Microhydro Systems

Pro Advice for End Users

Interviews by Ian Woofenden

Home-scale microhydro-electric systems can give the best renewable bang for the buck. With the right situation and implementation, you can have a low-impact, low-maintenance, reliable system that supplies clean energy over the long haul.

Courtesy SunWater Power Systems

As with any renewable energy system, the dividing line between a dream and a working project includes education, experience, and expertise. When dealing with something as powerful and fragile as a flowing watercourse can be, it's important to find people who have "been there and done that."

Here, 12 hydro experts share the perspective of decades of hydro experience and wisdom. The group's experience includes off-grid hydro living; system design, specification, and installation; engineering, consulting, and contracting; and equipment design and manufacturing. Read on and consider whether you have the right site, situation, and motivation to pursue energy from falling water.

Q: What's the first step to identifying a good hydro site?

The two primary components of hydro-electric power are head (vertical drop) and flow. A good site needs a combination of these two. Higher head sites may be more cost-effective to tap, since you can use smaller pipe and less water. Ideally, you want water tumbling down the hillside—this is one sign of a potential hydro site. Water that is dead "flat" won't do much for you—if there is no head, there is no power.

If you double the head, you double the power available. The same is true if you double the flow. Higher head is the least expensive way to generate more power. Increasing the head increases the water pressure, which requires more robust components, but doesn't add significant cost to the turbine. On the other hand, more flow requires a physically larger turbine to handle the mass. As a general rule, higher flow requires more steel, which drives up the cost. A good home-scale system might have a vertical drop in the range of 40 to 200 feet.

A steady flow from a perennial stream is ideal. Seasonal streams that suffer wide fluctuations in flow linked to wet and dry seasons can be designed for, but require compromises in the design parameters.

Look for a good site rather than the closest site. With high-voltage transmission coupled to modern MPPT controllers and grid-connected inverters, wire cost for longer distance is often not the biggest issue. Other good attributes are a convenient and environmentally friendly intake site, easy access and permitting, and a relatively short pipe run.

Before you even consider hydro sites, realistically assess your energy needs. A common error is overestimating actual electricity needs. We live in a wasteful society, and use a lot more energy than is necessary due to inefficient appliances and lack of attention to conservation. The trouble with overestimating your energy needs is that it makes systems larger and more expensive, and often such large and expensive projects have a way of not getting done. In a hydro system, building a system for a wasteful home may mean using more materials and taking a larger portion of the stream flow.

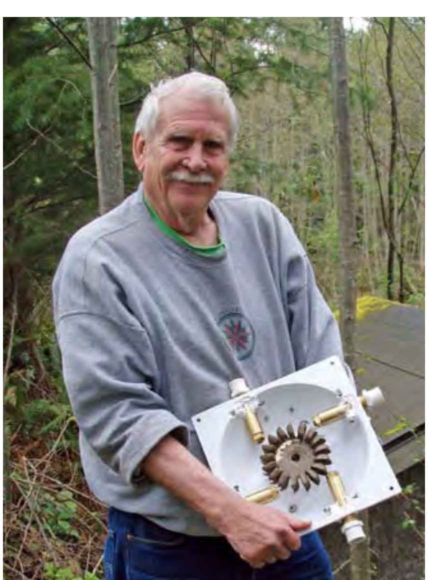
Q: What types of water sources are not appropriate for microhydro systems?

Because available power comes from head and flow, water sources with little flow or little head will not work. Flat-water rivers are difficult or impractical to capture energy from, which is why we see few if any products on the market for this type of site. Large, gently flowing rivers like the Amazon, Nile, and Mississippi are generally unsuitable for any microhydro systems other than paddle-wheel floating designs that seldom generate more than a token amount of power. A "low-head" site typically needs to dam the whole river or divert a large amount of water in a canal to create some head.

Obviously, water that is not moving has no energy in it. And water that is being pumped is not a source of renewable energy, since it takes more energy to develop the pressure than can be gotten back from it. Some fish-bearing streams may not be a wise choice for development due to environmental impact. And of course, you need to have legal access to the water source, and the ability to tap it without undue restrictions.

Very high-head sites (above 500 feet) can be costly to tap because of long pipe runs and high pressure. Tapping a part of the available head can be a viable solution. Also note that water sources that have very high water at some time in the year make for difficult intakes. High water often means a lot of debris comes down the stream, which can clog or damage intakes. And some intake designs do not function well if submerged.

