Portable Hydroelectric Generator: Product Concept and Feasibility

1 Product

Problem

People on multi-day backpacking, camping, paddling, fishing, or other off-grid trips still need electricity for phones, GPS units, satellite communicators, cameras, lights, radios, and other small electronics.

The two simplest options are currently batteries and portable solar:

- **Power banks** are compact and reliable, but contain a fixed amount of energy. Once depleted, they cannot be replenished without another power source.
- **Portable solar panels** can replenish a battery, but only when sufficient sunlight is available. Output varies with cloud cover, shade, time of day, panel angle, and other conditions, and there is no solar generation at night.
- Solar can be particularly limiting in heavily forested or cloudy environments. Western Washington, for example, is characterized by substantial cloudiness and precipitation. [1]
- Meaningful solar power also requires collection area. For example, the Goal Zero Nomad 20 is rated at 20 W, weighs 1.03 kg, and unfolds to approximately 29×55 cm. [2]

A portable hydroelectric generator could provide another option for users traveling near rivers or streams. Unlike solar, it could generate continuously during the day, at night, under tree cover, and during cloudy weather as long as sufficient moving water is available.

Product Overview

The proposed product is a compact hydrokinetic generator that can be placed or anchored in flowing water for several hours. Water spins a turbine, which drives a generator and charges an internal battery pack. The stored energy can then be used to charge phones, GPS units, satellite communicators, headlamps, cameras, radios, fishfinders, or other electronics.

A possible form factor is a water-bottle-sized body containing the generator, battery, and electronics, with a **folding turbine** that expands when deployed. Alternatively, the turbine and generator could be anchored in the water and connected by cable to a battery and power-electronics module on shore. This would keep the battery and charging ports dry and accessible and could better support continuous device charging. Some power would be lost through the cable and conversion electronics, but both configurations remain viable design options.

Target Users

- Backpackers and multi-day hikers

[1] NOAA, Marine Weather of the Inland Waters of Western Washington.
[2] Goal Zero Nomad 20 specifications.

- Remote campers
- Kayakers, canoeists, and rafters
- Fishermen and anglers
- Hunters
- Explorers
- Outdoor photographers
- Field researchers and other remote workers

Best Use Cases

The strongest use case is a multi-day trip where the user is regularly near moving water and cannot easily recharge from the electrical grid.

Examples include:

- Leaving the generator in a stream overnight while backpacking
- Charging a battery while camping beside a river
- Anchoring the generator during a multi-day rafting or canoe trip
- Recharging navigation and communication equipment in remote areas
- Slowly replenishing batteries used for fishing or hunting equipment

2 Technical Feasibility

Turbine Size

The amount of water intercepted by the turbine depends on its swept area:

$$A = \frac{\pi D^2}{4}.$$

Therefore,

$$\boxed{P \propto A \propto D^2}.$$

For

$$D = 0.15 \text{ m},$$

the swept area is

$$A = \frac{\pi(0.15)^2}{4} = \boxed{0.01767 \text{ m}^2}.$$

Water Density

Fresh water has a density very close to

$$\boxed{\rho = 1000 \text{ kg/m}^3},$$

which will be used throughout the calculations. [3]

Power Available in Moving Water

The kinetic energy of a moving mass of water is

$$KE = \frac{1}{2}mv^2.$$

The mass of water passing through the turbine each second is

$$\dot{m} = \rho A v.$$

Therefore, power—energy transferred per unit time—is

$$P_{\text{water}} = \frac{1}{2}\dot{m}v^2 = \boxed{\frac{1}{2}\rho A v^3}.$$

This is the standard hydrokinetic power relationship. [4]

This represents the kinetic power passing through the turbine's swept area. A real turbine cannot capture all of it.

Turbine Power Coefficient

The **power coefficient**, C_p, is

$$C_p = \frac{P_{\text{shaft}}}{P_{\text{water}}}.$$

It describes how efficiently the turbine converts the kinetic energy available in the water passing through its swept area into **mechanical rotation of the turbine shaft**.

Therefore,

$$P_{\text{shaft}} = C_p P_{\text{water}} = \frac{1}{2}\rho A v^3 C_p.$$

For example,

$$C_p = 0.10$$

means that approximately 10% of the kinetic power available in the water passing through the turbine's swept area becomes mechanical shaft power. It does **not** mean that 10% reaches the battery.

