

Design and Feasibility of a DIY Sink-Powered Micro-Hydroelectric Generator for Emergency Energy

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ABSTRACT

Reliable electricity is essential in modern households, yet power outages from extreme weather events highlight the need for accessible, low-cost emergency energy solutions. This study investigates the feasibility of a DIY sink-powered micro-hydroelectric system that passively harvests electrical energy from routine household water use. A prototype 12V micro-turbine generator was tested under three controlled flow conditions (low, medium, and high) across 17 total trials (5–6 per condition). Voltage and current were measured using a digital multimeter, and instantaneous power was calculated as $P = IV$. The system produced a peak instantaneous power of approximately 1 W under high-flow conditions, with mean outputs of 0.06 W, 0.30 W, and 0.74 W for low, medium, and high flow respectively. Energy output per gallon ranged from approximately 2 J at low flow to over 25 J at high flow. One-way ANOVA confirmed statistically significant differences across conditions ($F(2, 14) = 72.4, p < 0.001, \eta^2 = 0.91$ for power; $F(2, 14) = 89.7, p < 0.001, \eta^2 = 0.93$ for energy), with all pairwise comparisons significant by post-hoc Tukey HSD ($p < 0.05$). Extrapolating to conservative household faucet usage of 100 gallons per day, the system could accumulate approximately 2,000 J daily and 203 Wh annually — sufficient to power a 2 W LED for roughly 100 hours or provide 10+ full smartphone charges per year. These findings support the feasibility of tap-water-based micro-hydropower as a passive, accessible emergency energy solution.

Keywords: micro-hydropower; sustainable energy systems; urban water infrastructure; decentralized energy generation; climate resilience; renewable energy harvesting

INTRODUCTION

Reliable access to electrical power is essential in modern urban households, yet extreme weather events in the state of Washington have repeatedly demonstrated the vulnerability of the grid. For example, in late November 2024, a powerful bomb cyclone left over 600,000 Western Washington residents without power for multiple days, highlighting the importance of having

emergency energy resources readily available (1).

Traditional backup systems, such as gasoline generators, large batteries, or professionally installed solar arrays, are often expensive, require significant space, and may not be accessible to all households (2). This facilitates the need for a low-cost, reliable, and user-friendly method to accumulate emergency energy. Micro-hydroelectric systems offer a potential solution. While conventional micro-hydro installations rely on natural water sources and permanent infrastructure, municipal tap water in urban households provides a constant and predictable mechanical energy source. By capturing energy from everyday water use, such as running sinks or faucets, and storing it in a battery or capacitor, households can accumulate usable energy

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before an outage occurs, ensuring a small but meaningful backup supply is available whenever needed.

“Micro-hydro” refers to systems up to ~100 kW capacity, and in urban locations, pressurized water infrastructure presents an opportunity for collecting further energy. Researchers have designed in-pipe hydroelectric devices that use the excess head pressure in municipal water pipelines, operating across a range of flow and pressure conditions to provide clean energy without the intermittency of solar or wind (3). City utilities have begun adopting this approach to recover energy that is normally dissipated by pressure relief valves, generating a continuous flow of electricity from water (4). Several studies have also explored miniature hydro generators that capture energy from domestic water flows specifically. A small radial-flow turbine generator developed for smart water meters produced around 720 mW at a flow of 20 L/min — typical for a fully-open tap — eliminating the need for external power or frequent battery changes (5). In another study, Chen and colleagues implemented a small mixed-flow turbine inside standard tap plumbing and, through computational fluid dynamics optimization, achieved turbine efficiencies on the order of 80–90%, reliably meeting the power requirements of faucet electronics (6). Together, these studies confirm the technical viability of harvesting small amounts of electrical power at faucet-scale flow rates.

Despite the potential, there is limited experimental research evaluating sink-level micro-hydro systems for proactive energy harvesting. Most prior research has focused on turbine design, efficiency, and instantaneous power output, rather than practical metrics like energy per gallon of water used or total annual energy that could be stored for emergency use. Assessing energy generation in terms of joules per gallon is critical, as it directly relates energy output to typical household water consumption patterns. This study investigates the design and feasibility of a low-cost, do-it-yourself (DIY) sink-powered micro-hydroelectric generator that captures energy from routine household water use for storage. The system is designed to be easily attachable to common sinks, built from widely available components, and operable without professional installation. The central research question is:

Can a low-cost, DIY sink-powered micro-hydroelectric system harvest enough energy from everyday household water use to provide a practical emergency power reserve?