Other inappropriate sources would be using drinking or irrigation water systems just to make electricity. These sources often rely on energy to pump and pressurize the water, so they are not actually renewable energy sources. And the intended end uses often need pressure, which a hydro system brings to zero. In addition, the volume of flow is usually not adequate to make much energy.



Courtesy Ian Woofenden

Hydro guru Don Harris

Courtesy Asian Phoenix Resources

Asian Phoenix's Power Pal low-head turbine in Honduras. At lower heads than this, things get tricky.

Q: Once you've identified a potential site, what measurements do you take to assess the site's production capacity?

What are the best methods for taking these measurements?

Several measurements are needed, and there are multiple ways to obtain most of them. Most important is to take very accurate measurements of head and flow. This will tell you how much power is available, and the type of turbine appropriate to the site.

To measure **vertical drop (head),** you can use:

- Altimeters, if meter accuracy is good
- GPS units (some may have enough accuracy)
- Survey level or laser level
- Maps with good contour lines, for higher-head sites
- Google Earth (in some cases) for offsite pre-assessment
- Accurate pressure gauge (if there is an existing pipeline)

An altimeter is used to survey elevation. This measurement shows only 180 feet of head, but with a 12-inch pipe, this site will develop 75 kW.

Courtesy SunWater Power Systems

The "bucket method" can be used to measure flow in small streams. Larger streams require an alternative measurement method.

To measure **flow** (this is best done multiple times throughout the year to ascertain seasonal variations):

- Bucket and stop watch to measure gallons per minute for small- to medium-flow sources and time surface velocity
- Weir with measuring notch and appropriate flow tables
- 100-foot (or longer) tape measure to determine the cross-section of stream

See "Intro to Hydropower, Part 2: Measuring Head & Flow" in *HP104* for more details.

Q: What do you consider to be the maximum feasible distances for penstock length and transmission wire run?

This depends on the scale of the system, the power available, cost of alternatives, the system voltage, and the terrain, among other factors. Penstock and transmission cable lengths of more than a mile are workable in the right situations, though less than 1/2 mile is more typical.

If you need long pipe and long cable, the site will need to be very good or the economics may not work. But if you need a long pipe and a short cable or a short pipe and a long cable, you may have a viable site. There are too many variables involved to generalize on distance limits, because so much depends upon the diameter and the material composition of the penstock that is required for the local conditions, and the voltage, distance, and size of wire.

Financial feasibility is usually the governing factor. How much is the power worth? Note that transmitting small amounts of energy, such as an energy-efficient household would use, can be pretty inexpensive over long distances. Every site is unique, and careful balancing of factors is required. Ultimately, the maximum feasible distance is directly related to the depth of your checkbook and what is "worth it" to you.

Q: What are the advantages of a microhydro system compared to other renewable electricity systems (wind turbine, PV array)?

A microhydro system will generate continuously, if it has a constant water supply. This alone is a significant advantage over either wind or solar power because a battery bank may not be required, and a smaller battery bank will suffice if one is needed. Also, microhydro is generally less expensive per kilowatt-hour than either wind or solar electricity. It's working all day, every day. If you had a site where all three systems had equal potential near to the point of use, microhydro would probably be the least expensive choice per delivered watt-hour.

The hydrological cycle follows the human consumption cycle very well where summer cooling is not used. In winter, when a stream usually has more flow, households tend to use more energy; in summer, households use less energy and generally have less water. Solar electricity provides the opposite result, giving the highest yield in the summer, when you typically need less. Hydropower is there when you need it. When the sun goes down and the wind stops blowing, your hydro turbine will continue generating electricity.

95 psi shows the static head of almost 220 feet of head.

Courtesy EcoInnovation (2)

Q: What are the limitations of hydro-electric systems compared to other RE systems?

The main limitations of hydro-electric systems are the limitations of the water supply. No water equals no power. Few people have access to a good microhydro site—there are far fewer potential sites than solar and wind sites. And few people who live near good sites are aware of the potential of microhydro. Hydro is for one home in 1,000 at best, so the technology has only a light dusting of installations. These will generally be in rural environments near or in the mountains.

Even though hydropower is comparatively inexpensive and consistent, it requires special conditions that may be hard to come by. First, you need head, which usually means a location close to mountains. Second, it takes the land area to collect the water and develop the head. Third, it requires physical spaces for an intake, penstock, and power house. Fourth, the permitting process can be difficult, because you will be physically altering the watershed, even if only a little.

Q: How do you assess the financial viability of a system, compared to, say, energy produced by a PV system?

