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# ANALYSIS OF THE EFFECTIVENESS OF WATERWHEELS AS WATER PUMP DRIVERS

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***Abstract.*** A pump is a device used to move liquids from one location to another through a pipeline, typically by increasing fluid pressure using electrical power. This increase in pressure helps overcome various types of flow resistance, such as pressure differences, elevation changes, or frictional losses. Transporting fluids from lowland to highland areas is not a simple task, particularly in remote regions where access to electricity is limited. This research was conducted at Pura Beji, Tanah Lot, Beraban Village, Tabanan Regency—an area that has abundant clean water resources in the lowlands compared to the highlands. The study focuses on the process of transferring clean water using water wheels as mechanical drivers in a system known as PATA Technology (Pompa Air Tenaga Air). Therefore, the objective of this research is to analyze the mechanical power generated by the water wheels and the resulting pumping performance of the water pump. This study investigates the effectiveness of waterwheels as mechanical drivers for water pumps in rural areas with limited electricity access, using the PATA (Pompa Air Tenaga Air) system. According to the research result, it was found that for mass flowrate of water wheel 75.5 kg/s then for the mass flowrate of water pump 14.7 kg/s. The efficiency for the waterwheels against the water pump obtained >40%. The water wheels act as the main drive of the water pump through rotation axle gear mechanism which is transmitted to the housing pump with average power water wheel 650 $kg.m/s^2$.

*Keywords : PATA, Fluid, Water pump, Water wheel.*

## 1. INTRODUCTION

Water is a fundamental natural resource that sustains all forms of life and supports a wide array of human activities[1], including drinking, bathing, cooking, sanitation, agriculture, and industry. Access to clean and sufficient water is not only essential for daily survival but also for economic development and public health. In many parts of the world, especially in developing countries, the challenge of water accessibility is exacerbated by population growth, climate change, pollution, and unequal infrastructure distribution [2]. These issues are particularly pronounced in rural and remote areas where centralized water systems and electricity supply are limited or even non-existent[3]. To fulfill daily water needs, people commonly rely on water pumps to transport water from sources such as rivers, wells, or reservoirs to locations of use [4]. A water pump is a mechanical device that functions by increasing fluid pressure to move water through pipes [5],[6],[7] enabling it to overcome various forms of resistance, including elevation and frictional losses [8].

Most modern pumps are electrically powered, and while this is effective in urban environments with a stable electricity grid, it becomes problematic in areas where electricity is inaccessible or unreliable. The cost of installation and dependence on electrical infrastructure presents significant barriers to rural water access, often leaving communities without practical solutions for basic water supply [9]. In response to this problem, there is a growing interest in exploring alternative, renewable energy-based water pumping systems that are affordable, environmentally friendly, and independent of the electrical grid. One such solution is the use of water wheels, a time-tested technology that harnesses the kinetic or potential energy of flowing or falling water to perform mechanical work. Historically, water wheels have played an important role in traditional industries such as milling, sawing, and even early electricity generation [10]. Today, their utility can be reimagined to meet modern sustainability needs, particularly for water pumping in off-grid locations. Building upon this concept, the development of PATA Technology (Pompa Air Tenaga Air) represents a significant step toward sustainable water access[11][12]. PATA utilizes a water wheel to drive a mechanical pump, transferring water from lower to higher elevations without relying on electrical energy [12]. This system is especially advantageous in regions where natural water flow is abundant but limited technological infrastructure. By converting the natural motion of water into rotational energy, the water wheel becomes a clean and renewable power source that can meet the daily water needs of remote communities.

Water access in remote, off-grid regions remains a major development challenge, particularly where electricity is limited or unreliable. Although water-wheel-driven pumps present a promising off-grid alternative, earlier studies show significant limitations in efficiency and flow rate. For example, Gunarto et al. (2023) reported an undershot water wheel system with only 16.5% efficiency and a flow rate of 0.32 L/min, insufficient for community needs [13]. Taweewithyakarn and Setthapun (2018) developed a hybrid water pumping system that reached 10–14 L/min flow with 13–14 m head[14]. Poudel et al. (2021) introduced a hydro-powered turbine pump for irrigation, demonstrating better scalability and sustainability [15]. These studies suggest significant untapped potential in water-wheel systems for rural development. The current study addresses this gap through the development of PATA Technology (Pompa Air Tenaga Air), a water-wheel-powered mechanical pump. Designed for areas with abundant natural water flow but lacking electricity, PATA prioritizes simplicity, low cost, and ease of maintenance using local materials.