Experimental work on a horizontal-axis hydrokinetic turbine measured a peak $C_p = 0.278$. [5]

Because our turbine would be small, portable, and unlikely to be as optimized as a research turbine, this analysis uses a substantially more conservative

$$\boxed{C_p = 0.10}.$$

[3] U.S. Geological Survey, Water Density.
[4] Design and Experimental Performance Characterization of a Three-Blade Horizontal-Axis Hydrokinetic Water Turbine.
[5] Seo et al., Experimental Study on Kinetic Energy Conversion of a Horizontal Axis Tidal Stream Turbine.

Generator and Electrical Efficiency

After the turbine produces shaft power, that rotation must still be converted into usable electricity.

The energy path is approximately

$$\boxed{\text{Water} \rightarrow \text{Turbine} \rightarrow \text{Generator} \rightarrow \text{Rectifier/DC Converter} \rightarrow \text{Battery}}$$

The generator, rectifier, converter, wiring, and battery charging process all introduce additional losses.

A hydrokinetic permanent-magnet generator study measured generator efficiency above 80%, and efficiency remained above 75% when operating with a diode rectifier. [6]

For the conservative case, this analysis assumes

$$\boxed{\eta_{\text{elec}} = 0.70}.$$

However, an electrical efficiency closer to 80–90% may be achievable with well-designed power electronics (Professor Neal Simmons said electrical efficiency can be very high). Therefore, an additional case using

$$\boxed{\eta_{\text{elec}} = 0.80}$$

is also considered to illustrate the effect of improved electrical conversion efficiency.

Thus, the two primary efficiency terms describe different stages:

$$\underbrace{C_p}_{\text{Kinetic Energy of Water} \rightarrow \text{Mechanical Energy of Shaft}} \quad \text{and} \quad \underbrace{\eta_{\text{elec}}}_{\text{shaft} \rightarrow \text{stored electricity}}.$$

The estimated usable electrical power is therefore

$$\boxed{P_{\text{elec}} = \frac{1}{2}\rho A v^3 C_p \eta_{\text{elec}}}.$$

For the conservative case, with $C_p = 0.10$ and $\eta_{\text{elec}} = 0.70$,

$$(0.10)(0.70) = 0.07,$$

so approximately

$$\boxed{7\%}$$

of the kinetic power available across the turbine's swept area ultimately reaches the battery.

For the higher-efficiency case, with $C_p = 0.10$ and $\eta_{\text{elec}} = 0.80$,

$$(0.10)(0.80) = 0.08,$$

so approximately

[6] Grabbe et al., Efficiency of a Directly Driven Generator for Hydrokinetic Energy Conversion.

$$\boxed{8\%}$$

of the kinetic power available across the turbine's swept area ultimately reaches the battery.

15 cm Turbine Model

For a 15 cm diameter turbine,

$$A = \pi \left(\frac{0.15}{2}\right)^2 \approx 0.01767 \text{ m}^2.$$

Using

$$\rho = 1000 \text{ kg/m}^3, \qquad A = 0.01767 \text{ m}^2, \qquad C_p = 0.10,$$

the predicted electrical output depends on the assumed electrical efficiency.

Conservative Case: 70% Electrical Efficiency

For

$$\eta_{\text{elec}} = 0.70,$$

the electrical output is

$$P_{\text{elec}} = \frac{1}{2}(1000)(0.01767)v^3(0.10)(0.70),$$

giving

$$\boxed{P_{\text{elec}} \approx 0.619v^3 \text{ W}}.$$

Higher-Efficiency Case: 80% Electrical Efficiency

For

$$\eta_{\text{elec}} = 0.80,$$

the electrical output becomes

$$P_{\text{elec}} = \frac{1}{2}(1000)(0.01767)v^3(0.10)(0.80),$$

giving

$$\boxed{P_{\text{elec}} \approx 0.707v^3 \text{ W}}.$$

In both cases,

$$\boxed{P \propto v^3}.$$

Therefore, water velocity has a much larger effect on output than a moderate change in electrical efficiency. Doubling the water velocity increases the available power by approximately a factor of eight.