A little simple math will answer this question. First, measure your head and flow and apply a formula to determine how much you can generate. Then get price quotes for the intake, penstock, and powerhouse equipment. Add it all up and divide by the lifetime energy you expect to produce, and you will have your cost per kilowatt-hour.

While every site has so many unique elements that generalizing is pretty risky, with an appropriate water supply, a microhydro system is usually many times less expensive than a PV system. Maintaining a microhydro system also can be quite inexpensive. There is just the one moving part, and bearing replacement is required only every few years. The intake can be the only point of regular maintenance, and the system shouldn't cost anything but labor to maintain. On the other hand, PV arrays that are mounted on fixed racks have no moving parts, or intakes, to maintain.

Courtesy Hydroscreen

The right intake design will affect system performance greatly.

PV and microhydro systems aren't always treated equally with various incentives (rebates, tax credits, and net metering may only be available for PV systems), so that may also be a consideration. Financial viability is ultimately a personal assessment of the value of the energy produced for the system owner.

Q: What financial incentives are available for those who install a microhydro system?

Microhydro systems seem to have the fewest incentive programs worldwide. The incentives vary widely, so a generalization is impossible. If you have a farm, you may qualify for financial incentives to use the same water for multiple purposes.

Incentive programs tend to come and go, and can be fairly arbitrary. If you are counting on government money, act on it sooner than later. The paperwork burden in some cases can be significant. Check out your local incentive situation as part of the site assessment process.

Long-term, low-interest financing is quite a powerful incentive. Microhydro rebates tend to not be generous enough to affect the payback time very much, and therefore often don't

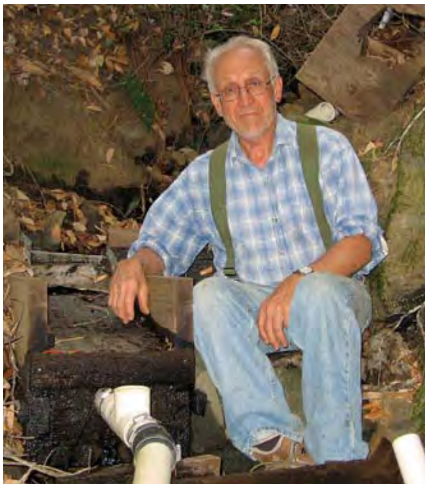
Hugh Piggott, Scoraig Wind Electric

Courtesy Scoraig Wind Electric

David Seymore, Asian Phoenix Resources

Courtesy Asian Phoenix Resources

Denis Ledbetter, Lo Power Engineering



Courtesy Lo Power Technologies

Christopher Freitas, WiFu Energy

Joseph Hartvigsen, Hartvigsen-Hydro

Scott Davis, Friends of Renewable Energy BC

work very well. Every incentive situation is unique as well. Off-grid electricity from fuel-fired generators may cost something like $1 per kilowatt-hour to produce. This is a powerful incentive because well-designed and implemented off-grid microhydro typically costs less over the long term. Generators are noisy, stinky, and expensive. By contrast, a microhydro system can quietly run for years on end, dependably providing energy with a minimum of hassle and no emissions.

Q: In what cases do you advise people to go with an alternative to microhydro?

The decision on which resource to use for an RE system depends on:

- Economic issues: what do they pay for electricity currently? How have rates increased over the years, and what's their expected rate of increase?
- Location
- Grid availability and connection costs
- Quality of the hydro resource
- Household energy consumption
- Homeowners' environmental philosophy

Q: What is the typical process required to get regulatory approval for home hydro systems, and where do potential users find information about it?

Local regulations vary widely. Water rights are regulated everywhere and must be respected. Wherever you are, check with appropriate authorities before spending significant money on construction. Start with the water resources department where you live. Some states have little to no requirements and some states have a great deal of red tape.

It should be about natural law and ecology with good sense, and most small hydro systems have a very minimal impact on the environment. From anecdotal reports, many home-sized systems are not permitted because the level of regulation is out of scale with the potential impact, and the value of the systems to small landowners exceeds their desire to work with bureaucracies. For larger grid-connected systems, it can run the gamut—from just getting local water regulator permits to having to appeal to the Federal Energy Regulatory Commission for licensing or exemption. Both levels seem to be arbitrary and indeterminate processes. Working the system seems to be much more practical abroad, such as in the U.K.

Q: What are common challenges encountered in installation?

Each site has its own challenges, but most are overcome by the use of common sense and some basic engineering skills. Steep, wooded terrain and rocky stream courses can make installation more difficult.