The implementation of PATA Technology is planned at Pura Beji, located in the Tanah Lot area of Beraban Village, Tabanan Regency, Bali. This sacred temple site is characterized by its abundant water resources in the lowlands and the need to deliver water to higher ground for ritual and communal purposes. This area's natural topography and water availability make it an ideal location for testing and applying a sustainable water-lifting system powered entirely by the environment. Furthermore, by leveraging local resources and simple mechanical principles, this solution promotes community self-sufficiency and resilience in the face of energy-related challenges contrast, the PATA system is designed to be low-cost, mechanically simple, and operable with minimal training. This research study aims to evaluate the mechanical performance and efficiency of the waterwheel-powered pumping system (PATA) installed in Pura Beji. The successful implementation of PATA Technology at Pura Beji could serve as a model for other villages across Indonesia and beyond, especially those situated in hilly or mountainous terrain with access to flowing water. As water scarcity, energy poverty, and climate resilience become increasingly pressing global concerns, locally adapted systems like PATA can offer scalable, replicable, and impactful pathways toward sustainable development.

## 2. METHODS

This research provides a comprehensive analysis of the effectiveness of water wheels as mechanical drivers for water pumps by thoroughly evaluating the operational performance of a water wheel-powered pumping system. The study focuses on critical technical parameters such as energy transfer efficiency, hydraulic power output, rotational power input, and overall system responsiveness under real-world conditions. A key aspect of this research is to measure and compare the input energy derived from flowing water with the actual volume and pressure of water delivered by the pump, in order to assess the energy efficiency and mechanical viability of the PATA system. Understanding these performance metrics is essential, especially for rural communities where reliable and sustainable access to clean water is vital for daily life. Efficiency in this context does not only refer to mechanical performance but also to the system's ability to function consistently with minimal maintenance and without reliance on electricity. Thus, the findings are expected to inform future implementations of environmentally friendly, off-grid water supply systems in other locations with similar geographical and infrastructural challenges.

The research was conducted at Pura Beji Kangin, located in Banjar Pakedungan, Beraban Village, Kediri District, Tabanan Regency, Bali. This site was selected due to its abundance of natural flowing water in the lowlands and the cultural importance of water in temple rituals and community activities. The research was conducted using quantitative data from various testing phase involved a systematic collection of operational data, including wheel rotation speed, water discharge rate, and head height, among others then analyzed by statistical analysis to show as table and figure. These parameters were carefully measured under varying flow conditions to simulate different environmental scenarios. Additionally, the study incorporates both theoretical modeling and empirical validation to ensure that the outcomes are technically sound and applicable beyond the case study location. By integrating design principles with field experimentation, the research aims to bridge the gap between conceptual engineering and community-level implementation. The interaction between the wheel's mechanical energy and the pump's hydraulic function is at the core of this investigation, as it determines the feasibility of

PATA as a practical solution for decentralized water pumping. Ultimately, this research not only highlights the performance of the system but also contributes to the growing body of knowledge surrounding appropriate technologies for rural water infrastructure. The study's outcomes may serve as a reference for engineers, development planners, and policymakers seeking sustainable, replicable, and low-impact technologies for rural development. A schematic representation of the PATA technology installation is illustrated in Figure 1, providing a visual overview of the system configuration and layout used during field testing.

