Thesis Project Portfolio

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

(Technical Report)

Developing Policy to Uplift Native American Tribes Affected by Hydropower in the Columbia River Basin

(STS Research Paper)

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Executive Summary

The Earth is warming due to the burning of fossil fuels, leading to a growing interest in renewable energy sources such as solar, wind, and hydropower. Hydropower plays a vital role in meeting global carbon mitigation targets, especially in the Mid-Columbia (Mid-C) energy market in the Pacific Northwest (PNW), where it currently comprises 50-65% of generation. However, with other renewable energy sources expanding, such as solar power in California (CA), hydropower operations at plants within the connected Mid-C market need to be modified to balance the more intermittent supply from renewables in CA. Our technical project aims to redesign 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 2035, balancing objectives such as minimizing environmental spill violations, maximizing hydropower production, maximizing flood protection, and maximizing economic benefits through multi-objective optimization. The Columbia River Basin, which spans over an area of 260,000 square miles, is a significant watershed in the United States that is solely dedicated to the Columbia River. It serves as the drainage system for numerous rivers, creeks, and streams. In the 1930s, the federal government began constructing dams along this river for various purposes such as preventing floods, generating hydroelectric power, supplying water for irrigation, creating locks for navigation of boats and barges, and developing recreational areas. However, the hydropower operations and the construction of dams in the Columbia River Basin have resulted in significant environmental and social impacts, including the reduction of accessibility to salmon populations and disruption to the way of life of Indigenous populations who have relied on these lands, the Columbia River, and the salmon for centuries. The government has implicitly relied on technological determinism, sacrificing the humanitarian rights of Native Americans for the sake of hydropower

advancement, while simultaneously achieving progress on their economic and environmental objectives for the larger American population who rely on the dams and the power grid. My STS research seeks to draw upon hydropower legislation and policy analyses in a global context to argue for successful approaches and frameworks for hydropower policy going forward in the California River Basin that ensure the rights and survival of Native American tribes in the region. A multi-stakeholder process in the context of hydropower in California could provide a valuable precedent for addressing the needs of multiple social groups and constituents in the future. Both projects enable me to explore how the United States can make systemic changes, motivated by the current state of the hydropower and energy sector, to balance multiple competing interests and stakeholders in the Columbia River Basin.

For our technical project, we focused on adapting hydropower operations to support renewable energy transitions and freshwater sustainability in the Columbia River Basin. Achieving net-zero energy sector emissions requires rapid adoption of renewable alternatives to existing high-emissions infrastructure. The on-demand energy from hydropower uniquely facilitates the transition to renewable energy by meeting demands not met by weather-dependent energy sources like wind and solar. Because there are conflicting tradeoffs in hydropower operating policies, it was necessary for us to perform a multi-objective optimization after we had simulated the operations of reservoirs in the Columbia River Basin which serve as the supply of water for hydropower in the region. Our case study focused on designing operations at four reservoirs in the Columbia River Basin to balance environmental and economic objectives under potential future energy and climate conditions. These reservoirs included Hungry Horse, Libby, Dworshak, and Grand Coulee. Our objectives were to minimize environmental spill violations, minimize peak flood height, minimize flood frequency, maximize hydropower production, and

maximize Bonneville Power Administration (BPA) revenue. We performed multi-objective optimization to design alternative reservoir operating rules that balance these conflicting objectives. We made use of two computational models – a power systems model for generating electricity prices from synthetic weather data to represent regional wind, solar, and hydropower capacities and a reservoir optimization model for generating optimal policies that balance the objectives. These models are coupled through the objective of maximizing the BPA revenue in our reservoir optimization, since calculating that revenue requires the electricity prices in the region. Our optimization model yielded nineteen non-dominated reservoir operating policies that dictate when to release water using parameters such as the previous day's inflow and the storage of the reservoir. To evaluate the robustness of these policies and account for uncertainty, we simulated the outputted policies over four climate change scenarios and an energy scenario inspired by the National Renewable Energy Laboratory's (NREL) Mid-Case with 95% Renewables by 2035. The climate change scenarios we used were futures that are dry with high warming, dry with low warming, wet with high warming, and wet with low warming. Furthermore, the energy scenario we selected describes the projected distribution of energy across renewable sources for the years 2025, 2030, and 2035. In the end, we selected one optimal policy out of the nineteen which had the least significant tradeoff between the objectives. It effectively maximized hydropower output and BPA revenue, while minimizing spills, flood height, and flood risk. In this policy, the Dworshak reservoir is used for flood protection and all policies chose to keep Grand Coulee reservoir full to maximize hydropower production. Thus, through multi-objective optimization and scenario analysis, we were able to find alternative reservoir operations for the Columbia River Basin that balance all the system objectives and are robust to uncertainty. Future work should explore how uncertainties in energy and climate

