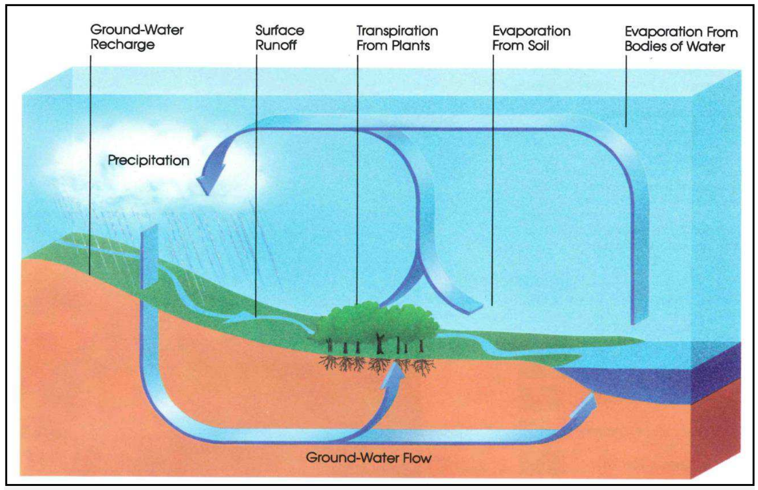
Youth Education & Interpretation It's in Our Nature

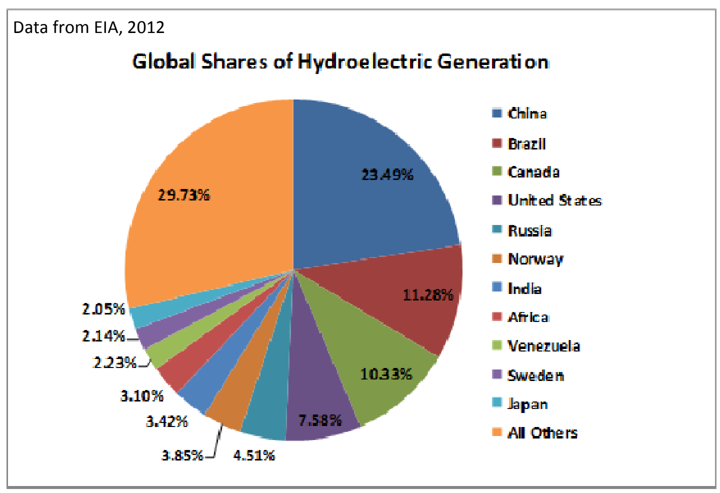
Energy Producing Systems: Hydropower

Humans have used the power of flowing water for thousands of years. Early civilizations used wooden paddle wheels to grind corn and wheat to flour. The word *Hydro* comes from the Greek word for water. **Hydropower** traditionally represents the energy generated by damming a river and using **turbine** systems to generate **electric power**. However, there are several other ways we can generate energy using the power of water. Ocean waves, tidal currents and ocean water temperature differences can all be harnessed to generate energy. More than 70 percent of the Earth is covered in water. In many ways the Earth is a water planet and the water is in constant motion thanks to the hydrologic cycle (see diagram).