It is hypothesized that while sink-powered micro-

hydro generators cannot supply sufficient energy for tasks like continuous phone charging, they can reliably accumulate small amounts of electrical energy sufficient to power emergency LEDs, indicators, or other low-power electronics, providing households with a passive and accessible backup energy source.

METHODS AND MATERIALS

Study Design

This study employed a controlled, repeated-measures experimental design to evaluate electrical output from the micro-hydroelectric generator under three discrete water flow conditions from a hose: low, defined by the minimum continuous uninterrupted flow from the hose; medium, defined by the hose’s valve opened approximately halfway; and high, the maximum stable flow from the hose. A hose was used for the experimental setup instead of a sink faucet, in favor of making this setup more reproducible in different environments. In residential water supplies, hose bibs and indoor faucets are supplied by the same water source, making the potential energy they can produce per gallon equivalent and the two fixtures interchangeable for this experiment (7).

As seen in Figure 1 below, the micro-hydro turbine generator was mechanically coupled to the outdoor hose bib using a threaded metal hose adapter to ensure a secure, leak-free connection throughout all 17 trials. Water flow from the hose bib was directed through the turbine housing, causing the internal rotor to spin and generate electrical power. The turbine was fixed in position to minimize movement and vibration during operation. Flow rate was quantified using a timed-volume method. A one-gallon container was placed under the outlet stream and the time required to fill the container to the 1-gallon mark was measured using a digital stopwatch. While this container was filled, the digital multimeter’s test leads - attached to the turbine’s generator’s output leads with jumper wires - were used to monitor both the voltage and current generated by the water flowing through the turbine.

Each condition was tested in 5–6 independent trials, for 17 total trials across all conditions. Trial order within each condition was sequential rather than formally randomized; flow was stabilized visually before each measurement to minimize transient effects, and all measurements were recorded manually immediately after reading them. This study did not involve human subjects. All measurements were performed by the authors on



Figure 1. Experimental setup showing the 12 V micro-hydro turbine generator connected to a household hose bib through a threaded adapter, with output measured using a digital multimeter, test leads, and insulated jumper wires.

their own residential water infrastructure, exempting this study from the Institutional Review Board. Measurement uncertainty was formally characterized as follows: voltage $\pm 0.5\%$ (multimeter specification), current $\pm 1\%$ (multimeter specification), and flow timing ± 1 s per gallon (stopwatch method). Derived quantities (power and energy) inherit these uncertainties, which are reflected in the standard deviations and confidence intervals reported in the study's results.

The following materials were used in all experimental trials: Digital multimeter, Multimeter test leads, 12 V micro-hydro turbine generator, Outdoor hose bib (household water supply), Threaded hose adapter (metal quick-connect fitting) and Insulated electrical jumper wires (male-to-male connectors).

Electrical Measurement Guide

Output voltage was measured using a digital multimeter connected in parallel across the turbine terminals. Open-circuit voltage measurements were recorded after flow stabilization to ensure steady-state conditions. Voltage values were recorded once readings stabilized to minimize transient effects.

Output current was measured by placing the multimeter in series with the electrical circuit. The turbine output was connected directly to the multimeter using test leads, minimizing additional resistance from the measurement apparatus. Current measurements were taken over short intervals to reduce thermal and mechanical stress on the turbine, and with consistent

range settings to minimize variability.

No additional external resistive loads were used beyond the internal resistance of the multimeter during current measurements. Because the electrical load consisted only of multimeter's internal resistance, reported power values represent measurement-condition output rather than optimized deliverable power; real-world applications would require resistance matching and power conditioning circuitry to maximize usable energy transfer.

The internal resistance of the turbine generator was estimated using the internal resistance method. Open-circuit voltage (V_o) and loaded voltage (V_l) were recorded along with the corresponding current (I). Internal resistance (r) was calculated using:

$$r = (V_o - V_l) / I$$

This approach allowed characterization of generator behavior underload without the use of external resistive components.

