Miller-McCune

Hydro Doesn’t Have to Be Big

By Lea-Rachel Kosnik | 01.22.2008 | 12:20 PM (UTC)

First of three parts

The era of large hydropower dams is clearly over in the United States. Hydropower production, however, has a future: By concentrating on small hydropower facilities with limited impacts on river ecosystems, we can maintain — and even improve upon — an important renewable energy resource.

Two-thirds of all renewable electricity production in the United States — itself about 7 percent of the nation’s total energy consumption — currently comes from hydropower. Electricity generated through the kinetic energy of falling water, a proven technology, provides a number of benefits beyond acting as a renewable source of electric power.

First, all water power is emissions free and, in this era of growing concern over climate change, that is of increasing value.

Second, water power is energy efficient. Other forms of generating power, from fossil fuels to solar power, have conversion rates of energy into electricity that average 50 percent or less; traditional hydroelectricity boasts an efficiency conversion rate of 90 percent, better than any other form of generation.

Third, water-powered electricity plants are extremely cost-effective. The main cost of most water-powered facilities is their initial construction and installation. Thereafter, they require no fuel inputs and very little maintenance.

Fourth, water power is both instantaneous and flexible; it requires only seconds to open a floodgate or press a switch and release water into a turbine for generation — a blessing during sudden (and frequent) increases in peak electricity demand.

Other sources of energy, including renewables such as wind or solar power, have flexibility and reliability problems as they generate electricity only intermittently and, perhaps even worse, unpredictably.

Hydropower also can be entirely domestic. Decentralized and thus less susceptible to industry-wide power outages, it features excellent reliability and energy-efficiency properties.

Its reputation in recent years, however, has grown seriously tarnished as a result of the harm that large, conventional hydropower plants often cause river ecosystems. The construction of new, large hydropower dams is not only environmentally harmful and politically unpalatable (at least in the developed world) but also simply not viable as an option for increasing renewable energy alternatives.

Hydroelectric power initially emerged in the late 19th century. In the United States, some of the first hydroelectricity-powered streetlights stood near Niagara Falls, in New York. Once the technical viability of hydroelectric power was established, hydropower production grew rapidly in the United States until, in the early 1900s, hydropower accounted for more than 40 percent of the total U.S. electricity supply (and more than 75 percent of electricity supplied in the West and the Pacific Northwest).

Such large hydroelectric dams as the Hoover in the Southwest and the Grand Coulee in the Northwest, built in the 1930s, brought Depression-era jobs to a flailing U.S. economy and eventually supplied the industrial sector with the electricity necessary to ramp up armament production for World War II.

But after the war, hydropower's dominant role in the nation's overall electricity supply diminished.

Today, hydropower generates between 7 percent and 10 percent of the total U.S. energy supply — a falling percentage. Around the world, hydropower's share of energy production averages 17 percent, and in some countries, such as Canada, Brazil, Norway and New Zealand, hydropower actually serves as the primary source of electricity production.

Large hydropower plants constitute most of the current capacity of hydropower production worldwide, so the discussion of these projects is implied whenever arguments occur over the relative benefits of hydropower capacity development.

The most contentious aspect of large hydropower dams is their environmental impact on local rivers, most specifically on fish. While the net number of fish may not diminish (certain fish thrive in reservoirs and the altered water flows downstream of a dam), indigenous fish, particularly those that migrate (such as salmon, trout, sturgeon, lampreys and shads), often receive injuries. For example, significant declines in native fish species resulting from large dam development have been cited along the Columbia, Snake and Mississippi rivers.

As a result, construction of large, traditional hydropower plants has essentially stalled in the U.S. and in most developed nations. Although many under- and less-developed nations continue to build new, large hydropower dams (prominent examples of which include the Three Gorges in China and the Ataturk Dam in Turkey), international funding for such projects has largely dried up. The World Bank, in its dam-funding heyday in the early 1970s and 1980s, approved more than eight dam-related projects a year; today it approves fewer than one a year.

The story is similar in the United States. In 1993, for the first time in its 70-year history, the Federal Energy Regulatory Commission, the agency responsible for hydropower dam licensing, denied an operational license for a traditional hydropower project — essentially because of the dam's negative riverine impacts.

Hydropower's story, however, does not end here.

The negative impacts on rivers diminish with plant size. Though exact definitions vary, in general, small hydropower plants generate between one megawatt and 30 megawatts of power, and micro hydropower systems produce less than one megawatt of power, enough to supply a small village or town.

These plants affect rivers and streams only minimally. Significant power can be generated with flows of just two gallons per minute or from drops as short as two feet. This allows a substantial amount of river flow to remain in-stream, available to maintain riverine integrity. Small and micro hydropower systems, therefore, generate emissions-free electric power without many of large dams' negative environmental effects.

Consider the other benefits, too. Small and micro hydropower prove much more reliable than such alternative renewables as solar or wind power. The sun goes down at night and for much of the winter, and in any given day, can spend a lot of time behind clouds, which reduces (but doesn't eliminate) solar energy output. Wind is also variable, intermittent and unpredictable on a daily basis.

