HYDROPOWER

Hydropower makes up 37% of total U.S. renewable electricity generation and about 7% of total U.S. electricity generation.[1] There are several different types of hydropower. Some rely on large dams, some rely on small dams, and some have no dams at all, instead relying on the run of the river to turn a turbine. The advantage of dams is that they can store water as potential energy and release it when it is most needed. Run-of-river (also called hydrokinetic) hydropower does not include opportunities for energy storage unless it is paired with external energy storage technologies such as batteries.

Total estimated U.S. technical potential for hydropower is 60 GW.[2] Current installed capacity of hydropower is actually more than this, at just under 80 GW,[3] indicating that the U.S. has already built out most of its hydropower resource. Idaho, Washington, and Oregon obtain most of their electricity from hydropower.[4]

Hydropower is one of the most affordable sources of electricity and U.S. states that get the majority of their electricity from hydropower have lower energy bills than the rest of the country.[5] Globally, the levelized cost of energy of large-scale hydropower projects can be as low as $0.02/kWh, while average levelized cost of energy for capacity added in 2019 was just under $0.05/kWh.[6] Because hydropower is already a mature technology and many of the best sites are already in use, it is unlikely that costs will go down in the future.[7]

Unlike wind and solar energy, dam-based hydropower is a dispatchable energy source that can be produced on-demand, such as during peak hours of energy use. Hydropower co-benefits include flood control, irrigation support, and water supply. [8]

Large-scale hydropower is associated with a number of impacts to fish populations and aquatic ecosystems. According to the USFWS, large-scale hydropower can have the following environmental impacts:[9]

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[1] DOE. "Hydropower basics." https://www.energy.gov/eere/water/hydropower-basics
[2] NREL. 2012. *U.S. renewable energy technical potentials: A GIS-based analysis.* https://www.nrel.gov/docs/fy12osti/51946.pdf
[3] EIA. "Hydropower explained: Where hydropower is generated." https://www.eia.gov/energyexplained/hydropower/where-hydropower-is-generated.php
[4] DOE. "Hydropower basics." https://www.energy.gov/eere/water/hydropower-basics
[5] DOE. "Hydropower basics." https://www.energy.gov/eere/water/hydropower-basics
[6] IRENA. "Power generation costs: Hydropower." https://www.irena.org/costs/Power-Generation-Costs/Hydropower
[7] IRENA. "Power generation costs: Hydropower." https://www.irena.org/costs/Power-Generation-Costs/Hydropower
[8] DOE. "Hydropower basics." https://www.energy.gov/eere/water/hydropower-basics
[9] USFWS (May 2, 2018). "Energy technologies and impacts: Hydropower." https://www.fws.gov/ecological-services/energy-development/hydropower.html

- Water impounded behind dams converts riparian and free-flowing-river habitats into lakes, which can alter fish community composition and ecosystem productivity.
- Dams block passage of fish upstream and downstream, interfering with migration to spawning habitat, overwintering habitat, and even daily feeding or territorial movements. Although fishways can be installed to promote safe passage of fish upstream and downstream, many are species-specific and in general, they are not as effective as movement in a free-flowing river.
- Habitat fragmentation degrades the ecosystem and disrupts life cycles of fish and other aquatic species.
- Fish may be killed when entrained or impinged in moving turbines.
- When turbines are located in a bypass canal or pipeline (instead of in the main stem of the river), operations may dewater the bypassed reach of the river. This impact can be avoided by establishing minimum conservation flows to protect fish and wildlife.
- Water quality may be impacted by increased water temperatures in the impoundment and downstream, sediment releases (turbidity), gas supersaturation, resuspension of toxic substances and reduced dissolved oxygen levels. All of these factors may impact the viability of fish and other aquatic life.

Average lifecycle emissions from hydropower are estimated at 21 grams CO_2e/kWh, which is not only lower than fossil fuel power plants but also lower than solar and geothermal power.[10] However, hydropower plants vary widely in their GHG emissions, and some can actually emit *more* emissions than fossil fuel plants.[11] GHG emissions result from decomposition of vegetation within reservoirs created behind dams, which release CO_2 and methane. On the other hand, some reservoirs act as carbon sinks, sequestering more CO_2 through photosynthesis than they emit through respiration and decomposition. Whether a reservoir becomes a net emitter or a net sink depends on location and design, and it is vital to consider these potential impacts when siting and planning new hydropower facilities.[12]

In contrast to large hydropower dams, run-of-river hydropower uses in-stream turbines that need not alter the landscape, the flow of water, or fish passage. Turbines are turned by the natural flow of water in a stream or river, providing continuous electricity day and night as long as the water is moving. The amount of electricity generated depends on the rate of water flow in the stream or river, which may change seasonally. Small-scale hydro is most frequently used in remote areas without grid access, but it can also be used in urban areas by placing turbines in city water mains (called conduit hydropower). Any policy or incentive structure applying to DER

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[10] NREL. 2021. "Life cycle greenhouse gas emissions from electricity generation: Update." https://www.nrel.gov/docs/fy21osti/80580.pdf