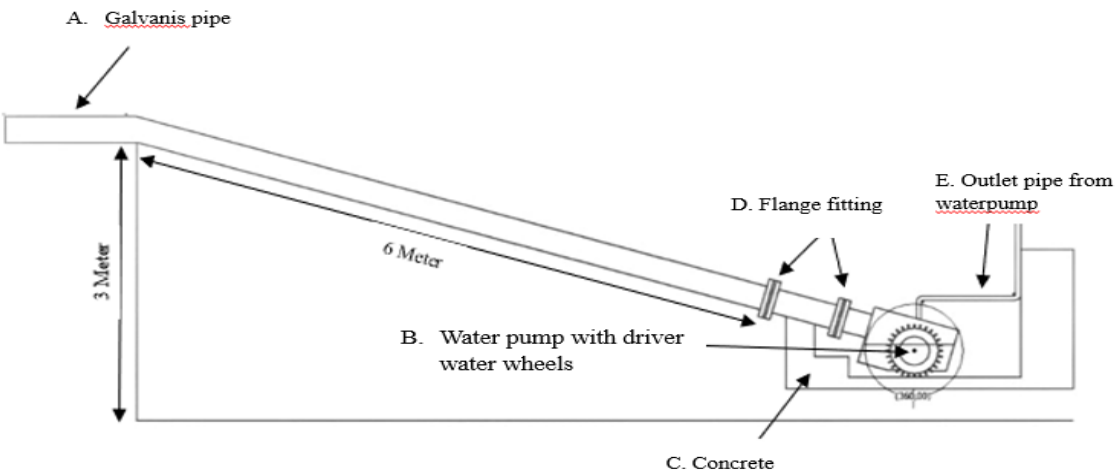


Figure 1. Schematic of water wheels installation against water pump (PATA)

From Figure 1, it can be observed that the water wheel-driven pump system is designed to utilize gravitational water flow as a renewable source of mechanical energy. The system begins with the entry of water through a 3-inch galvanized iron pipe (A), which functions as the intake conduit. This pipe collects water from a source located at a height of approximately 3 meters, enabling a consistent flow with sufficient pressure head to drive the mechanical system. The water exits the pipe with enough velocity to strike the paddles or blades of the water wheel (B), initiating rotational motion. The wheel is directly connected to the water pump via a flange coupling (D), allowing rotational torque to be transferred efficiently to the pump's drive mechanism. As the wheel spins under the force of the falling water, it provides continuous mechanical input to the pump, which begins to draw water from the source and push it through the system. This conversion of gravitational potential energy into mechanical energy forms the core principle behind the PATA (Pompa Air Tenaga Air) system. To maintain structural integrity, the system is firmly supported by a foundation bracket (C), which anchors the pipe and wheel assembly to a fixed base. The bracket is positioned precisely between the two flange fittings (D) to ensure stability and prevent misalignment or vibration during operation. This structural component is crucial for maintaining the correct axis of rotation and minimizing energy loss due to mechanical friction or imbalance. Once the pump is activated, it delivers water through a half-inch PVC pipe (E), which serves as the distribution line. This pipe directs the pumped water to a height of 1.2 meters, supplying it to a nearby fountain or water reservoir.

Despite the relatively modest size of the system, it successfully lifts water against gravity using only the kinetic energy of a naturally flowing stream, without relying on electricity or fossil fuels. This system exemplifies a sustainable water pumping solution for remote or rural areas where conventional energy sources are scarce or unreliable. By leveraging the natural topography and local water availability, it eliminates the need for electric motors and reduces both environmental impact and long-term operational costs. Furthermore, the simplicity of its design makes it easy to install, maintain, and replicate in various settings, from agricultural irrigation to community water supply.

The complete system configuration, including water intake, transmission components, structural support, and water outlet, is illustrated in Figure 2. This diagram provides a clear overview of the mechanical interactions and spatial layout of the PATA technology. The figure also emphasizes the modularity of the system, showing how each part can be adapted or scaled according to site-specific requirements, such as flow rate, lift height, or terrain conditions. In summary, this setup not only demonstrates the practical use of water wheel technology in modern rural engineering applications but also serves as a model for integrating renewable mechanical energy into small-scale infrastructure. It contributes to ongoing efforts in sustainable development, particularly in enhancing access to clean water through locally appropriate and energy-independent solutions.