Small and micro hydropower sites, meanwhile, can be winterized to provide power throughout the year. Additionally, even very small microhydro systems, at about 18 kilowatt-hours, will produce more power than many (more expensive) photovoltaic systems. (Ten 100-watt bulbs lighted for an hour consume one kilowatt-hour.)

Small and micro hydropower development continues to take place worldwide; China now houses more than 43,000 small hydro facilities producing more than 19,000 megawatts of electricity, and more than 100 other countries have constructed small hydro plants in recent years.

In the United States, the Department of Energy completed a study in 2006 on the possibilities for small and micro hydropower development across the U.S. and found a total available capacity, for facilities generating less than 30 megawatts of power, of more than 275,000 megawatts — nearly three times our current hydropower production. This capacity, while concentrated in the Pacific Northwest, is distributed across the United States.

A smooth, functioning economy depends on reliable energy supplies. Climate concerns depend on increased use of emissions-free energy supplies. For an economically strong, emissions-free future, look to small hydropower — and that's what we'll do in the second part of this series.

Reducing the Big Problem of Climate Change by Adding Little Hydroelectric Plants

By Lea-Rachel Kosnik | 01.23.2008 | 09:25 AM (UTC)

Second of three parts

The leading cause of climate change today is the burning of fossil fuels related to energy production. Numerous proposals to reduce greenhouse gas emissions have included implementing cap-and-trade markets, applying carbon taxes and encouraging research and development into promising new energy production technologies such as fuel cells, ocean power and ethanol. We are currently at the vanguard of discovering which of these methods will prove fruitful, politically palatable and cost-effective.

As we proceed, it is worthwhile to continue exploring all of our available options, to help diversify avenues of approach into this difficult and pressing problem.

Another approach to reducing greenhouse gas emissions, therefore, involves more actively switching to proven renewable technologies in the production of electricity and reducing the use of fossil fuels in electricity production.

This is the main objective of the Renewable Portfolio Standards being passed in many states across the U.S. In 2003 only three states had passed legislation implementing renewable portfolio standards, but by 2007 the number had grown to 28, and the U.S. House of Representatives introduced legislation to implement a federal-level RPS at 15 percent of electricity generation.

Renewable alternatives to fossil fuel use include solar, wind, geothermal, biomass and hydroelectric power.

Currently, hydroelectric power is far and away the main renewable in use, satisfying two-thirds of all renewable electricity production in the United States. A proven technology, its benefits reach beyond just emissions-free electric power. Entirely domestic, hydropower relies on no foreign imports for production, it is decentralized and it has excellent reliability and energy-efficiency properties.

Not without its detractions, of course, hydropower does affect fishery resources and river ecosystems. Often underemphasized, however, is that there are gradations of hydropower production, and “small” or “micro” hydropower systems have extremely minimal impacts on river ecosystems. The exact definitions vary, but small hydropower plants are generally considered those that generate between 30 megawatts and one megawatt of power, and micro hydropower systems are those that produce enough power to supply a small village or town: less than one megawatt.

In the early 1990s the Department of Energy began a concerted effort to assess the total amount of undeveloped hydropower resources within the United States, part of a larger national energy strategy to identify all available energy resources within the U.S. In 1998 the first report — based on a compilation of previously identified developable sites, with the source data coming from existing state- and federal-level databases — came out, concentrating on conventional (i.e., large) hydropower capacity development.

Understanding that environmental concerns limited the development of much of this potential, the next report, which came out in 2004, concentrated on sites with potential for smaller-scale development. The unique assessment method used in the study identified both previously known sites and new ones, combining digital elevation models with geographic information system tools to estimate the power potential of a mathematical analog of every natural stream segment in the country.

This gross power “potential” was re-evaluated in 2006. The figure fell as a result of removing sites in land protected from development by federal statutes and policies or because of known environmental sensitivities. The remaining power potential, referred to as gross power “available,” still amounts to more than 275,000 megawatts of capacity, distributed across the United States.

Next, the 2006 report identified all “available” resources by their feasibility. The practical feasibility of development at each site was based on three criteria: site accessibility, load or transmission proximity, and land-use and environmental sensitivities that would make development unlikely (according to data from the Conservation Biology Institute).

Finally, the ultimate estimates of the power potential at each site were based on a rigorously environmentally “friendly” development model. The model consisted of a “penstock” running parallel to the stream, culminating in a powerhouse where the “tailwater” — after turning the turbine to create electricity — returned the working flow to the stream. No dams or impoundments of any kind that would obstruct the watercourse or form a reservoir were assumed in the estimates. The model also made sure to never utilize more than half the water flow of the waterway for electricity generation and limited penstock lengths.

Table 1 displays the results of these conservative analyses, presenting for each state the small and micro “potential,” “available” and “friendly” gross power numbers. Clearly, a large potential exists for small and micro hydropower development. Even if we concentrate on just the friendly hydropower resources, the numbers imply increased hydropower resources of nearly 60,000 megawatts — a 75 percent increase from current renewable hydropower production levels. Western states dominate in friendly gross power, as they do with potential gross power, but smaller resources are still located in every state in the country.

Big Hydro Is Dead! Long Live Big Hydro!

