

## Fact Sheet: Microhydro

### What is Microhydro?

With the right resource, microhydro systems enable clean, renewable, on-site generation of electricity at an affordable price with minimal environmental impact.

The power in falling water has been harnessed for over 2000 years in activities such as milling grains, sawing wood, and pumping water. Slow-moving, traditional waterwheels provided this mechanical power. Efficiency improvements made to early waterwheels led to the rise of the *hydroelectric turbine*. The first hydroelectric power systems were developed in the 1880s.

The water cycle is the driving force behind hydropower. Solar energy drives plant transpiration and evaporates water from lakes and oceans, whose water vapor condenses into clouds and causes precipitation. Mountain ranges, with their relatively cooler temperatures, receive much of this precipitation. These headwaters of rivers and streams begin the downward flow of water towards the ocean. The kinetic energy in this moving water results in hydropower.

Large-scale hydroelectric power plants, such as Hoover Dam, divert water through turbines that spin generators that produce a large amount of electricity. These projects require tremendous amounts of land for impoundment and flood-control, and often produce many environmental impacts despite their emission-free electricity production. According to the Energy Information Administration (EIA), large-scale hydroelectric plants currently supply 16% of the world's electricity and roughly 6.5% in the US.



Microhydro is generally defined as electricity generation capacity up to 100 kW. Many of these systems are "run of river" which do not require an impoundment. Instead, a fraction of the stream's water is diverted downhill through a pipe to a small turbine that sits alongside the stream. Properly designed, a microhydro system causes minimal environmental disruption to the stream, and can coexist with the native ecology.

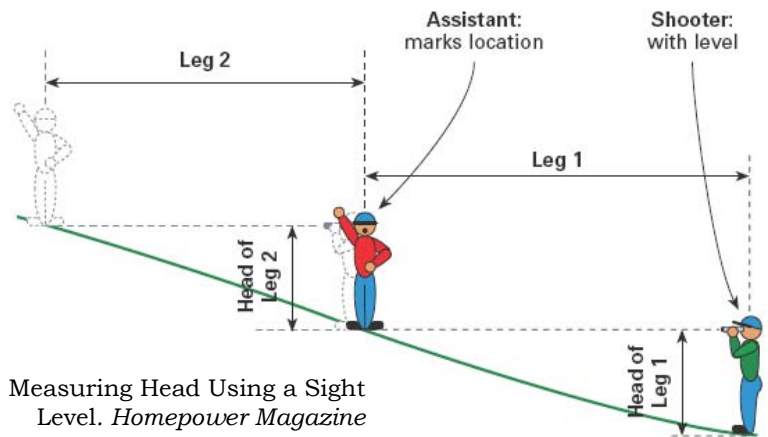
According to the EIA, the average energy consumption of a house in the southeast is 1100 kWh/month which could be completely satisfied by a 3 kW turbine. A system providing even a fraction of this energy may still be a good investment. Microhydro is often the most cost effective way to renewably generate electricity - in many cases competing with the price of grid power - with no emissions.

A study completed in 1983 by researchers at Appalachian State University identified 1,592 potential sites between 5 & 20 kW in the 24 western counties of NC for a total of approximately 30 MW and there are likely at least this many additional sites between 1 & 5 kW in size which would be adequate for a residential-scale system.

### Site Assessment

To determine a site's suitability for a microhydro system, a site assessment must be performed. Accurate assessments of head and flow, as well as measuring for infrastructure components, should be performed to determine project feasibility. Four key site characteristics should be determined: *head, flow, pipe length and wire run*.

Head is the elevation difference between the source of the water and the turbine, or the total vertical drop, usually measured in feet. Head can be measured several ways using a sight level, transit, water level, topographical maps, or a GPS unit. A simple uphill survey method using two people and a sight level is a cost effective way to measure the head. In situations where a pipeline is already in place, such as gravity-fed domestic water, installing a pressure gauge is the easiest way to determine static head. 1 pound per square inch (psi) = 2.31 ft



Flow is a volumetric measure of moving water typically measured in gallons per minute (gpm), cubic feet per minute (cfm), or cubic feet per second (cfs). The “container method” works well in streams up to about 300 gpm. Find a spot where the stream flows from a culvert or a place where most of the flow can be collected in a 5-gallon bucket and determine how long it takes to fill your bucket. Flow is equal to the size of your container, divided by the time to fill in seconds, multiplied by 60. A 5 gallon bucket that fills in 3 seconds equals a stream with 100 gpm of flow. For larger waterways, the float method or a weir can be used to measure flow. These methods are described in detail in publications such as *Homepower Magazine #104*.