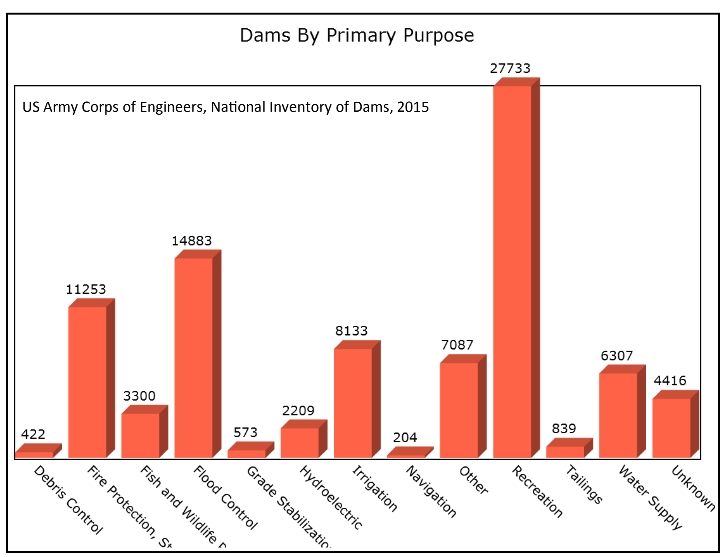


The energy to drive the hydrologic cycle is gained from the Sun. Thus, hydropower is a renewable energy source and one that is prevalent all over the Earth.

The United States is the fourth highest producer of hydroelectric power in the world (see chart). About 7 percent of the electrical power generated in the U.S. is currently derived from hydropower systems. Hydropower is very regional in the United States. Washington, Oregon, and Idaho generate more than half of their total electricity using hydropower, while it accounts for less than 1 percent in some Midwestern states. Missouri produces 1.32% of its electricity using hydropower. More than half of the **renewable energy** generated in the United States comes from hydroelectric dams. Hydroelectric power is currently less expensive than other **renewable energy sources** like wind, solar, and biomass.



Worldwide more than 16 percent of all electricity is generated using hydropower. Albania, Paraguay, Tajikistan, Nepal, Zambia, and the Dem. Rep. Congo all generate more than 99 percent of their electricity using hydropower. Most of the rivers in the United States already have one or more dams constructed along their course. However, most of these dams are not used to generate energy. Only 2.5 percent of the more than 85 thousand dams in the U.S. are classified as hydroelectric dams. Most dams are designed to create recreational opportunities (lakes), control flooding, or create irrigation, fire protection, or drinking waster reservoirs.



Types of Hydropower Systems

Impoundment

Impoundment hydropower systems take advantage of the conversion of potential energy of a dammed river to kinetic energy. The water is released from the dam through a series of pipes and used to operate turbine systems that generate electrical power. The lake volume can be regulated and represents a source of stored energy. These systems can be very efficient with as much as 95 percent of the energy being converted to electrical power.

In some cases impoundment systems are used specifically to store energy. Electrical power generated from other sources is used to pump water uphill from a lower reservoir to an upper reservoir. Typically this occurs at night when electrical consumption is low. The stored water is then released during peak energy periods, such as on hot summer days when air-conditioning use is high, by flowing downhill to the lower reservoir through a turbine. The efficiency of this system can be as high as 80 percent. Ameren Missouri currently operates the Taum Sauk pumped storage plant near Johnson's Shut-Ins State Park in Reynolds County, Missouri.

Pump storage hydropower systems offer a solution to the intermittent nature of some renewable energy sources such as solar or wind power. During sunny or windy days electrical power can be used to pump water to the upper reservoir. During cloudy days or during periods of low wind the impoundment then serves as a back-up energy source. Such approaches allow renewable energy sources such as solar or wind power to provide consistent and uninterrupted electrical power, regardless of changes in solar availability or wind velocity.

Diversion Systems

Diversion hydropower systems essentially channel the flow of a river or a portion of the flow to a turbine system used to generate electrical power. A set of pipes or canals is used to redirect the flow and such systems usually do not require a dam. Such systems are only applicable to very fast flowing bodies of water and the amount of power produced is very dependent on the flow. These systems cannot store power in the way a dam does and are best applied for smaller scale local power applications in remote locations away from main utility power grids.

Wave Power

Any one who has gone swimming in the ocean can attest to the power of even small waves. **Wave hydropower systems** involve constructing artificial canyons or troughs designed to channel the power of each wave. This motion is then used to drive turbines, compress air, or lift hydraulic pumps designed to generate electrical power. These systems are often applied to generate specific local electrical power needs such as lighting a marker buoy or providing power to a remote lighthouse. However, entire systems could be built along stretches of coast line and provide for much larger power needs.