Expected Output

Conservative Case: $\eta_{\text{elec}} = 0.70$

Using $C_p = 0.10$ and $\eta_{\text{elec}} = 0.70$:

Water Speed	Electrical Power	Energy in 8 h	Energy in 24 h
0.5 m/s	0.08 W	0.62 Wh	1.86 Wh
1.0 m/s	0.62 W	4.95 Wh	14.84 Wh
1.5 m/s	2.09 W	16.70 Wh	50.10 Wh
2.0 m/s	4.95 W	39.58 Wh	118.75 Wh
2.5 m/s	9.66 W	77.31 Wh	231.94 Wh
3.0 m/s	16.70 W	133.60 Wh	400.79 Wh

Higher-Efficiency Case: $\eta_{\text{elec}} = 0.80$

Using $C_p = 0.10$ and $\eta_{\text{elec}} = 0.80$:

Water Speed	Electrical Power	Energy in 8 h	Energy in 24 h
0.5 m/s	0.09 W	0.71 Wh	2.12 Wh
1.0 m/s	0.71 W	5.65 Wh	16.96 Wh
1.5 m/s	2.39 W	19.08 Wh	57.25 Wh
2.0 m/s	5.65 W	45.24 Wh	135.71 Wh
2.5 m/s	11.04 W	88.35 Wh	265.05 Wh
3.0 m/s	19.08 W	152.67 Wh	458.01 Wh

The higher values assume that the stated water velocity is maintained continuously. Very fast currents would also create much larger mechanical and anchoring loads.

The 70% case is retained as the conservative baseline, while the 80% case shows the expected improvement if a more efficient generator and power electronics system is achieved.

Watts vs. Watt-Hours

A **watt (W)** measures power, or how quickly energy is being produced:

$$1 \text{ W} = 1 \text{ J/s}.$$

A **watt-hour (Wh)** measures energy:

$$E = Pt.$$

For example, if the generator continuously produces 2 W for eight hours,

$$E = (2\text{ W})(8\text{ h}) = 16\text{ Wh}.$$

It would therefore be incorrect to say "2 W per hour." The generator is producing **2 W of power**, which accumulates to **16 Wh of energy after eight hours**.

How Fast Does Water Actually Move?

River velocity varies substantially with stream depth, slope, discharge, and channel geometry.

Measurements reported for mountain streams commonly fall in approximately the 0.5–1 m/s range, with 0.5 m/s used as a representative mountain-stream velocity. [7]

USGS measurements of the Colorado River found velocities of approximately 0.5–2.0 m/s in pool sections, while 2–3 m/s occurred under higher-discharge conditions. Rapids can be substantially faster. [8]

For this project, it is therefore reasonable to treat:

- **0.5–1.0 m/s** as a conservative/slow-stream case,
- **1.0–1.5 m/s** as a useful target operating range,
- **2–3 m/s** as fast river or high-discharge conditions.

3 Worked Example: 1.5 m/s Current

Assume a 15 cm turbine in a current of

$$v = 1.5\text{ m/s}.$$

First, the kinetic power available across the turbine's swept area is

$$P_{\text{water}} = \frac{1}{2}(1000)(0.01767)(1.5)^3 = \boxed{29.82\text{ W}}.$$

Using the conservative $C_p = 0.10$, the turbine converts 10% of this into mechanical shaft power:

$$P_{\text{shaft}} = (29.82)(0.10) = \boxed{2.98\text{ W}}.$$

The generator and electronics then convert an estimated 70% of the shaft power into stored electrical power:

$$P_{\text{elec}} = (2.98)(0.70) = \boxed{2.09\text{ W}}.$$

If the generator operates for eight hours,

$$E = (2.09)(8) = \boxed{16.7\text{ Wh}}.$$

If it remains deployed for 24 hours,

[7] Chen et al., Quantifying Flow Resistance in Mountain Streams.
[8] U.S. Geological Survey, Water Velocity of the Colorado River.

$$E = (2.09)(24) = \boxed{50.1 \text{ Wh}}.$$

Thus, even with the conservative $C_p = 0.10$ assumption, continuous operation can accumulate useful energy over several hours.

4 Comparison to an Existing Product

Blue Freedom developed a portable hydroelectric generator using a **12 cm turbine**, a **5 W-rated generator**, and a **5000 mAh internal battery**.

The manufacturer states that the internal battery can be charged in roughly **3–4 hours** in water moving at approximately **1.2 m/s**. [9]

The 5 W value is the generator rating rather than independently verified continuous output. However, the product shows that portable hydroelectric systems of a similar physical scale have been designed around watt-level power generation. Our model intentionally uses a lower $C_p = 0.10$ to provide a more conservative estimate for an early prototype.