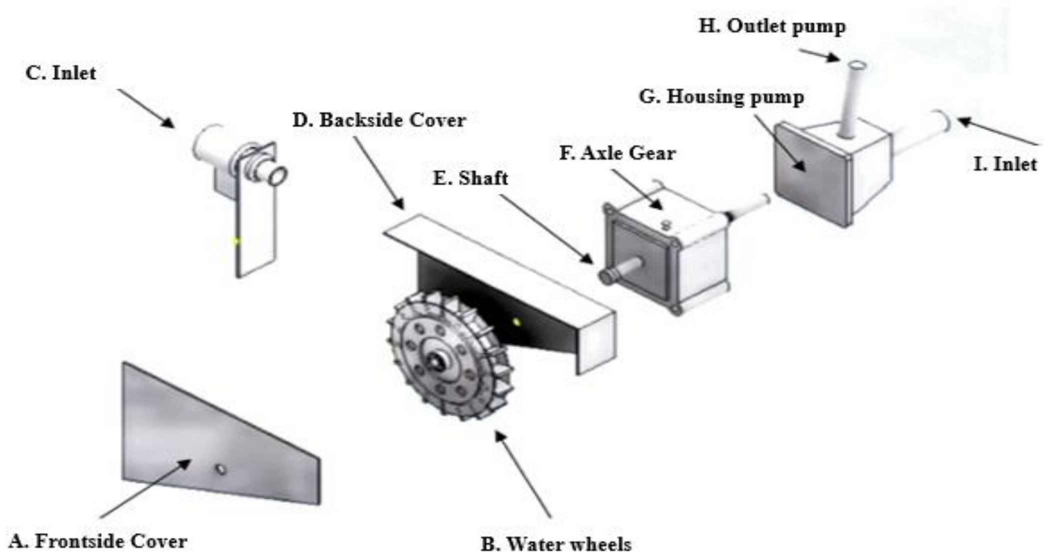

Figure 2. Design configuration devices

From Figure 2, the working principle of the water-powered pumping system can be described as a continuous and integrated mechanical process that begins when water enters through an inlet pipe and is directed toward the inlet nozzle (C), where the flow is concentrated and channeled under gravity and pressure to strike the blades of the water wheel (B). This flow generates torque that causes the wheel to rotate, with the resulting mechanical energy transmitted through a horizontal shaft (E) connected directly to the central hub of the wheel. The rear cover (D) not only serves as a mechanical enclosure protecting internal components from environmental factors and splashing water, but also functions as a bearing support that ensures alignment and reduces friction along the shaft during continuous operation. At the same time, the front cover (A) provides structural support and acts as a water guide, focusing the jet stream efficiently onto the blades to optimize rotation.

The rotational energy generated by the water wheel is then transmitted to a secondary drivetrain in the form of a 2016 Honda Beat axle gear (F), a repurposed motorcycle component that acts as a mechanical gear reducer and speed increaser. This gear assembly plays a crucial role in adjusting the rotational output from the relatively low RPM of the water wheel to a higher RPM more suitable for driving the pump system efficiently. The gear system then drives the Shimizu PC-260 Bit Jet Pump (G), a domestic centrifugal jet pump capable of lifting and pressurizing water for household or agricultural use. Clean water sourced from the Beji spring is drawn into the pump through its suction inlet (I), where it is pulled into the impeller chamber due to the rotational motion generated by the gear system. Once inside, the water is pressurized and discharged through the outlet pipe (H), allowing for vertical or horizontal distribution as needed.

This self-contained, gravity-driven system demonstrates the ability to convert the kinetic energy of naturally flowing water into usable mechanical energy for water pumping applications without requiring external electricity or fuel, making it an ideal solution for remote or off-grid rural environments. The entire setup exemplifies not only the creative integration of locally available components—such as repurposed vehicle parts and standard household pumps—but also the potential for community-scale implementation of sustainable, renewable technology. Furthermore, due to its simple construction and modularity, the system is easy to maintain, repair, and adapt to various flow rates or terrain conditions, offering practical value for rural water management, agricultural irrigation, or community water supply. Its design reflects both functional efficiency and innovative thinking, promoting a model of appropriate technology that bridges traditional mechanical engineering with local resource utilization to achieve energy independence and environmental sustainability.

## 3. RESULTS AND DISCUSSION

According to research results, the required data has been obtained through experiments and calculation were carried out to obtain the power of the water wheel and pump and the efficiency of the PATA implementation. In the test of waterwheel pump, the pump uses a waterwheel with an overshoot concept, water enters and pushes the blades with an input section with a pipe head height of 3 meters and using 42$^{o}$ inclination angle. The results are shown in the Table 1.