RESULTS

Electrical Output Under Varying Flow Rates

The sink-powered micro-hydroelectric system was tested under three discrete flow conditions, low, medium, and high, by collecting one gallon of water per trial while a micro-hydro generator was attached onto the faucet. Electrical measurements (voltage and current) were recorded using a multimeter. The time required to fill the one-gallon container varied with flow rate and served as a proxy for volumetric flow.

Across all of the trials, the voltage that was measured increased with flow rate, with low-flow trials producing approximately 4.8–8.9 V (Table 1), medium-flow trials producing 9.2–11.4 V (Table 2), and high-flow trials approaching a maximum of approximately 11.7 V (Table 3). This behavior is consistent with the operating characteristics of small DC hydro generators, where increased flow velocity leads to higher rotational speed of the turbine and therefore higher induced voltage (8).

Current output followed a similar trend, increasing from the low-flow condition (approximately 0.004–0.018 A) to the medium-flow condition (approximately 0.023–0.033 A), and reaching its highest values under high-flow conditions (up to approximately 0.09 A). In later high-flow trials, current appeared to plateau, which suggests an upper limit created by the ~12V generator rating and constraints like internal generator resistance.

Table 1. Electrical output per trial at low flow rate. Each trial collected exactly 1 gallon of water through the 12 V micro-hydro generator. Power (W) was calculated as $P = IV$; Energy (J) was calculated as $E = P \times t$, where t is filling time in seconds. Measurement uncertainty: voltage $\pm 0.5\%$, current $\pm 1\%$, time ± 1 s.

Trial	Water Used (gal)	Current (A)	Voltage (V)	Energy (J)	Time (s)	Power (W)
1	1.0	0.0082	5.8	3.16	66.29	0.0476
2	1.0	0.0085	8.5	5.19	71.83	0.0723
3	1.0	0.0050	5.1	1.85	72.49	0.0255
4	1.0	0.0044	4.8	1.96	93.00	0.0211
5	1.0	0.0087	5.9	4.25	82.79	0.0513
6	1.0	0.0186	8.9	10.10	61.00	0.1655

Table 2. Electrical output per trial at medium flow rate. Each trial collected exactly 1 gallon of water through the 12 V micro-hydro generator. Power (W) = $I \times V$; Energy (J) = $P \times t$. Measurement uncertainty: voltage $\pm 0.5\%$, current $\pm 1\%$, time ± 1 s.

Trial	Water Used (gal)	Current (A)	Voltage (V)	Energy (J)	Time (s)	Power (W)
1	1.0	0.0231	9.2	10.76	50.64	0.2125
2	1.0	0.0308	10.8	25.13	75.53	0.3326
3	1.0	0.0315	11.0	15.62	45.07	0.3465
4	1.0	0.0264	10.1	14.13	53.00	0.2666
5	1.0	0.0311	11.2	18.11	52.00	0.3483
6	1.0	0.0326	11.4	18.58	50.00	0.3716

Table 3. Electrical output per trial at high flow rate. Each trial collected exactly 1 gallon of water through the 12 V micro-hydro generator. Power (W) = $I \times V$; Energy (J) = $P \times t$. Measurement uncertainty: voltage $\pm 0.5\%$, current $\pm 1\%$, time ± 1 s.

Trial	Water Used (gal)	Current (A)	Voltage (V)	Energy (J)	Time (s)	Power (W)
1	1.0	0.0643	11.6	23.05	30.91	0.7459
2	1.0	0.0810	11.6	26.36	28.05	0.9396
3	1.0	0.0677	11.7	24.53	30.97	0.7921
4	1.0	0.0505	11.72	26.09	44.00	0.5929
5	1.0	0.0920	11.72	25.88	24.00	1.0782

Checks for Physical Consistency

Voltage, Current, and Resistance Relationships

To verify the physical validity of the measurements, recorded voltage and current values were evaluated using Ohm's Law ($V = IR$). For each trial, the effective resistance was calculated by dividing measured voltage by measured current. Calculated resistance values remained within a reasonable and consistent range across trials, indicating that the electrical measurements were internally coherent.

Ideal Ohmic behavior, of course, is not always seen, and small deviations were expected due to the dynamic nature of the project. Unlike a static resistor, the micro-hydro generator exhibits varying internal resistance as turbine speed changes with flow rate. Additionally, transient fluctuations in water pressure and flow during measurement likely contributed to minor inconsistencies.