Flow sometimes varies seasonally. For accuracy, flow should be measured and monitored throughout the year. The system should be designed for a flow that will be present year round; otherwise seasonal adjustments will be necessary. This is the *design flow*. Flow from the penstock is controlled by the size of the nozzle(s) at the turbine. Nozzle sizing is a function of design flow and net head.

To minimize impact on stream ecology, the design flow should be *up to* half of the water in the stream with a goal of minimizing the design flow and maximizing head. *Maintaining adequate water in the stream for aquatic life is a cornerstone of environmentally sound microhydro production.*

Pipe Length is a key factor in determining the size pipe to use. The pipe that delivers the water from the stream to the turbine is called the penstock and is typically constructed of polyvinyl chloride (PVC) or high-density polyethylene (HDPE) pipe. Pipe sizing is a function of pipe length and flow. The pipe must be sized properly to minimize losses due to friction. When water is moving through the pipe, some of the available head will be lost due to pipe friction losses. This resulting head is the *net head*.

The following excerpt from a pipe loss table shows how pipe size effects head loss. For a system with a static head of 100 feet, a design flow of 50 gpm, and 800 feet of 3 inch PVC pipe, the head loss would be 5.2 feet due to pipe friction (.65 feet per 100 feet of pipe x 8). This would result in a net head of 94.8 feet.

**Head Loss per 100 feet of PVC Pipe**  
Design Flow in Gallons per Minute & (Cubic Feet per Second)

Pipe Size (in.)	25 (.05)	50 (0.1)	100 (0.2)	150 (0.33)	200 (0.45)	300 (0.66)	400 (0.89)	500 (1.1)	600 (1.3)	700 (1.5)	800 (1.78)	900 (2.0)	1,000 (2.23)	1,200 (2.67)
2	1.28	4.65	16.80	35.70	60.60	99.20	-	-	-	-	-	-	-	-
3	0.18	0.65	2.33	4.93	8.36	17.90	30.60	46.10	64.40	-	-	-	-	-
4	0.04	0.16	0.57	1.23	2.02	4.37	7.52	11.30	15.80	21.10	26.80	33.40	-	-
6	-	0.02	0.08	0.17	0.29	0.62	1.03	1.36	2.20	2.92	3.74	4.75	5.66	8.04
8	-	-	-	0.04	0.07	0.15	0.25	0.39	0.50	0.72	0.89	1.16	1.40	1.96

Power in watts (W) is the rate at which energy is delivered and can be estimated by net head times flow divided by an efficiency factor. The efficiency factor can range from 9-14 depending on the system. A factor of 10, which corresponds to 53% system efficiency, is commonly used for modern microhydro systems.

$$\text{Estimated Power}(W) = \frac{\text{Net Head}(ft) \times \text{Flow}(gpm)}{10}$$

Energy in kilowatt-hours (kWh) is power times time. Since a hydro system typically runs continuously, the estimated monthly energy output can be calculated using the following equation.

$$\text{Monthly Energy Output}(kWh) = \frac{\text{Power}(W)}{1000} \times (24 \text{ h/day}) \times (30 \text{ days/month})$$

Wire Run. The electricity from the generator must be transmitted to the point of use. Wire sizing is a function of *system voltage* and *distance*. The voltage drop from wire losses is minimized by increasing the system voltage and/or minimizing the wire run. The system voltage is typically 12, 24, or 48VDC. Special microhydro generators are available which transmit power over a mile at much higher voltages (see Hydro Induction Power link in "Resources" section at the end of this fact sheet).

## Types of Systems

### AC/DC

The majority of microhydro systems use batteries to store electric energy. The turbine drives a generator which charges a battery bank. An inverter converts the direct current (DC) into standard alternating current (AC) that can be used for typical household loads.