Specific challenges include:

- Intake site selection and installation
- Proper pipe selection and installation, including dealing with poor access and long distances
- Routing pipeline or power line over rough or steep terrain
- Avoiding private land, public land, or road crossings
- Air blockage in pipes laid with an uphill slant
- Proper transmission cable selection, installation, and protection
- Inaccurate measurements of head, flow, and distances
- Protection of penstock from sun, slides, and other physical damage
- Permitting and regulatory issues
- Freezing conditions (i.e., ice plugging screens and low water levels)

Another significant challenge in microhydro installation is finding local, experienced installers. Many more people install solar-electric systems and some also install wind-electric systems with some level of expertise, but microhydro is the most obscure of the renewable technologies.


Courtesy SunWater Power Systems

An excavator lifting a 3,000-pound section of 8-inch steel onto a steep slope. The pipe was then pulled 500 feet up the hill using the excavator and a long steel cable through a pulley.

Q: Have there been any notable advances in turbine, control, or system design strategies in recent years?

There have been only a few major advances. Some improvements have been made by tweaking original designs, such as adjustable guide vanes on certain low-head, propeller turbines and adjustable permanent-magnet alternators.

Modern electronic load controllers have freed us from the need for the elaborate and delicate mechanical speed-governing systems used in the past. Inexpensive permanent magnets now allow manufacturers to offer very efficient, simple battery-charging alternators. The use of induction motors as generators has reduced the cost of basic AC hydro systems.

Hydropower systems continue to become more efficient and reliable, but most hydro systems are based on fundamental principles that have been proven for more than 100 years. New on the scene is the ability to maximum power point track (MPPT) a hydro turbine, which can solve some of the mid-range transmission issues mostly for 12- or 24-volt systems. MPPT controllers allow a hydro turbine to run above battery voltage, allowing longer wire runs and more efficient output—both in the operation of the turbine and in the line losses. And rather than having to manually adjust some alternators' magnetic field as battery voltage and flows fluctuate, a MPPT controller can do it electronically.

Grid-tied equipment is gradually moving into the microhydro world, increasing the opportunities to sell energy to local utilities. "Bleeding edge" technology has experimenters using PV arrays as part of hydro control strategies (using the array as a zener diode) in both battery-based and batteryless systems.

Q: What kinds of maintenance do microhydro systems require?

As with all machines, hydropower systems require maintenance. Bearings must be checked occasionally and lubricated as necessary. Intake systems must be cleared of debris that might hinder water flow. When there are seasonal changes in flow, it may be necessary to change nozzle or gate settings. In some cases, ice at intakes can be a problem. You may need to check that the pipeline is free of damage and supporting anchors are secure. Other maintenance includes replacing generator bearings and periodically checking electrical connections for corrosion.

It's good practice to shut down your hydro system at least once a year to inspect the runner and other hydraulic components for wear. For battery-based systems, you need to care for your batteries, ensuring that they are sized correctly to start with, and that they are fully charged most of the time to get the best life from them. Top up with distilled water when needed.

Properly maintained, a quality hydro system will run reliably for many years.