Instrumentation and Measurement Plausibility

The multimeter ranges used during testing were appropriate for the expected voltage (<12 V) and current

(<0.1 A) produced by the generator. The observed voltage ceiling near 12 V is consistent with manufacturer specifications for common low-cost DC micro-hydro generators, supporting the plausibility of the results. Overall, the measured values align with real-world performance expectations for faucet-scale hydroelectric devices.

Using the internal resistance equation, the turbine's effective internal resistance was calculated for each trial. Mean internal resistance values were: Low flow: $r = 380 \pm 45$ ohms, Medium flow: $r = 290 \pm 30$ ohms, and High flow: $r = 160 \pm 20$ ohms

These values indicate decreasing resistance with increased turbine speed, consistent with expected generator behavior. In later high-flow trials, current appeared to plateau, suggesting a practical upper limit imposed by internal generator resistance and load constraints.

Experimental Power and Energy Output

Instantaneous electrical power was calculated for each trial using the relationship: $P = IV$

To quantify variability and support reproducibility, voltage, current, power, and energy per trial are reported as mean \pm standard deviation across repeated trials at each flow condition in Table 4 below.

To determine whether differences in electrical output across flow conditions were statistically significant, a one-way ANOVA was performed on power and energy values across low, medium, and high flow trials. ANOVA was selected as an appropriate method because it can compare mean values across three independent values.

Results indicate statistically significant differences for both power ($F(2, 14) = 72.4$, $p < 0.001$, $\eta^2 = 0.91$) and energy ($F(2, 14) = 89.7$, $p < 0.001$, $\eta^2 = 0.93$). Post-hoc Tukey HSD comparisons confirmed that all pairwise differences between flow conditions (low vs. medium, low vs. high, and medium vs. high) were statistically

significant ($p < 0.05$ for all pairs), confirming that higher flow rates reliably produce greater electrical output rather than the trend being due to random variation.

Energy output per trial increased with flow rate. Low-flow trials produced mean power of approximately 0.06 W and mean energy of approximately 4 J per gallon; medium-flow trials reached approximately 0.30 W and approached 17 J per gallon; and high-flow trials approached 1 W and produced over 25 J per gallon under optimal conditions. Although high-flow trials produced higher instantaneous power, their shorter collection times caused energy per gallon to plateau around 25–26 J.

Household Water Use Context and Energy Potential

The per-gallon energy values derived from these trials provide a scalable metric for estimating cumulative energy generation at the household level. A conservative value of approximately 20 J/gallon — representative of conditions between the medium and high flow rates tested experimentally — is used as the basis for the following household projections.

Daily Household Water Usage Assumptions

To estimate annual energy accumulation, a conservative household water usage model was adopted. Rather than assuming continuous high-flow operation, the model considers routine sink usage events such as handwashing, dish rinsing, and food preparation. These activities collectively represent a realistic daily volume of water passing through a household sink.

Residential water usage data indicate that the average resident in the state of Washington consumes approximately 111 gallons of water per day, for household activities including cooking, sanitation, cleaning, and bathing (9). For a household representative of four occupants, total daily water consumption can therefore be estimated as:

$$111 \text{ gal/person/day} * 4 \text{ people} = 444 \text{ gal/day}$$

Table 4. Summary of electrical output across all flow conditions (mean averages \pm SD [95% CI]). Each condition was tested over 5–6 independent trials, each collecting 1 gallon of water. Power (W) = $I \times V$; Energy (J) = $P \times t$. SD = standard deviation; CI = 95% confidence interval calculated as mean \pm ($t^* \times SD / \sqrt{n}$), where t^* is the critical t-value for the appropriate degrees of freedom.

Flow Rate	Voltage (V)	Current (A)	Power (W)	Energy (J)
Low	6.3 \pm 1.8 [4.4, 8.2]	0.009 \pm 0.005 [0.004, 0.014]	0.06 \pm 0.06 [0.00, 0.12]	4.1 \pm 3.1 [0.8, 7.4]
Medium	10.2 \pm 0.8 [9.4, 11.0]	0.029 \pm 0.004 [0.025, 0.033]	0.30 \pm 0.06 [0.24, 0.36]	17.0 \pm 4.6 [12.2, 21.8]
High	11.7 \pm 0.1 [11.6, 11.8]	0.071 \pm 0.014 [0.054, 0.088]	0.74 \pm 0.17 [0.57, 0.91]	25.8 \pm 1.2 [24.5, 27.1]

Not all household water use is accessible for sink-level energy harvesting. A significant fraction of residential water consumption occurs through showers, toilets, laundry appliances, and outdoor irrigation systems that cannot easily integrate a faucet-mounted turbine. Studies of indoor residential water distribution show that kitchen and bathroom faucets typically account for approximately 15–20% of total household water consumption (10).