[11] Osso, Ilissa (November 15, 2019). "Long considered a "clean" energy source, hydropower can actually be bad for climate." *EDF.* https://blogs.edf.org/energyexchange/2019/11/15/long-considered-a-clean-energy-source-hydropower-can-actually-be-bad-for-climate/

[12] Osso, Ilissa (November 15, 2019). "Long considered a "clean" energy source, hydropower can actually be bad for climate." *EDF.* https://blogs.edf.org/energyexchange/2019/11/15/long-considered-a-clean-energy-source-hydropower-can-actually-be-bad-for-climate/

can theoretically be used to support distributed small hydropower, depending on how regulations are phrased.[13]

Although run-of-river hydropower projects are often assumed to avoid the major environmental impacts associated with large-scale hydroelectric dams, they can nonetheless cause water depletion downstream of the diversion, water quality deterioration, loss of longitudinal connectivity, habitat degradation, and simplification of the biota community composition.[14] Impacts should be avoided and minimized through design and siting.

- Fishery friendliness: Hydropower projects can have negative impacts to fishery resources, and dam-based hydropower projects have historically been responsible for decimating populations of anadromous fish such as salmon and river herring. To some extent, these impacts can be reduced through fish passage modifications, but these modifications are not 100% effective. Run-of-river hydropower is fishery-friendlier than dam-based hydro, but can still have a variety of negative impacts. Great care should be taken to avoid and minimize impacts to fish when siting and constructing hydropower projects.
- Co-benefits: Micro-hydropower can provide electricity to areas without access to the grid.
- Environmental externalities: Hydropower can have serious impacts to aquatic resources and water quality. Reservoirs behind dams are created through the inundation of riparian and terrestrial habitat, which eliminates habitat for wildlife that utilizes these habitats and creates lake habitat in their place. Creation of new reservoirs can cause the release of methane and CO_2 from decomposition of vegetation.
- Policy catalysts: Hydropower can be promoted through tax incentives, power purchase agreements, standard offer contracts including feed-in tariffs, public investment in research and resource mapping, carbon pricing, and renewable/clean energy portfolio standards. Small-scale hydropower can also be promoted through programs tailored to DER, such as net metering programs, interconnection standards, tax incentives, grants, loans, on-bill repayment/financing, carbon pricing, and renewable/clean energy standards, and DER carveouts.
- More information:
    - Drawdown: Small hydropower
    - Wikipedia: Run-of-the-river hydroelectricity
    - Wikipedia: Small hydro
    - DOE: Hydropower basics
    - EIA: Hydropower explained
    - DOE: Microhydropower systems
    - NREL: *State models to incentivize and streamline small hydropower development*

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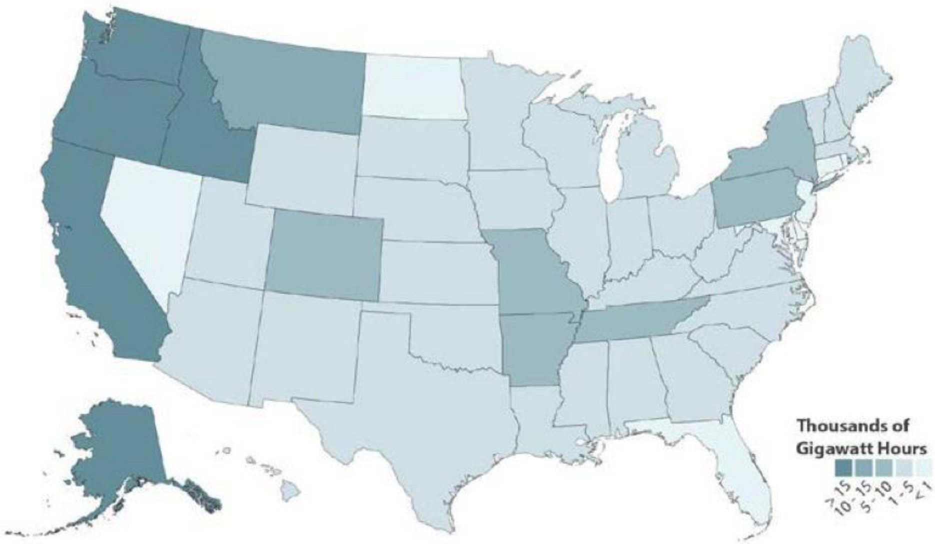
[13] Project Drawdown. "Small-scale hydropower." https://drawdown.org/solutions/small-hydropower
[14] Kuriqi, Alban, et al. 2021. Ecological impacts of run-of-river hydropower plants: Current status and future prospects on the brink of energy transition. *Renewable and Sustainable Energy Reviews* 142: 110833. DOI:10.1016/j.rser.2021.110833

Figure 1. Total estimated technical potential for hydropower in the U.S. Source: NREL 2012. [15]



Continue reading at https://fisheryfriendlyclimateaction.org/solutions

[15] NREL. 2012. *U.S. renewable energy technical potentials: A GIS-based analysis.* https://www.nrel.gov/docs/fy12osti/51946.pdf