Table 1. Data results of waterwheel input flow rate and water pump output flow rate during running test

| No | Date | Flow rate waterwheels, Pin ($m^3/s$) | Rotation (rpm) | Flow rate Waterpump, Pout ($m^3/s$) | Remarks |
|---|---|---|---|---|---|
| 1 | Saturday, 26-03-2022 | 0.0025 | 456 | 0.0005 | Stable rivers flow |
| 2 | Sunday, 27-03-2022 | 0.0025 | 442 | 0.0005 | Stable rivers flow |
| 3 | Monday,28-03-2022 | 0.0025 | 467 | 0.0005 | Stable rivers flow |
| 4 | Thursday,14-04-2022 | 0.0025 | 451 | 0.0005 | Stable rivers flow |
| 5 | Friday, 15-04-2022 | 0.0028 | 512 | 0.0007 | Fast rivers flow |
| 6 | Friday, 15-04-2022 | 0.0026 | 519 | 0.0007 | Fast rivers flow |
| 7 | Sunday, 01-05-2022 | 0.0025 | 486 | 0.0005 | Stable rivers flow |
| 8 | Sunday, 01-05-2022 | 0.0025 | 471 | 0.0005 | Stable rivers flow |
| 9 | Sunday, 01-05-2022 | 0.0025 | 452 | 0.0005 | Stable rivers flow |
| 10 | Monday, 02-05-2022 | 0.0025 | 493 | 0.0005 | Stable rivers flow |

Measurement conducted from morning to afternoon, while keeping remarks on the river's flow condition. Based on the data produced with stable river flow conditions, the results of the discharge on the waterwheels and discharge out on the water pump, as well as rpm, are optimal enough to supply water, especially with fast river flow conditions, causing the discharge and rpm to increase proportionally. Based on the data in Table 1 above, the discharge from the waterwheel and water pump can be compared based on their RPM, which is illustrated in Figure 3.

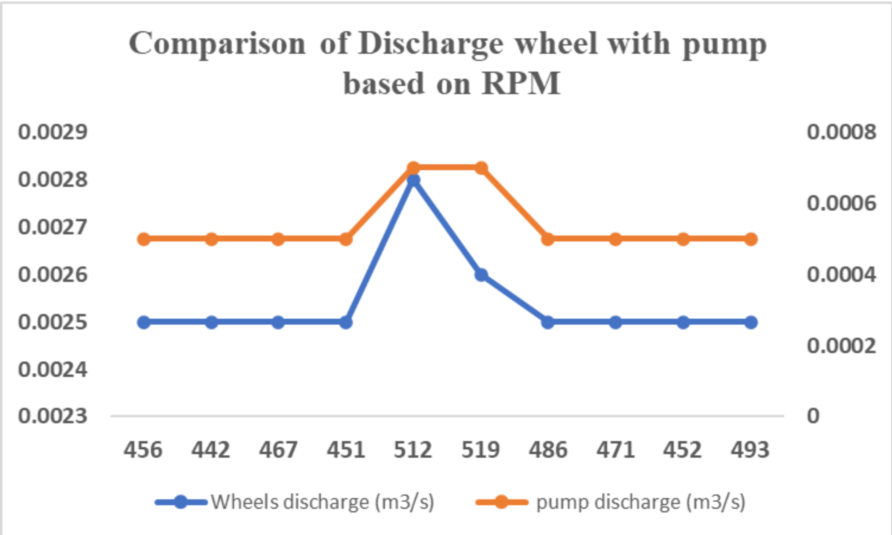


Figure 3. Comparison of the discharge of waterwheels and water pumps

From Figure 3, it can be explained that if the discharge from the water wheels is greater, then the water discharge produced by the pump will also be greater[16],[17]. This is because the water supply to the waterwheel increases its rotational speed[18][19], which in turn affects the suction and discharge power of the pump[20][21], resulting in a higher output[22]. Conversely, a lower water supply leads to a reduced output