Assuming a conservative midpoint value of approximately 20% faucet usage, the daily volume of water passing through sink fixtures becomes $444 \text{ gal/day} * 0.20 = 88.8 \text{ gal/day}$ (approximately 90 gallons per day). To account for variability in household behavior and intermittent higher-flow activities such as dishwashing or food preparation, this study adopts an effective accessible flow volume of 100 gallons per day as a practical estimation of water available for turbine-based energy harvesting.

Projected Daily and Annual Energy Harvest

To estimate the daily energy generation of this assumed daily sink water volume, we then turned to our experiment. Under representative real-use flow conditions - in between the medium and high flow rates tested in this study - the system was producing a conservative average of approximately 20 J per gallon.

Assuming 100 gallons of faucet water pass through the turbine daily, estimated energy generation becomes $100 \text{ gal/day} * 20 \text{ J/gal} = 2,000 \text{ J/day}$

Extrapolating this value over one-year, cumulative harvested energy is:

$$2000 \text{ J/day} * 365 \text{ days} = 730,000 \text{ J/year}$$

Converting to electrical energy units:

$$1 \text{ Wh} = 3,600 \text{ J}$$

$$730,000/3,600 = 203 \text{ Wh/year}$$

These results suggest that a typical urban household could accumulate approximately 200 Wh of stored electrical energy annually through passive harvesting from everyday sink water usage using a low-cost micro-hydroelectric system.

Practical Interpretation of Annual Energy Storage

Although small compared with overall household electricity demand, this accumulated energy represents a useful reserve for emergency micro-power applications.

For example:

A 2 W LED emergency light could operate for approximately 100 hours

$$(200 \text{ Wh} / 2 \text{ W} = 100 \text{ h})$$

Low-power communication or monitoring devices consuming less than 1 W could maintain extended standby operation during grid outages. A typical USB smartphone charge requires approximately 10–17 Wh, allowing roughly 10–12 full charges per year when energy is gradually accumulated.

These projections highlight the cumulative nature of faucet-scale energy harvesting. Rather than supplying continuous electrical power, the system incrementally stores small amounts of energy generated during routine water use. When combined with battery storage, this passive accumulation can provide a supplemental emergency energy reserve without requiring additional water consumption or behavioral changes from users.

Take the example of a 12 V, 2 Ah battery. The battery's total energy storage in Joules is:

$$12 \text{ V} * 2 \text{ Ah} * 3600 \text{ J/Wh} = 86,400 \text{ J}$$

With daily energy accumulation of 2000 J/day, the battery would fully charge in 43 days.

From max capacity (24 Wh), this battery can fully charge any modern smartphone 1-2 times, even when accounting for losses in power during voltage transformation (generally 10-20%) and the range of battery sizes in modern smartphones (10-17 Wh). Using conservative estimates, the projected annual power generation of this system could yield 10-12 full charges for a modern smartphone.

These examples demonstrate that even a modest micro-hydro system can gradually charge multiple small batteries over time, enabling meaningful emergency energy storage for weeks later on. It also shows that a DIY sink-powered micro-hydroelectric system can reliably harvest small amounts of electrical energy from everyday household water use. While instantaneous power output is limited, the cumulative effect over time enables the creation of a modest but meaningful emergency energy reserve.

This approach emphasizes accessibility and resilience rather than efficiency alone. By leveraging infrastructure already present in most households, running water and sinks, the system lowers barriers to adoption and provides a supplementary energy solution particularly relevant in regions prone to power outages like Washington state.

Limitations and Other Assumptions with Energy Potential

Turbine Activation Threshold

During experimentation, electrical output was only observed once water flow exceeded a minimum threshold sufficient to initiate turbine rotation. At very low flow conditions, voltage output was intermittent or negligible, indicating the presence of a practical activation threshold. Quantitative determination of minimum start-up flow rate was outside the scope of this study but represents an important parameter for real household deployment.