5 What Could It Actually Power?

For the conservative 1.5 m/s design case,

$$P_{\text{elec}} \approx 2.09 \text{ W}.$$

Smartphone

As a representative smartphone, the standard Apple iPhone 16 has a battery capacity of approximately 3561 mAh. With a nominal battery voltage of approximately 3.885 V, this corresponds to an energy capacity of

$$E = (3.561 \text{ Ah})(3.885 \text{ V}) \approx \boxed{13.83 \text{ Wh}}.$$

[10]

Using the conservative electrical output of 2.09 W at a water velocity of 1.5 m/s, the time required to **generate one iPhone 16 battery's worth of energy** is

$$t = \frac{13.83 \text{ Wh}}{2.09 \text{ W}} \approx \boxed{6.6 \text{ hours}}.$$

Thus, leaving the generator in a 1.5 m/s current for approximately 6.6 hours could generate enough stored energy to equal the full battery capacity of a standard iPhone 16. An eight-hour deployment would generate approximately 16.7 Wh, which exceeds the iPhone 16's 13.83 Wh battery capacity.

Actual charging of the phone would require somewhat more generated energy because additional losses occur when transferring energy from the generator's storage battery to the iPhone.

[9] Blue Freedom portable hydro generator description.
[10] iFixit, iPhone 16 Battery Replacement.

Satellite Communicator / GPS

The Garmin inReach Mini 2 contains a 1250 mAh, 3.6 V battery, corresponding to approximately

$$E = (1.25 \text{ Ah})(3.6 \text{ V}) = \boxed{4.5 \text{ Wh}}.$$

[11]

At 1.5 m/s, this amount of energy could theoretically be generated in

$$t = \frac{4.5 \text{ Wh}}{2.09 \text{ W}} = \boxed{2.15 \text{ hours}},$$

before final device-charging losses.

LED Flashlight / Headlamp

A typical LED flashlight or headlamp used for camping may draw roughly 1–3 W during normal operation.

At 1.5 m/s, the generator produces approximately 2.09 W. It could therefore continuously support lower-power lighting, but would not continuously power a 3 W light.

Eight hours of generation would store approximately 16.7 Wh, equivalent to

$$\frac{16.7 \text{ Wh}}{3 \text{ W}} = \boxed{5.6 \text{ hours}}$$

of operation for a 3 W light.

Fishfinder

A Lowrance HOOK Reveal 5 lists typical power consumption of

$$(0.9 \text{ A})(13 \text{ V}) = \boxed{11.7 \text{ W}}.$$

[12]

The generator would not continuously power the fishfinder at 1.5 m/s, but could recharge its battery over time. Eight hours of generation would provide

$$16.7 \text{ Wh},$$

equivalent to approximately

$$\frac{16.7 \text{ Wh}}{11.7 \text{ W}} = \boxed{1.43 \text{ hours}}$$

of fishfinder operating energy before additional conversion losses.

[11] Garmin inReach Mini battery specifications.
[12] Lowrance HOOK Reveal 5 specifications.

6 Technical Feasibility Conclusion

Using a deliberately conservative turbine power coefficient of

$$\boxed{C_p = 0.10},$$

a portable hydroelectric generator still appears capable of providing useful energy for low-power outdoor electronics, although long deployment times or faster currents are required.

For a 15 cm folding turbine, the model predicts approximately

$$\boxed{1.0 \text{ m/s} \rightarrow 0.62 \text{ W} \rightarrow 4.95 \text{ Wh in 8 hours}}$$

and

$$\boxed{1.5 \text{ m/s} \rightarrow 2.09 \text{ W} \rightarrow 16.7 \text{ Wh in 8 hours.}}$$

At 1.5 m/s, an overnight eight-hour deployment would generate approximately one smartphone battery's worth of energy. A low-power GPS or satellite communicator could be replenished substantially faster, while larger loads such as fishfinders would primarily benefit from slow battery replenishment rather than continuous operation.

Faster currents greatly improve performance because

$$P \propto v^3.$$

For example,

$$2.0 \text{ m/s} \rightarrow 4.95 \text{ W},$$

while

$$2.5 \text{ m/s} \rightarrow 9.66 \text{ W}.$$

The main feasibility constraint is therefore access to sufficiently fast, continuous water flow. The most promising design remains a compact generator and battery system with a deployable 15 cm turbine and a secure anchoring system.