Mike New, Canyon Hydro


Courtesy Canyon Hydro

Michael Lawley, EcoInnovation

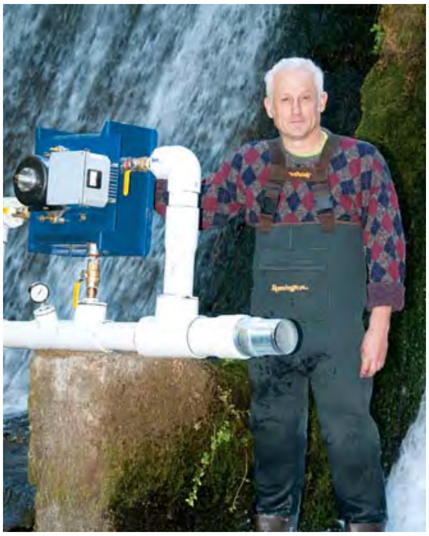

Courtesy EcoInnovation

Robert Weir, Hydroscreen

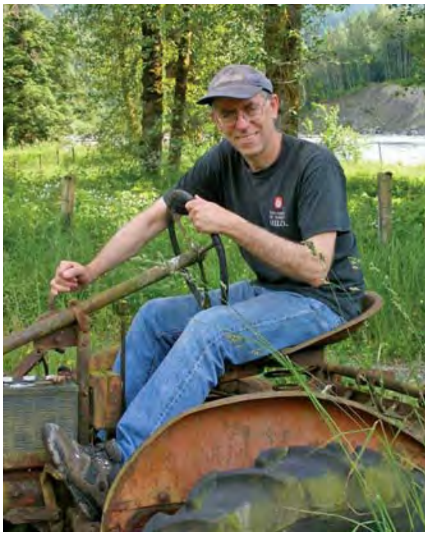

Courtesy Hydroscreen


Courtesy Hydro Induction Power

Derik Veenhuis, Hydro Induction Power


Shawn Schreiner

Jerry Ostermeier, Alternative Power and Machine


Courtesy SunWater Power Systems

Peter Talbot, SunWater Power Systems

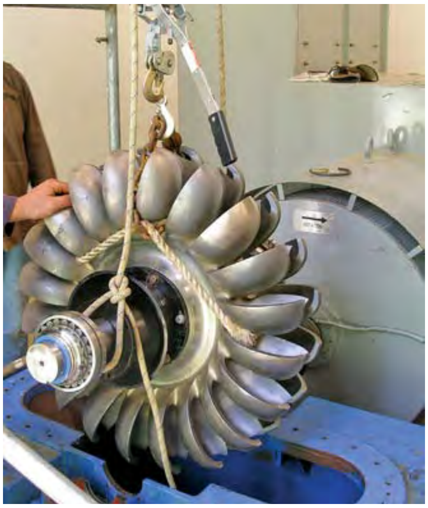
Access

Michael Lawley, director and engineer at EcoInnovation in New Plymouth, New Zealand, has a degree in mechanical engineering and has lived off-grid for the last 16 years. EcoInnovation manufactures hydro turbines using renewable energy. www.powerspout.com

David Seymour, president and CEO of Asian Phoenix Resources in Victoria, BC, Canada, is a semi-retired mineral exploration geologist who, while working in Vietnam, recognized the positive impact that individual low-head microhydro turbines had on the residents of remote settlements. For 14 years, he has been supplying PowerPal microhydro products to more than 80 countries. www.powerpal.com

Hugh Piggott, owner of Scoraig Wind Electric in Scoraig, Scotland, lives off-grid in windy northwest Scotland and specializes in homebuilt wind turbines. He would specialize in hydro if he lived in a suitable location, and has installed a number of small off-grid hydro systems ranging from 20 to 7,000 watts. www.scoraigwind.com

Jerry Ostermeier, owner/engineer at Alternative Power & Machine in Grants Pass, Oregon, has been focusing on hydro and off-grid applications in the renewable energy business for 32 years. www.apmhydro.com


Courtesy SunWater Power Systems

This heavy runner is being inspected for wear and bearing replacement.

Mike New, vice president of Canyon Hydro in Deming, Washington, is a longtime hydro enthusiast who wrote the *Guide to Hydropower* and developed the public information site www.whyhydropower.com. www.canyonhydro.com

Christopher Freitas, an electrical engineer with WiFu Energy in Big Lake, Washington, is a hydro system owner and renewable energy engineer who has worked in the RE industry since 1986. Recently, he's focused on projects in the developing world, including Haiti, South Sudan, and Pakistan. www.sunepi.org

Peter Talbot, owner of SunWater Power Systems in British Columbia, Canada, made his first hydro generator at age 8, and still enjoys the simple concept of harnessing flowing water to do useful work. To him, it's not a job; it's a passion. www.homepower.ca

Scott Davis, president of Friends of Renewable Energy BC in Victoria, BC, Canada, is a renewable energy project developer and the author of *Serious Microhydro: Water Power Solutions from the Experts* and *Microhydro: Clean Power from Water.*

Joseph Hartvigsen, owner of Hartvigsen-Hydro in Kaysville, Utah, has been building water turbines for a dozen years. While hydropower has always been a fascination, his direct involvement arose out of necessity to provide power on the family's mountainous wheat farm in Idaho. www.h-hydro.com

Denis Ledbetter, owner of Lo Power Engineering/Harris Hydro in Redway, California, divides his time between his family's homestead in the coastal mountains of northern California and using RE to manufacture the Harris microhydro turbine.

Robert K. Weir, president of Hydroscreen in Denver, Colorado, is a registered professional engineer with 43 years experience in diversion and screen engineering. He works directly with owners and engineers to design functional, cost-effective screening applications. www.hydroscreen.com

Derik Veenhuis, owner of Hydro Induction Power in Redway, California, has been working in renewable energy and building hydro turbines since 1980, developing his own line of low- and high-voltage turbines. www.hipowerhydro.com