Thesis Project Portfolio

Adapting Hydropower Operations to Support Renewable Energy Transitions and Freshwater Sustainability in the Columbia River Basin

The Negative Affects of Hydropower Infrastructure and Hatcheries in the Columbia River Basin

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Sociotechnical Synthesis

There is unequivocal evidence that the Earth is warming at an unprecedented rate, and that the burning of fossil fuels is the principal cause. This situation is fostering a growing interest in shifting global energy production toward renewable energy sources such as solar, wind, and hydropower. Hydropower plays an important role in meeting global carbon mitigation targets and eventually achieving net-zero carbon emissions, especially within the Mid-Columbia (Mid-C) energy market in the Pacific Northwest (PNW), where hydropower currently comprises 50-65% of its generation. However, other renewable energy sources in the Mid-C market and connected California Independent System Operator (CAISO) power grid are expanding significantly, particularly solar power in California (CA). Thus, hydropower operations at plants within the connected Mid-C market may need to be re-operated to balance the more intermittent supply from renewables in CA so that energy supplies are in phase with demands. In this study, our goal is to re-design hydropower operations in the Columbia River Basin (CRB) of the PNW to achieve a 95% renewable energy power grid in CA and the PNW by the year 2035. This will require not only filling supply gaps from other renewable energy sources, but also balancing other conflicting objectives to be fulfilled by the dam operations, such as minimizing environmental spill violations, maximizing hydropower production, maximizing flood protection, and maximizing economic benefits. We use multi-objective optimization to design alternative operations at four CRB dams to balance these objectives over the historical record. We then simulate their operations over alternative possible future climate change and energy development scenarios to find a recommended set of operations that are robust to these uncertainties. The energy scenarios include the National Renewable Energy Lab's (NREL) Mid-Case Energy Scenario for the years 2025, 2030 and 2035, which achieve 95% Renewables by 2035, as well as a business as usual (BAU), or base case, scenario represented by the historical

energy mix. The four climate scenarios are made from combinations of low or high warming and low or high streamflow for three overlapping time steps: 2020-2029, 2025-2034, and 2030-2039. Our optimization is able to find a robust compromise policy that balances the system's conflicting objectives well both now and in the future. We close by exploring how this policy coordinates operations across system reservoirs, which could inform reservoir operators in the CRB about how to adapt operations as the system changes in the future.

While creating a plan for the Grand Coulee to support the transition to a 95% renewable grid, it's important to also investigate the impact hydropower operations and infrastructure have on the surrounding environment, ecosystem, and communities, especially the effect on salmon populations and other freshwater wildlife. Dams and reservoirs can have a huge impact on the natural flow of rivers, reducing water flow and hindering the migration of fish as well as harming the Columbia River estuary. This area is crucial to lots of wildlife, including salmon, as it is where freshwater meets saltwater tide, creating an area for wildlife to gradually adjust to salt water in the Pacific. In addition to wildlife and the surrounding ecosystem, communities that rely on these staying consistent for their lifestyle are greatly affected by these changes as well. Specifically, lots of indigenous communities rely on salmon beds for food and as the salmon population declines, so does their livelihood.

There have been multiple projects aimed at mitigating the negative effects of hydropower infrastructure like Grand Coulee, especially the decline in salmon populations. One main example is the startup of hatcheries in the Columbia River. These began as an effort to replenish salmon, and other fish populations in the river, but these projects, like the dam, don't come without their flaws and negative effects on the ecosystem. In this paper I will explore the impacts of the Grand Coulee Dam operations on the surrounding environment, such as the decline of the

ecosystem and how projects like the fish hatcheries added after the dam don’t do the good they set out for. Furthermore, these fish hatcheries may have negative consequences for surrounding populations, such as indigenous communities in the PNW and the unethical attributes of hydropower infrastructure. In attempting to develop infrastructure for renewable energy amid climate change, that initial goal of protecting the environment and those living in it must not be forgotten.