Expanding Hydroelectric Generation, the Easy Way

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November, 2022

1. Introduction

More renewable electric generation along with less fossil-fueled generation is needed in order to reach net-zero greenhouse gas (GHG) electricity. My home state (California) does not consider nuclear generation or medium to large hydroelectric generation "renewable," although I do. California defines the two excluded "non-renewable" electricity sources as "zero-carbon resources." [1]

Hydro power is also a bit strange in other respects, whether it's small medium or large. First of all it serves several masters. In addition to needs by the electric grid it responds to needs for water. For more details on this see the earlier post described and linked below.

Hydro – Management: *Although hydropower is used nation-wide, it is somewhat proportional to the average amount of precipitation across a state, and a given state's land area to collect that precipitation.*

Although most hydroelectric projects have reservoirs to buffer the river-flows that feed them, there is still a strong incentive to make optimal use of the water that flows through each project's generators, but this is complicated by differing definitions of "optimal," differing non-generation requirements and other constraints. This paper will review the applications that help each project's management deal with these requirements.

https://energycentral.com/c/gn/hydro-%E2%80%93-management

This post is mostly about medium to large hydro generation, specifically those that have dams, and thus reservoirs. Small hydro mostly are run-of-the stream, and frequently do not have reservoirs, other than small spillways needed to provide sufficient inlet or outlet water pressure (head).

2. Efficiency Improvements

Early this century, the Vernon Station hydropower dam on the Connecticut River generated an average of 135,000 megawatt hours (MWh) per year. In 2008, nearly a century after the Vermont dam was first commissioned, its owner, TransCanada, invested $50 million to replace 4 aging turbines with modern ones, increasing both capacity and generation efficiency, a retrofit that boosted annual generation to nearly 200,000 MWh per year, a 42% increase.[2]

That was a substantial expansion of low-carbon electricity generation for the New England grid, without any new dams on rivers. Vernon Station is not unique. Globally,

[1] Liz Gill, Aleecia Gutierrez, Terra Weeks, California Energy Commission, "SB 100 Joint Agency Report: Charting a path to a 100% Clean Energy Future," page 39, March 15, 2021, https://www.energy.ca.gov/publications/2021/2021-sb-100-joint-agency-report-achieving-100-percent-clean-electricity

[2] Jeff Opperman, Forbes, "Significant Global Potential To Increase Generation From Hydropower Projects Without Adding New Dams," Oct 6, 2022, https://www.forbes.com/sites/jeffopperman/2022/10/06/significant-global-potential-to-increase-generation-from-hydropower-projects-without-adding-new-dams/

similar opportunities are common - projects that can help tackle the climate crisis without building new dams.

Central to stabilizing the planet's climate is a rapid decarbonization of the economy, including power systems, requiring a dramatic expansion of renewable generation capacity. Hydropower is currently the global leader among renewable generation technologies (although wind and solar PV are by far the dominant sources of new generation added each year). Several forecasts of how the world can achieve a net zero power system by 2050 include a doubling of global hydropower capacity, such as analyses from the International Energy Agency (IEA) and the International Renewable Energy Agency (IRENA).

Yet hydropower expansion at that level would have major negative impacts on the world's rivers and the people and ecosystems that depend on them. Only one-third of large rivers remain free flowing, and a doubling of global hydropower capacity would result in the damming of about half of those that remain, which would have major negative impacts on communities, migratory fish and the viability of agriculturally crucial river deltas.

Construction of new hydropower dams thus risks negative impacts and major tradeoffs. There is healthy debate about how to reduce the impacts of hydropower dams, at the level of projects or whole systems, but there is another question worth asking: ***How much additional hydropower generation could the world add without building any new dams?***

There are two primary ways that power systems can add hydropower generation without adding new hydropower dams: (1) retrofitting existing hydropower projects with modern turbines and other equipment, such as the Vernon Station example; and (2) adding turbines to non-powered dams.

For existing hydropower projects, retrofits with modern equipment can often increase generation by 8 – 10% or more for the same capacity. Further, some projects are undersized for their location, so retrofits can also increase capacity (and thus generation). For example, the original 26 MW Rheinfelden project on the Rhine River in Switzerland, built in the early 20th century, was replaced in 2011 by a new 100 MW project that will triple annual generation, from 185,000 MWh to 600,000 MWh.