By Lea-Rachel Kosnik | 01.23.2008 | 04:30 PM (UTC)

Third of three parts

We opened this series by stating bluntly that the era of large, new hydropower projects is over, at least in the United States.

But electricity generated from traditional hydropower — those big dams that aren't going away any time soon — as well as from new hydrokinetic technologies such as tidal and oceanic power offers both many benefits and the possibility of incremental improvement.

Plus, water-powered electricity plants are extremely cost-effective. The main cost of most water-powered facilities is their initial construction and installation — there are no perpetually incurred fuel costs — and once a dam or a turbine exists, its maintenance and operation costs are minimal.

Experts have suggested that if current stocks of traditional hydroelectric power were reduced in certain regions of the country, no other source of generation could immediately replace that output — possibly leading to substantial spikes in wholesale electricity prices during peak demand periods.

Traditional hydropower is also the only currently viable way to "store" significant amounts of electricity. Technically, electric energy must be consumed as it is generated, but water stored behind a dam gets around this constraint by storing kinetic energy embodied in the pent-up water, which at the flip of a switch can be turned into electrical energy as the water falls through mechanical turbines.

This has important implications for "moving" energy between time periods, smoothing overall electricity supply and keeping prices from spiking to meet demand. This "shifting" characteristic of traditional hydropower alone has led many to conclude that one of the most important factors in determining the potential for market power in deregulated electricity supply systems is the level of available hydroelectric capacity.

Water power, therefore, proves fundamentally important to the overall U.S. electricity industry. Unfortunately, supplies of traditional hydropower in the U.S. have been decreasing steadily for more than a decade, and new hydrokinetic technologies are still in their infancy. Can we do anything to maintain, or even improve upon, current stocks of water-powered electric capacity?

We cannot build new, large hydroelectric dams; they have significant negative effects on migrating fish and local riverbeds. While the benefits of traditional large hydro development are questionable, however, efficiency improvements at existing dams, called "uprating," have the potential to increase hydropower production from as little as 8 percent to as much as 50 percent.

This comes without any increases in reservoir size or dam size and with, through improved turbine technology, diminishing fish mortality levels. The increasing cost of energy and the need to find fossil fuel alternatives, combined with the concern over fishery impacts of large dams, has led to a considerable acceleration of research over the last decade into technological improvements for fish passage and protection.

At Wanapum Dam in Washington state, for example, a new, advanced-design turbine is providing increases in power output of 14 percent, a water-use efficiency gain of 3 percent, and fish passage survival of 97.82 percent — a record.

These new turbines are expensive, but as the cost of energy increases, such options become more cost-effective. The Low Impact Hydropower Institute, a nonprofit organization "dedicated to reducing the impacts of hydropower generation," has developed a program that provides certification for environmentally acceptable development of hydropower at existing dams. As of 2007, LIHI has certified 28 facilities, in 19 states, producing nearly 2,000 megawatts of power.

It is also possible to develop new hydropower facilities at existing dams. The National Inventory of Dams documents more than 79,000 dams in the United States. Less than 3 percent of these currently feature developed hydropower capacity; most were built for such purposes as irrigation, navigation or flood control. Adding hydropower facilities to these dams would bring relatively little in additional negative riverine effects but could generate substantial amounts of renewable energy.

Not all facilities could be developed profitably, of course, and studies would need to be conducted at the individual site level to determine capacities and realized environmental effects, but even a slight increase in development of existing dams for hydroelectric power production could lead to large increases in energy production. In 1998, the Department of Energy made a very conservative estimate of "environmentally friendly" capacity additions to existing large dams and came up with 17,000 megawatts of potential, distributed across the United States.

Plus, there is a history of cost-effective private development of new hydropower facilities at existing dams.

Finally, the future holds promise with a number of emerging technologies that utilize river and ocean water to develop emissions-free, environmentally benign electric power. Hydrokinetics, the study of fluid in motion, is being developed to access the energy in river, tidal and ocean currents to generate electric power. Early estimates point to these sources as providing, at a minimum, an additional 23,000 megawatts of power in the United States.

Hydrokinetic and wave energy technologies require no impoundments, rendering irrelevant the negative environmental effects associated with dam construction and reservoir creation.

While these technologies are still very new, prototypes continue to pop up with increasing frequency in New York, Washington, Oregon, California and Florida. In 2006 the Federal Energy Regulatory Commission received more than 40 applications for preliminary permits for potential hydrokinetic projects, and in 2007 FERC issued a notice seeking public comment on how to streamline permitting and licensing of these facilities.

The data on hydrokinetic potential nationwide are still very preliminary, and any potential power will be located primarily along the coasts, where current wave and tidal prototypes are employed. Future hydrokinetic technologies, however, will also take advantage of the wave power in streams and rivers, and this will benefit many of the inland states.

Water power is important to our nation's overall electricity security. These avenues for maintaining current water power capacity, while not simultaneously adding significantly to negative riverine effects, deserve our attention.

Lea-Rachel Kosnik is an Economics professor at the University of Missouri in St. Louis. Her main area of research is environmental and regulatory economics, and she has published a number of papers in a variety of journals on the implications of hydroelectric power in particular.