interact rather than their independent influences and optimize policies across these possible futures to improve performance.

For my STS project, I focused on developing potential public policy to uplift Native American tribes affected by hydropower in the Columbia River Basin. The ongoing operations of dams in the Columbia River Basin have negatively impacted salmon populations, disrupting the traditional way of life and culture of Indigenous populations who rely on salmon as a staple food and cultural symbol. The construction of these dams between the 1930s and 1980s also resulted in the displacement and loss of Native American territory, leaving tribes living in federally assigned settlements with unsafe living conditions. The heavy use of the Columbia River has caused significant declines in water quality and threatens the survival of species like salmon. The negative impacts have disproportionately affected Indigenous tribes in the region, including the Nez Perce, Warm Springs, Yakama, and Umatilla tribes who settled with the federal government for their lost sites. Notable legislation that has been enacted thus far to address the environmental disruptions to salmon populations and displacement of Native Americans include the Northwest Power Act of 1980, the Columbia Basin Water Transactions Program of 2002, the Army Corps of Engineers' development of more permanent housing for Native Americans under the Obama Administration in 2016, the Water Infrastructure Improvements for the Nation Act of 2016, and the Biden-Harris Administration's ongoing litigation with Indigenous tribes in the Columbia River Basin regarding salmon populations. Members of Congress and the US Department of Energy admit that inefficiencies in hydropower licensing processes are causing higher development costs and longer timelines which reduce the flexibility of the government to perform stakeholder analyses. Thus, the effects of hydropower operations on fisheries, recreation, and tribal and public lands are not being considered by the federal government. A

framework I discovered in the academic literature on hydropower policy both domestically and internationally that can be applied to the case of Native Americans in the Columbia River Basin is the political ecology framework. In the paper, *Discussing Large Dams in Asia After the World Commission on Dams: Is a Political Ecology Approach the Way Forward?*, the authors present this framework which is characterized by the following: the framework examines the effects of large dams as well as the causes (economic and political motivations), it requires that ecological structures and functions be coupled with social, political, cultural, and economic influences, and it incorporates an actor-oriented model to look at environmental change and land-use conflicts that are occurring within politicized environments. In their paper, they analyze the case of the Bhakra Dam in India using this framework and comment on the social, political, and economic motivations behind the dam that are not immediately evident. An important similarity between the Bhakra Dam case and the Columbia River Basin case is the issue of arbitrary demarcations of land. The Bhakra Dam was built by India in a disputed territory with Pakistan called Punjab. Furthermore, India hindered Pakistan's use of the Sutlej river which ran through both countries to construct the dam. In the Columbia River Basin case, Native Americans do not own the land they reside on—rather it is held 'in trust' by the federal government making it an arbitrary demarcation. Therefore, I pose two potential solutions using the framework of political ecology in the Columbia River Basin case—award property rights to Native Americans and design new licensing processes for hydropower. By giving Native Americans property rights, they have equity in the land and can therefore reap monetary benefits and power by selling it or cultivating the natural resources on it. With their own source of money, they can take charge over environmental restoration and uplifting the Native American community alongside the federal government instead of being dependent on the government for change to occur. By designing

new licensing processes for hydropower, this enables the federal government to place reasonable conditions on hydropower licenses and protect tribal and public lands, safeguard water quality, and fishery resources.