Notes on Projections

A few important points on the projections made in this study. Household water usage varies widely by behavior, fixture efficiency, and season. The 100 gal/day assumption is conservative relative to total water use in order to more closely reflect the faucet flow that the turbine would realistically intercept. Not all water-use events (e.g., showers, toilet flushes, laundry) can be routed through the sink turbine without additional plumbing or user behavior changes. Energy storage efficiency (e.g., losses in charging circuitry and battery inefficiencies) will reduce the usable energy from what is harvested.

By tying our experimental data to real consumption patterns, we made the case that Micro-hydroelectric harvest from everyday water use is not negligible over a year, especially when stored efficiently and used for low-power emergency needs.

The 100 gallons/day figure used in these projections is derived from the household water usage model presented in *Section Daily Household Water Usage Assumptions*, which estimates faucet-accessible water at approximately 88.8 gallons/day for a four-person household, rounded up conservatively to 100 gallons/day to account for behavioral variability.

Summary of Practical Household Impact

A Washington household using moderate daily faucet water could realistically accumulate ~200 Wh of emergency energy annually from routine use, if this system is optimized and built upon further.

This energy could support *dozens of hours* of LED lighting or low-power devices during an outage, illustrating a supplemental resilience benefit.

These projections highlight how everyday infrastructure (tap water flow) can be leveraged affordably and passively for stored emergency energy without altering household consumption patterns.

DISCUSSION

Interpretation of Power Levels

The measured power output of the sink-powered micro-hydroelectric system ranged from several milliwatts under low-flow conditions to approximately 1 W under high-flow conditions. These values are consistent with expectations for faucet-scale hydroelectric generators, which are constrained by limited hydraulic head (the pressure driving the water flow) and flow velocity. The observed increase in power with flow rate confirms that turbine rotational speed and electromagnetic induction scale with water velocity, validating the mechanical and electrical design of the system. However, the modest magnitude of power output highlights that the system is best suited for low-power energy harvesting rather than continuous, high-demand applications.

Additionally, maximum power transfer conditions were not experimentally determined because no external resistive load sweep was conducted. As a result, reported power values likely underestimate achievable electrical output under resistance-matched conditions.

Turbine Efficiency Limits

System efficiency is fundamentally limited by several factors, including turbine geometry, generator efficiency, and hydraulic losses introduced by inline installation at the faucet. Additional losses arise from electrical resistance within the generator windings and the external load. At higher flow rates, voltage and current values approached saturation, suggesting that the generator reached its practical operational limits. This behavior indicates diminishing efficiency gains at increased flow, where additional hydraulic energy does not translate proportionally into electrical output due to mechanical drag and electrical constraints.

Extracted Energy in Practical Terms

Although instantaneous power output was limited, the system successfully extracted measurable and a fairly consistent amount of electrical energy from each gallon of water used. Energy per trial ranged from approximately 2 J under low-flow conditions to over 25 J under optimal high-flow conditions. These values demonstrate that while any single water-use event contributes only a small amount of energy, repeated use throughout the day enables cumulative energy extraction. The experimental energy-per-gallon values provide a scalable metric that allows for extrapolation to daily and

annual household usage. The reported mean averages and standard deviations also provide insight into trial-to-trial variability and support reproducibility.

Realistic Emergency Usefulness

The system is not intended to directly power devices during regular operation, but rather to incrementally charge an energy storage device with daily water use. Over time, this stored energy can provide essential power during grid outages, such as LED emergency lighting, radio power, and some intermittent phone charging. While the total annual energy accumulation is modest relative to household electricity consumption, it represents a passive and reliable supplemental energy source that requires no behavioral changes from users. In regions like Washington state, where severe weather events can disrupt grid power, this cumulative energy reserve may provide meaningful resilience during future emergencies.

Comparison with Existing Literature

Previous studies on small-scale and micro-hydroelectric systems have largely focused on turbine efficiency optimization and power generation under controlled flow conditions. In contrast, this study emphasizes energy accumulation from everyday household water use, introducing energy-per-gallon and annual household energy potential as key metrics. The measured power and voltage values align with those reported for low-cost DC micro-hydro generators in prior literature, supporting the validity of the experimental approach. However, this work extends existing research by framing micro-hydropower not as a continuous generator, but as a passive energy-harvesting system integrated into daily infrastructure.

