payback of 5 years and accumulated savings of approximately R$ 2.4 million over 30 years (estimated lifespan of the system), demonstrating the technical and economic viability of the implementation.

Dados da Placa		
Modelo	LR5-72HTH-575M UT Explorer	
Área (m^2)	2,583	
Rendimento	0,225	
E.P.M (kWh/mês)	89,09	
E.P.M.C (kWh/mês)	71,28	
Potência Máx. (W)	575	
Valor	R$	920,94

Demanda (kW)	N° de placas
2500	36

N° de Inversores	Custo mínimo de projeto	
2	R$	58.000,00

Dados do Inversor 1		
Modelo	Growatt 10 kW - Ongrid	
Potência (W)	10000	
Quantidade	2	
Valor	R$	17.600,00

Economia em 30 anos	
R$	2.399.298,47

Dados do Inversor 1		
Modelo	Growatt 2 kW 220V - Ongrid	
Potência (W)	2000	
Quantidade	1	
Valor	R$	1.600,00

Payback de 5 anos

Figure 7 – Sizing and Financial Analysis for the Community Well
Source: Author (2025).

Finally, on September 18, 2025, the closing Field Day took place, again bringing together an average of 50 participants. On this occasion, the final results of the project were presented and, in response to the direct request of the producers, the financing lines available for family farming (FCO, PRONAF, Caixa Agro and BNDES) were detailed.

The decision regarding the actual installation of the system remained open for future evaluation by the residents and the settlement association. However, the action achieved its main objective by training the producers, ensuring that they understood the technical and economic feasibility of sizing and future installation of the photovoltaic system, fulfilling the extension role of bringing technical knowledge to the community.

Finally, an evaluation questionnaire administered to participants indicated broad approval and pointed to new demands for future actions. The activities were publicized on the official pages of UFGD and on the project's official page, consolidating the formative and social impact of the extension activities developed.

DISCUSSION

The analysis of the results obtained shows how the collaboration between universities and rural communities can generate concrete impacts on the development of energy solutions and the technical training of participants. In general, it was observed that the process of active listening, methodological adaptation, and technological adjustment to local realities was crucial for the progress of the actions, demonstrating that effective extension projects depend not only on technical knowledge but also on contextual sensitivity and operational flexibility.

The transition from the initial proposal focused on pumps functioning as turbines to the application of photovoltaic systems stemmed directly from the demands identified in the field and the dialogue established with local producers. Rather than a deviation from the original plan, this shift represented a necessary adaptation to the situational diagnosis, reinforcing the importance of participatory methodologies, reinforcing the importance of participatory methodologies in which the formulation of solutions occurs in cooperation with the subjects involved. Thus, the adaptation of the project to the community's energy needs demonstrates the articulation between academic knowledge and practical expertise, resulting in more sustainable and socially embedded interventions.

The results also demonstrate that the training process generated significant impacts on the autonomy of the residents, who came to understand fundamental aspects of solar energy, the components of photovoltaic systems, and the conditions necessary for implementing these solutions on their properties. Although initial, this construction of technical autonomy contributes to the democratization of knowledge and the strengthening of local decision-making capacities.

Within the scope of research, the development of the experimental bench represented a considerable advance, consolidating a valuable didactic and scientific resource. The complexity of the constructed system and the overcoming of technical challenges throughout its assembly demonstrate how extension activities can feed back into university research, enriching student training and expanding the integration between theory and practice.

Thus, the project's findings align with conceptions that advocate for university extension as a transformative practice, capable of articulating teaching, research, and social action. At the same time, they reaffirm the relevance of participatory methodologies that are sensitive to local realities and oriented towards the collective construction of knowledge.

CONCLUSION

The set of actions developed throughout the project allowed for simultaneous progress in academic training, technological development, and the construction of solutions geared towards the real needs of the community served. The experience demonstrated that well-structured outreach initiatives can produce significant results even in the face of changes in direction, provided they maintain a commitment to active listening and adaptation to local conditions.

The development of the experimental bench consolidated an important legacy for the institution, offering a tool capable of supporting future studies, research activities, and teaching practices. Simultaneously, the work with the community contributed to expanding access to technical knowledge and strengthening the residents' capacity to evaluate viable energy alternatives for their properties. The delivery of the photovoltaic system proposal for the community well represents a concrete step in this direction, highlighting the interface between theory, practice, and social impact.

The evaluation questionnaire showed that the rural producers who participated in the training also began to disseminate the knowledge and materials acquired to their neighbors, creating a network of knowledge and reaching an even larger audience.

Thus, it can be concluded that the project not only fulfilled its objectives, but also highlighted the transformative potential of university extension. By promoting the integration of different forms of knowledge and prioritizing technically feasible solutions aligned with local needs, the role of the university as an agent for inducing social, technological, and human development is reaffirmed.

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