For non-powered dams, it is often cited that only about 3% of all dams worldwide have turbines to generate hydropower, suggesting a massive potential for adding turbines to those dams. However, there is a good reason that many of those dams lack turbines—developing hydropower was not economically viable—and/or they are very small and the added capacity would be minimal.

But there are indeed non-powered dams for which it does make financial sense to add turbines. For example, the Red Rock Dam on the Des Moines River in Iowa was originally built for flood management. In 2021, turbines were added, creating a new 49 MW hydropower project from an existing dam. Over the past decade, American Municipal Power developed four hydropower projects on existing navigation structures on the Ohio River, adding over 300 MW of new capacity – enough to power hundreds of thousands of homes in the region.

A national study by the U.S. Department of Energy found that developing the 100 largest opportunities on non-powered dams could add 8 GW of hydropower capacity. Further, the average age of a hydropower dam in the U.S. is nearly 70 years and thus there will be a steady demand for modernization retrofits…

3. Funding Sources

With the above current age of hydroelectric facilities, it is highly likely that many are not only good candidates for efficiency upgrades, but many of the facilities are also unsafe.

On Monday, November 15, 2021 President Biden signed the Infrastructure Investment and Jobs Act (IIJA) into law. This Act contains significant increases in funding for several dam safety programs:[3]

- *$585 million total for Section 8A grants to States (High Hazard Potential Dam Rehab grants), of which Not Less Than $75M shall be for dam removal*
- *$148 million total for Section 8(e) grants to States (state assistance grants)*
- *$67 million total under FEMA Operations and Support for dam safety activities and assistance to States under sections 7 through 12 of the National Dam Safety Program Act (all other NDSP areas)*
- *$118 million total for NRCS Small Watershed Rehab Program Grants*
- *Rehab WIFIA - $64 million total (includes Corps Water Infrastructure Financing Program (CWIFP) – the new US Army Corps of Engineers (USACE) program for low-interest loans for dam repair)*
- *NOAA - $492 million for studies including modernized precipitation frequency and probable maximum studies (i.e., nationwide PMP estimates)*
- *Approximately $800 million for dam removal projects*
- *Approximately $800 million for dam safety, environmental and electric grid upgrades for hydropower dams.*

4. Hydro plus Photovoltaics

There is another way to add substantial generation from hydropower projects without adding new hydropower dams – place solar panels on their reservoirs. Reservoirs provide a relatively low conflict location to develop solar projects (e.g., they will not compete with land uses such as agriculture or forests) and they can tie into existing transmission infrastructure. If these "floating solar" projects were added to just 10% of the surface area of hydropower reservoirs around the world, they would add 4,000 GW of capacity capable of generating nearly twice as much power as is generated from all hydropower today.[2]

[3] Association of State Dam Safety Officials, Inc., "Infrastructure Bill Includes Significant Funding for Dam Safety Programs," Nov 18, 2021, https://damsafety.org/article/legislative/infrastructure-bill-includes-significant%C2%A0funding-dam-safety-programs

The image below is a large hydroelectric reservoir that hosts a number of photovoltaic arrays.

The 17 giant photovoltaic flowers on the 12-mile-long Hapcheon Reservoir in South Korea generate 41 megawatts

If an existing hydropower facility is being upgraded to increase efficiency, this would also require an upgrade of the generator intertie that delivers the power to the grid. If a potential floating project is considered at the same time as the efficiency upgrade, only the incremental peak power of the PV arrays would need to be factored into the added cost for the generator intertie.

Also, since all hydropower facilities with reservoirs have an element of storage in their output (the option to release water through the hydro turbines now, or store it and release it later), the PV output could use this storage capability to move the solar generated energy to cover peak demand.

On the other hand, it would be difficult / unsafe to place floating PV Arrays on reservoirs that are used for recreational boating. I am aware of at least some hydroelectric reservoirs that are not so used (for instance the City of San Francisco's Hetch Hetchy Reservoir).[4]

[4] Hetch Hetchy Power System, https://www.sfpuc.org/about-us/our-systems/hetch-hetchy-power-system