Kelly Carter
Master of Environmental Studies

The Sustainability of Hydropower

For thousands of years, humans have been harnessing the power of water to benefit their livelihoods. While water flow was historically utilized in mills for things such as grinding grains and spinning cotton, the invention of the first water turbine by Benoit Fourneyron in the 1800s kick-started the evolution of hydroelectricity thus forever changing how we utilize water ("The History of Hydropower"). Since its creation, hydroelectric technology has experienced a trough and crest-like pattern in development and demand. The United States saw a boom of large-scale hydropower projects from 1930 - 1975 which is when some of our more well-known dams, The Grand Coulee, The Bonneville, and The Hoover dam were built. A 10-year absence of funding towards the late 1900s halted current projects and any new developments, until the early 2000's when the negative environmental impacts of fossil fuels became more apparent ("The History of Hydropower"). As new environmental policies and guidelines began to fall into place, bringing new focus to cleaner energy, hydropower made a rapid comeback. Today, hydropower makes up 28.7% of U.S. renewable energy generation, and maintains rank as the second largest source of renewable energy in the nation (Hydropower Basics). Renewable energy is defined as energy derived from natural sources that are replenished at a higher rate than they are consumed (Banton). Although hydropower is defined as a renewable source of energy, it is not as inherently clean and sustainable as most people are led to believe. This paper will review the basics of hydropower and explore the consequences, both positive and negative, that occur with its implementation.

Hydropower in the U.S.

Hydropower is more attainable than most people think, and is actually used in all but two states, Delaware and Mississippi, to generate some amount of clean energy (Hydropower Basics). While there are around 2,300 electricity-generating dams across the United States, the largest production of energy currently comes from the western region (Baumhardt). Washington, Oregon and California are the 3 largest contributors of hydroelectric generation and make up almost 50% of all hydropower across the U.S. Of all renewable energy in the western region, 90% is hydropower that is generated by 150 dams located throughout the Columbia River Basin (Baumhardt).

Currently, the 3 most common forms of hydropower plants are impoundment, pumped storage, and diversion. Impoundment and pumped storage both utilize stored water in reservoirs and generate electricity when the water is released and falls through turbines. Diversion, also known as Run of River, channels a portion of river through a canal and utilizes the natural decline and flow of the river to move turbines and generate electricity ("Types of Hydropower"). Each of these plants use methods like gates and valves to regulate how much water is released and when, to meet changing electricity needs ("Types of Hydropower").

Accessory benefits of hydropower

Typically unseen and unrecognized, the implementation of hydropower has more to it than just being a source of clean power. Hydropower plants have the ability to rapidly change their electrical output and can immediately provide power to the grid (Benefits of Hydropower). As our climate crisis continues to progress and we experience an increased frequency of intense and destructive climate disasters, this capability could prove to be essential in recovering during major power outages. Regulated electrical output also allows hydropower plants to supplement energy "in tandem with renewables such as wind and solar power when demand is high" (Benefits of Hydropower). The establishment of reservoirs, in conjunction with dams, do more than just create another lake to go fishing in. In regions that experience periods of heavy rainfall and snowmelt from mountains, reservoirs can be key components in maintaining the surrounding landscape. While reservoirs collect and hold water, their dams "[limit] the amount of water allowed to continue downriver" and can help reduce the risk of downstream flooding (Reservoir). Collecting and storing excess water during wet seasons also gives us the opportunity to utilize it at times of scarcity. Stored water provides security for freshwater and can be the determining factor in the survival of crops in a drought.

Environmental impacts of Hydropower

We cannot continue to explore and develop the use of hydropower without acknowledging that its benefits come with repercussions. In our efforts to produce cleaner energy, environmental health is coincidentally sacrificed and what seems like a second thought is now coming to the forefront. From the very beginning of installation, hydropower plants can produce negative impacts on their surrounding environments. The construction of dams and reservoirs impedes natural flow of water which introduces a few serious issues (Bednarek).

One of the largest wildlife-impacting issues we observe is the interference of fish migration and life cycle, which has "played a major role in the decline and extirpation of numerous salmon and steelhead populations" (Columbia River). Dams, even with the presence of fish passages, are disruptive to the upstream and downstream movement of native resident and migratory fish. Slowed and unnatural river flow created by dams can lead to altered water temperatures, which form thermal barriers and disrupt migrating fishes' ability to navigate to appropriate spawning grounds (Bednarek). Even with successful spawning, the unnatural, slow flow of rivers and reservoirs also increases the exposure of young fish to predators and drastically affects their chances of maturation (Columbia River).

Another significant impact that is not as easily observed, is hydropower's contribution to Greenhouse Gas (GHG) emissions. Most people have the impression that Hydropower is completely clean since it utilizes the flow of water. Hydropower plants and the process of generating electricity does not release GHG itself, but the reservoirs that they utilize do. It is important to note that not every reservoir is a contributor, and some are even considered carbon sinks. To be a carbon sink, a reservoir must "[take] in more carbon through photosynthesis by organisms living in the water than they emit through decomposition" (Ocko). Those that are not carbon sinks, release carbon dioxide and methane from decomposing vegetation in amounts much larger than they absorb, and can produce a carbon footprint equal to or larger than fossil fuels (Ocko). Multiple factors, including water levels and vegetation can play into reservoir emissions. The release of water from dams is variable and can lower water level in the reservoir and create shallow zones, where methane can easily bubble to the surface (Askey). Shallow zones also help create layers of different temperatures within the lake that influence plant life. Warmer temperatures at the surface provide ideal conditions for algae blooms while cold temperatures at the bottom create an anaerobic environment. Decomposing algae on the surfaces releases carbon dioxide and once at the bottom of the lake, microbes continue breaking down the matter and produce methane in the process. The methane produced in the bottom of the lake gets released into the environment when that water is pulled through deep-water intake in a dam (Askey).

Suggestions and conclusion

Hydropower is a phenomenal source of renewable energy, however, its level of sustainability needs to be reevaluated and improved. Its negative environmental impacts will continue to outweigh the accessory benefits we receive until we address them directly. There will be no definitive end to the use of hydropower, so priority lies in limiting its effects. The first steps could involve year-round monitoring to better understand the presence and movement of resident species and migratory fish in the involved waterway. This could be useful in identifying the most impactful dams and dictate the next steps towards solution. The easiest solution would be to reverse what has been done; the removal of highly impactful dams would, over time, lead to restored natural flow of streams and rivers and the reconnection of aquatic habitats (Ocko). 'Run of river' hydropower plants taking the place of impoundment dams may prove to be a solid compromise as they would allow rivers to return to natural flow while still generating power without the use of a dam.

GHG emissions from reservoirs directly contradict the purpose of utilizing hydropower and should be regarded as top priority. While each reservoir is different, monitoring of water temperatures and gas production could lead to regulations of water release to mitigate thermal stratification and the release of methane. Algae collections after peak growth season, before decomposition begins, could significantly reduce carbon dioxide and methane release by removing it from the equation altogether.

While we have substantially benefited from the use of hydropower, we must acknowledge the harm that it has done to the environment. There is no simple fix but there is potential for hydropower to truly be a sustainable long-term source of energy.

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