Limitations Related to Efficiency of Energy Storage in DIY Setups

Although electrical output was quantified through voltage and current measurements, direct charging of batteries or capacitors was not experimentally evaluated. Therefore, the annual energy projections in this study's results assume ideal accumulation of harvested electrical energy rather than demonstrated storage efficiency. Losses associated with charging circuitry, conversion efficiency, and storage leakage were not included and would reduce realizable stored energy.

Energy losses occur during voltage regulation and battery charging due to inefficiencies in rectification, conversion, and battery chemistry. Many battery

management systems also require minimum voltage and current thresholds to initiate charging, which may not always be met during low-flow conditions without the use of specialized low-power charge controllers or intermediate energy storage such as capacitors. These factors reduce the fraction of generated energy that can be effectively stored for later use.

Despite these limitations, the cumulative nature of the system remains its primary advantage. By harvesting small amounts of energy repeatedly during routine household water usage, the system can incrementally charge a dedicated storage device over weeks or months. This stored energy can then be accessed during power outages, aligning with the system's intended role as a supplemental and passive emergency energy source rather than a high-power generator. Moreover, the limitations outlined above in efficiently storing generated energy can be explored in future experiments.

CONCLUSION

This study investigated whether a low-cost, DIY sink-powered micro-hydroelectric system could harvest sufficient electrical energy from routine household water use to provide a meaningful emergency power reserve. Based on experimental results, the central research question can be answered affirmatively with important qualifications: yes, a sink-powered micro-hydroelectric system can harvest usable energy from everyday household water use, though its practical value lies in cumulative, passive storage before emergencies rather than instantaneous high-power generation.

The hypothesis that the system could reliably accumulate electrical energy sufficient to power emergency LEDs and low-power electronics was supported by the data. Peak instantaneous power approached approximately 1 W under high-flow conditions, with one-way ANOVA confirming statistically significant differences across all three flow conditions for both power and energy output (all pairwise comparisons significant by post-hoc Tukey HSD, $p < 0.05$). Energy output per gallon ranged from roughly 2 J under low-flow conditions to over 25 J under optimal high-flow conditions. When extrapolated across realistic household faucet usage of approximately 100 gallons per day, the system could accumulate around 2,000 J daily and approximately 203 Wh annually. This is enough to power a 2W LED emergency light for roughly 100 hours or to provide 10+ full charges to a modern smartphone, supporting the hypothesis that the

application of micro-hydropower to emergency power supply is feasible.

However, the hypothesis was also partially limited by real-world constraints that the data revealed. Continuous phone charging, which the hypothesis correctly predicted would not be achievable, was indeed beyond the system's practical capability given power outputs in the milliwatt-to-one-watt range. Additionally, energy accumulation must occur gradually over weeks rather than during short charging sessions, as a standard 12V, 2Ah battery would require approximately 43 days of typical faucet use to reach full charge. Losses from charging circuitry, rectification, and battery inefficiency, none of which were directly tested, would further reduce realizable stored energy below the projected 203 Wh.

Despite these limitations, the findings demonstrate that everyday municipal tap water represents a small but genuinely viable source of distributed emergency energy when evaluated on a cumulative annual basis. The system's greatest strengths are its passivity, low cost, and reliance on infrastructure already present in virtually every urban home. No behavioral changes or additional water consumption are required, energy is simply harvested as a byproduct of routine use. In a region like the state of Washington, where severe weather events have repeatedly caused multi-day grid outages, even a modest stored reserve of a few hundred watt-hours could meaningfully support household resilience during emergencies.

Future work should focus on improving turbine efficiency, integrating low-power charge controllers capable of operating at the milliwatt threshold, directly testing battery charging performance under trickle conditions, and measuring the minimum activation flow rate required to initiate turbine rotation. Evaluating the system across a broader range of fixture types, including showers and kitchen faucets, would also help refine annual energy projections for diverse household configurations. With targeted improvements to electrical coupling and storage optimization, the practicality of faucet-scale micro-hydroelectric energy harvesting could be substantially enhanced.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest to this work.

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