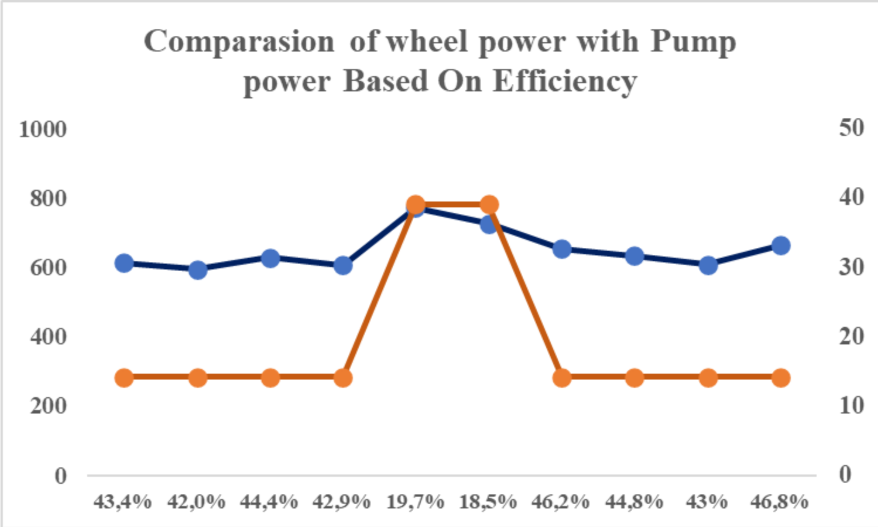


Figure 4. Comparison of power waterwheels and water pumps based on PATA efficiency

The power generated by the water wheel will increase if the height of the pipe inlet is raised above the current height of 3 meters. A higher inlet height will result in greater wheel power, which in turn will increase the water flow produced by the pump[23],[16], [24]. The overall efficiency of the system can also be improved by using materials that are waterproof, temperature-resistant, rustproof, and corrosion-resistant to protect against water leakage, which leads to a reduction in the generated energy[25]. Efficiency is a key aspect of the system, and ensures maximum conversion of running energy from water flow into energy to drive the water pump. Research from Koondhaar (2024) related to waterwheel design obtained an efficiency of 55-69% [12]. From Figure 2, it can be explained that the average efficiency value produced is 40%. Based on the available data results, implementation of PATA technology could be implemented, although the efficiency is less than optimal, which fluctuates based on flow rate and rpm of the waterwheels and pumps. Optimization of efficiency is possible by modifying the number and width of the blades in the water wheel [26]. In addition, if you want to increase efficiency can be done by modifying the nozzle line and waterway canal [26].

### 3.2. Equations

In processing the data obtained during the research, several equations were applied to analyze hydraulic performance and derive results aligned with the research objectives. The power of the pump was calculated using Equation (1) [24]:

$$P = g \times \rho \times Q \times H \tag{1}$$

Where: P = pump power (W),
$g$ = gravitational acceleration (9.8 m/s²),
$\rho$ = water density (kg/m³),
$Q$ = volumetric flow rate (m³/s),
$H$ = head or height (m).

The flow velocity was determined using Equation (2) [24]:

$$V = \frac{Q}{A} \tag{2}$$

where: $V$ = flow velocity (m/s),
$Q$ = flow rate (m³/s),
$A$ = cross-sectional area of flow (m²).

To estimate the hydraulic power delivered by the flow, Equation (3) [27] was used:

$$Pa = \frac{1}{2}\rho Q v3 \tag{3}$$

where: $Pa$ = available water power (kg/m),
$\rho$ = water density (kg/m³),
$Q$ = flow rate (m³/s),
$V$ = flow velocity (m/s).

For waterwheel torque calculations, the power input from water flow was applied to Equation (4):

$$T = Pin. r^2 \tag{4}$$

where: $T$ = torque (N·m),
$Pin$ = input power to the waterwheel (kg/s),
$r$ = radius of the waterwheel (m).

## 4. CONCLUSION

The water wheel, in this configuration, serves as the main driving element, converting the linear kinetic energy of water flow into rotational energy through a mechanical linkage. The average power generated by the system through this mechanism is approximately 650 kg·m/s², indicating a significant energy transfer from the water source to the pump. Based on performance analysis, the mass flow rate at the water wheel reaches 75.5 kg/s, while the water pump achieves a discharge mass flow rate of 14.7 kg/s, resulting in an overall system efficiency of 40%. This level of efficiency demonstrates the potential of the system for small-scale water lifting applications, particularly in rural or off-grid environments where access to electricity is limited. The combination of locally available components, simple mechanical design, and respectable performance metrics positions this system as a viable solution for sustainable and low-maintenance water pumping, promoting renewable energy utilization and supporting water resource management in remote areas. In conclusion, the water wheel-powered pump system not only offers a functional and environmentally friendly alternative to conventional electrically powered pumps, but also highlights the practical benefits of adapting mechanical engineering principles with repurposed components for community-scale renewable solutions. Its ease of construction, minimal operational cost, and independence from the electrical grid make it an ideal technology for supporting local water access and advancing energy resilience in developing regions.

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