Tidal Energy

The Moon exerts a strong gravitational force on our planet. This force combined with the rotational movement of our planet creates uplift in our ocean surface every 12 hours. The level of this tidal effect is greatly influenced by the depth of the water, local ocean currents, and geological constrictions that amplify the effect. Tides can be as small as a few inches on some coastal regions (west Florida coast) to as much as 30 feet or more in other locations (upper Baja peninsula). **Tidal Hydropower Systems** typically involve erecting a dam across the opening of a bay. As the tide comes in the flow of water is directed towards a series of turbines to generate electrical power. As the tide recedes the flow reverses and can again be captured to generate power. Some systems use the incoming tide to fill a large reservoir system then the gates close and power is generated from the controlled outflow. This type of power system has been successfully operated in France and currently provides power to 240,000 homes.

Ocean thermal Energy

Ocean Thermal Hydropower Systems take advantage of the temperature difference in ocean water with depth. The radiant energy from the Sun causes surface waters to be significantly warmer than colder deep water. Such systems require at least a 40 degrees Fahrenheit difference between surface and deeper waters. The warmer surface waters are used to vaporize a working fluid with a low boiling point (such as ammonia). The expanding vapor is used to drive a turbine and generate electricity. The working fluid is re-condensed using colder deep-sea water and the process repeated. Some systems use ocean water itself as the working fluid and have the advantage of producing fresh water in the process (via distillation). Such systems can be a significant advantage in areas of the world where fresh water is limited. Ocean thermal energy systems have been successfully piloted in Japan and Hawaii. However, the power generated from these systems is still currently more expensive than electricity generated by other means (fossil fuels, hydropower, etc). In the future, as the technology for ocean thermal energy systems is refined, both energy and fresh water may be routinely obtained from the sea. Sixty percent of the world's population is located near coastal regions and could greatly benefit from this emerging technology.