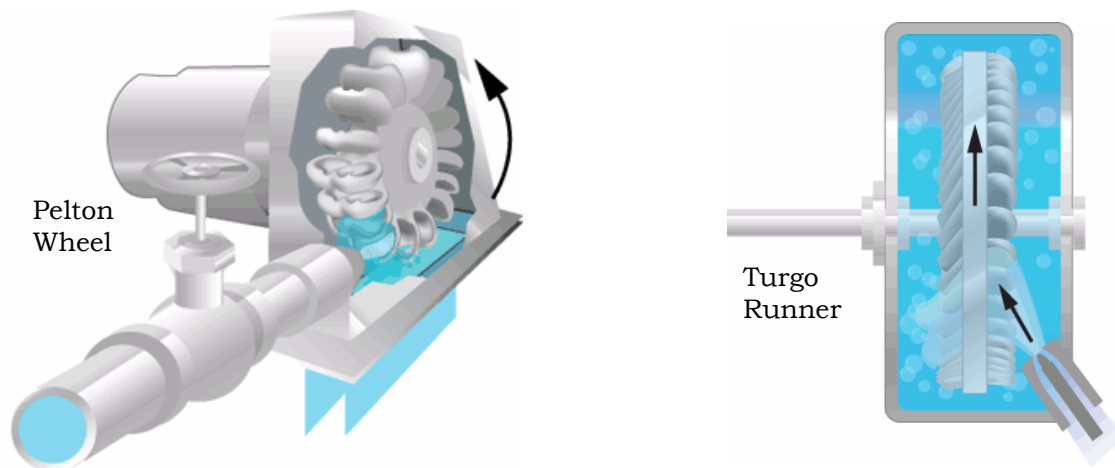
Batteryless AC hydro systems are typically either 1) *larger* systems sized to directly run the largest combination of loads in the household or sell energy directly to the utility or 2) *smaller* systems, similar to battery charging units, that have been configured for direct grid-tie.

### High/Low Head

The potential energy that is available from a microhydro system results from a combination of head and flow. A given amount of power can be generated from a high head/low flow system, a low head/high flow system, or anywhere in between. High head is generally considered 10 feet or greater. Specially designed systems are required for heads less than 10 feet due to the large amounts of water required.

In a high head system, a high-pressure jet impacts either a Pelton wheel or Turgo runner which directly drives a generator. Low head systems utilize Francis, Kaplan or Crossflow turbines to turn the generator.

The majority of microhydro systems in Western North Carolina are high head due to our mountain topography. High head systems typically cost less to install than low head systems per unit of energy.



Source: <http://www.energyalternatives.ca/amazing/HydroCourse/turbines.htm>

## Incentives

Microhydro systems qualify for the 35% North Carolina state tax credit.

Customers of the state's three investor-owned utilities (IOUs) who install microhydro systems per the North Carolina Utilities Commission (NCUC) interconnection standards are eligible for net metering. Some of the cooperatives in the region are also offering net metering.

North Carolina Greenpower will purchase energy from hydroelectric projects on a contract basis. They will pay a premium price for hydropower that is certified environmentally responsible or "low impact" by The Low Impact Hydropower Institute (LIHI). Details at [www.ncgreenpower.org](http://www.ncgreenpower.org) and [www.lowimpacthydro.org](http://www.lowimpacthydro.org).

The details related to incentive are updated often, please visit [www.dsireusa.org](http://www.dsireusa.org).

## Regulations

The US Army Corps of Engineers has jurisdiction over virtually all waterways in the United States. Any discharge of dredged or fill material into all waters of the United States, *which includes rearranging rocks within a streambed*, would require notification of the Corps per Section 404 of the Clean Water Act.

Contact the Asheville Field Office at (828) 271-7980 to notify the Corps about your proposed project *before you begin construction*. They will help decide whether or not a permit is required.