Characteristics of Hydropower

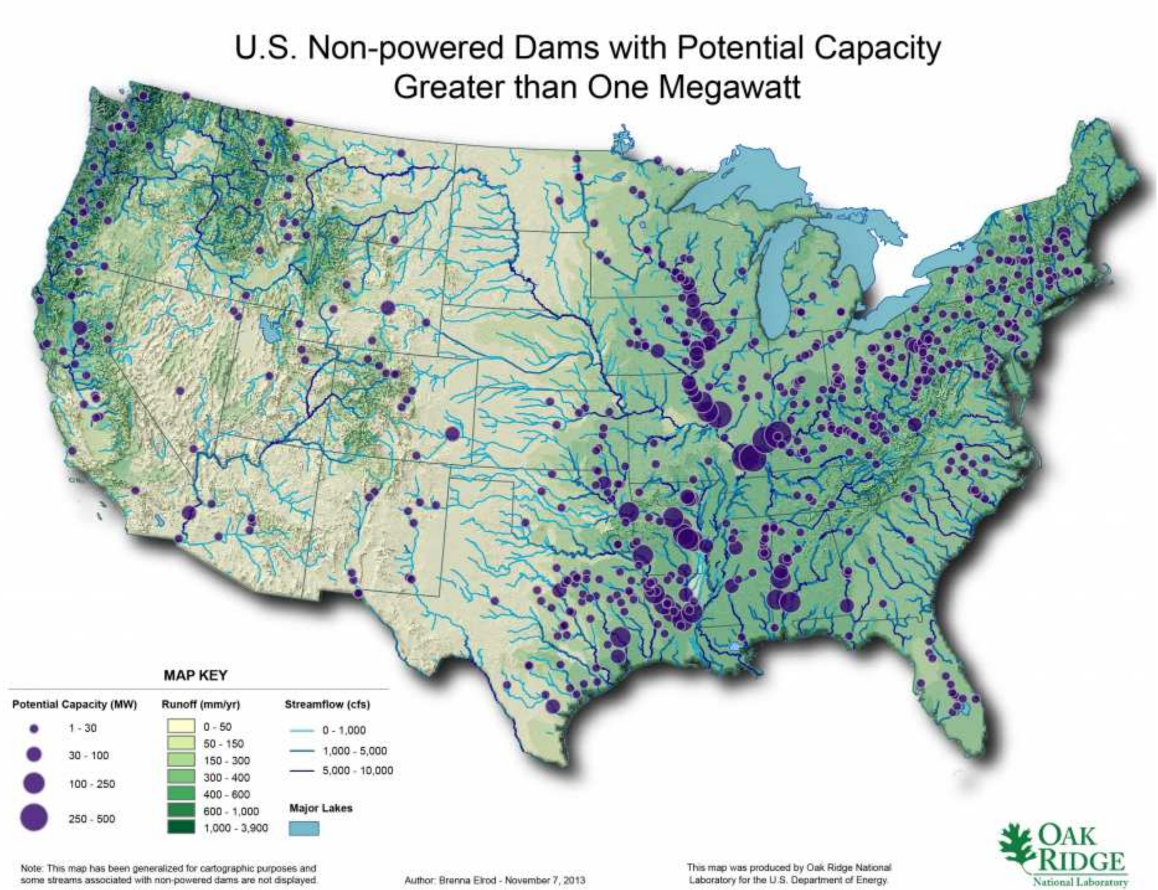
At one time as much as 40 percent of the electricity generated in the United States came from hydroelectric dams. Coal-fired power utilities currently provide the largest share of our electrical power and only 7 percent of electricity consumed is currently generated using hydropower. However, rivers and coastal areas are critical habitat for a substantial amount of the life found on Earth. Dams certainly change the characteristics of rivers and can have drastically negative impacts on fish populations and other aquatic organisms. A dam on a river can mitigate the natural flood cycles required by some fish for breeding, can limit migrations and can significantly alter the temperature of the water. Many dam installations have been shown to increase the processes of anaerobic degradation of organic matter resulting in increased levels of atmospheric carbon dioxide. Dams also compete with other water needs such as crop irrigation, drinking water and aquatic habitat protection. Water itself is becoming a precious resource as evidenced by the many lawsuits filed over water rights between the western states. In many parts of the world entire countries are in

Table ES.2. Summary of NSD Findings by States

State	Potential capacity (MW)	Potential generation (MWh/year)
AK*	4,723	(not estimated)
AL	663	3,522,000
AR	1,253	6,685,000
AZ	2,484	1,5459,000
CA	6,983	3,7564,000
CO	4,295	2,5623,000
CT	151	865,000
DE	6	35,000
FL	170	956,000
GA	621	3,604,000
HI*	145	699,000
IA	736	3,869,000
ID	7,018	41,015,000
IL	599	3,241,000
IN	581	3,123,000
KS	2,479	14,931,000
KY	675	3,301,000
LA	790	4,463,000
MA	194	1,114,000
MD	223	1,212,000
ME	1,132	6,532,000
MI	449	2,866,000
MN	568	3,191,000
MO	2,512	14,514,000
MS	1,129	6,449,000
MT	4,763	28,201,000
NC	857	5,067,000
ND	252	1,524,000
NE	1,942	11,917,000
NH	407	2,410,000
NJ	171	1,006,000
NM	1,280	7,193,000
NV	232	1,245,000
NY	1,900	10,715,000
OH	535	2,800,000
OK	1,147	5,838,000
OR	8,920	53,353,000
PA	2,889	15,795,000
RI	13	71,000
SC	309	1,844,000
SD	230	1,363,000
TN	1,002	5,618,000
TX	1,580	8,089,000
UT	1,376	8,246,000
VA	1,234	6,869,000
VT	401	2,344,000
WA	7,381	43,788,000
WI	556	3,513,000
WV	1,851	9,910,000
WY	2,960	10,776,000

* The AK and HI potential are estimated by a different approach from that used for the other 48 states.