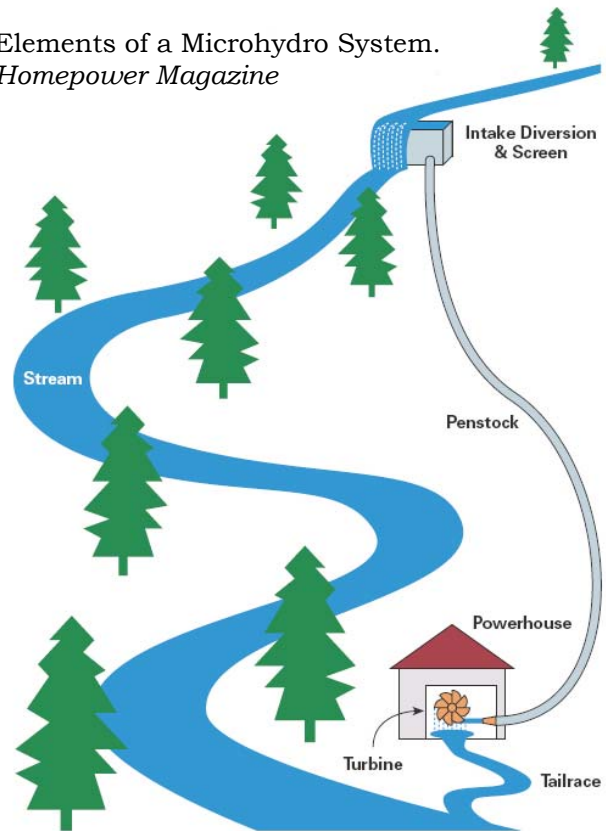
## Example System

**Measured Head:** 135 feet (41 meters)  
**Measured Flow:** 250 gpm minimum  
**Pipe Length:** 900 feet (274 meters)  
**Estimated power:** 1,140 watts

A battery-based system with an inverter is one possible choice for a hydro site with the above parameters. If an AC turbine were used, electrical usage would be limited to about 1,140 watts. This would not be sufficient to run the combined loads of a typical household. A battery-charging turbine will allow energy storage in a battery bank. The inverter will be able to provide surges of instantaneous power to the house. A smaller grid-tie AC system could be used to reduce or eliminate the power bill through net metering.

With a design flow of 100 gpm, using 3" pipe would result in a head loss of 21 feet (per pipe loss charts), for a net head of 114 feet and an estimated power of 1,140 watts. This would supply the house with 820 kWh per month.

Elements of a Microhydro System.  
*Homepower Magazine*



## Resources

US Department of Energy	<a href="http://www1.eere.energy.gov/windandhydro">www1.eere.energy.gov/windandhydro</a>
The Low Impact Hydropower Institute	<a href="http://www.lowimpacthydro.org">www.lowimpacthydro.org</a>
US Army Corps of Engineers, Regulatory Division	<a href="http://www.saw.usace.army.mil/wetlands">www.saw.usace.army.mil/wetlands</a>
Energy Systems & Design	<a href="http://www.microhydropower.com">www.microhydropower.com</a>
Harris Hydroelectric	<a href="http://www.harrishydro.com">www.harrishydro.com</a>
Hydro Induction Power	<a href="http://www.hipowerhydro.com">www.hipowerhydro.com</a>
Powerpal	<a href="http://www.powerpal.com">www.powerpal.com</a>
Canyon Hydro	<a href="http://www.canyonhydro.com">www.canyonhydro.com</a>
Alternative Power and Machine	<a href="http://www.apmhydro.com">www.apmhydro.com</a>
Otherpower	<a href="http://www.otherpower.com">www.otherpower.com</a>
Earthbound Services LLC	<a href="http://www.earthboundservices.com/microhydro.asp">www.earthboundservices.com/microhydro.asp</a>
NC Green Power	<a href="http://www.ncgreenpower.org">www.ncgreenpower.org</a>
Database of State Incentives for Renewables & Efficiency	<a href="http://www.dsireusa.org">www.dsireusa.org</a>
Homepower Magazine	<a href="http://www.homepower.com">www.homepower.com</a>
NC State Energy Office	<a href="http://www.energync.net">www.energync.net</a>

## Western North Carolina Microhydro Installers

*Appalachian Energy Solutions*, Kent Hively, (828) 773-9762  
[www.appalachianenergysolutions.com](http://www.appalachianenergysolutions.com)

*Big Frog Mountain*, Thomas Tripp, (423) 265-0307  
[www.bigfrogmountain.com](http://www.bigfrogmountain.com)

*Blue Ridge Energy Solutions*, Bill Poteat, (800) 689-8824  
[www.brescoltd.com](http://www.brescoltd.com)

*Solar Dynamics*, Ole Sorensen, (828) 665-8507  
[www.solardynamicsnc.com](http://www.solardynamicsnc.com)

*Solar Village Institute*, Chris Carter, (336) 376-9530  
[www.solarvillage.com](http://www.solarvillage.com)

*Sundance Power Systems*, Dave Hollister, (828) 689-2080  
[www.sundancepower.com](http://www.sundancepower.com)

For more information contact:

Western North Carolina Renewable Energy Initiative

Appalachian State University  
 (828) 262-7333

[wind@appstate.edu](mailto:wind@appstate.edu)

[wind.appstate.edu](http://wind.appstate.edu)

State Energy Office



Appalachian  
 STATE UNIVERSITY