A 2014 U.S. Dept. of Energy study identified the potential for increasing hydropower in streams across the country. The tables summarizes the potential in each state.



dispute over water rights. The Colorado River, for example, is so heavily utilized along its course that it no longer consistently flows from the United States through Mexico to the sea. The last one hundred miles of riverbed is often dry as a result of water diversion further upstream associated with agricultural irrigation and drinking water needs.

However, many river systems in the United States already have one or more dams installed along their path and only three percent of such dams are currently used to generate electrical power. Such dams could be retrofitted with turbine systems and electrical power obtained through modification of pre-existing facilities (see map above). Hydropower has the potential to be critical facet in the application of other renewable energy systems. Wind power and solar power systems are intermittent sources of energy. Pumped storage systems can be used to generate conventional hydropower during time frames when the primary source of power (wind or solar) is unavailable. New developments in tidal, wave and thermal ocean energy also promise to aid in establishing clean and renewable energy sources. As these technologies mature their practical application will increase helping to provide power for coastal populations.

The Future of Hydropower in Missouri

Missouri has five hydroelectric plants and two pumped storage facilities. Additionally, the Missouri river fuels 36 smaller hydroelectric units. The Osage Energy Center operated by Ameren Missouri in Bagnell Dam produces 500 million kWh of power and helps prevent the emissions of about 1 million tons of coal. The 2014 DOE report identifies about 30 projects for a generation potential of around 9,534,087 MWh—more than double the net total production by coal in Missouri. This is primarily driven by the heavy streamflow of the Mississippi and lower Missouri River. Of course, harnessing this potential is not always feasible. DOE took environmental and other factors into consideration in its identification of sites, but political will, construction funds, and other issues make hydroelectric less likely to be developed. One important development is micro-turbine technology which makes smaller **distributed energy generation** from hydroelectric systems for smaller geographic areas possible.

Glossary of Terms

Distributed energy generation: The use of small localized power production systems to generate electrical power usually for a specific on-site application and sometimes to the larger electric grid. Solar photovoltaic systems and wind power systems are common distributed energy generation methods

Diversion Hydropower Systems: A hydropower system which uses a diversion channel to direct swiftly flowing water to a turbine to generate electrical energy and then return water to the main channel of the water source

Electrical power: Electrical energy used to conduct work; the measure of the rate of electrical energy used by a circuit. This is usually measured using a unit called a Watt (W)

Hydropower: The utilization of the mechanical and sometimes thermal energy of moving water. In the modern era this is usually done to generate electrical power, but has historically been used for mechanical power

Impoundment Hydropower Systems: The most common type of hydropower system in which a completely or partially blocked water source, often a reservoir blocked by a dam, is released through turbines which then generate electrical power

Ocean Thermal Hydropower Systems: Hydropower Systems which use warm surface ocean water to vaporize a carrier fluid with a low boiling point to operate a turbine to generate electrical power and then condense the carrier fluid using deeper, colder water so that the process can be repeated

Pump Storage Hydropower Systems: A relatively new form of hydropower and energy storage in which excess electrical power during times of lower demand (often at night) is used to pump water from a lower reservoir into an upper reservoir. When demand is high and additional electrical power is needed, the water is released back into the lower reservoir operating turbines and generating electrical power

Renewable energy: Energy derived from renewable energy sources (See renewable energy source/fuel)

Renewable energy source/fuel: Primary energy source that can be replenished at an equal or greater rate to its consumption; sustainable energy source

Tidal Hydropower Systems: Hydropower systems that either capture and slowly release tides through turbines or direct incoming tidal water through turbines to generate electrical power

Turbine: A device which harnesses the kinetic energy of an incoming force (often steam, water, or air) to spin rotors and create mechanical power. In electrical power generation the spinning motion of turbine rotors is used to turn generators which use rotating magnets inside copper wire to create an electrical current

Wave Hydropower Systems: Hydropower systems that either funnel and capture waves in pools and release the water through turbines or use wave power to directly operate turbines to generate electrical power

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