Improving the CAPOW hydropower optimization model of the electricity market in the Columbia River Basin

Designing a hydropower system that is commensurate with the Indigenous way of life and survival by analyzing the impact of federal projects on Native American residents in the Columbia River Basin

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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General Research Problem: Modeling a hydropower solution that promotes a renewable energy power grid while protecting the way of life of Indigenous populations

How can transformation of the energy sector to be reliant on hydropower and renewable sources be done in a way that promotes Indigenous survival and ways of life?

The topic of focusing the world's energy and electricity on renewable sources has never been a more relevant topic. Climate change and global warming are in full force as carbon emissions and greenhouse gases continue to populate the atmosphere; this has the effect of trapping radiation emitted from Earth in the atmosphere resulting in rising temperatures across the planet. The world of science and public policy have equally acknowledged the dangers posed to our planet if shifts toward renewable energy sources like hydropower are not made. In the United States, one prominent hub of renewable energy is the Columbia River Basin. For decades, the dam system in this area has been a major energy supplier for the California power grid—a grid which also depends on solar, wind, and natural gas. With the trends in climate change, there are calls to find a way to optimize the existing dam system and shift the power grid to 100% renewable energy through simulation and modeling.

The dams constructed in this area have not come without significant drawbacks—namely the environmental impacts and resulting social impacts. The dams' ongoing operations have had the effect of reducing accessibility to salmon populations and reducing salmon runs in the Columbia River Basin. This is significantly disrupting the way of life of Indigenous populations who have relied on salmon for centuries as a staple food and a traditional symbol. Furthermore, the period between the 1930s and 1980s when the dams in this region were constructed was characterized by significant displacement and loss of Native American territory, leaving many tribes today living in federally assigned settlements with unsafe living conditions. Rapid

industrialization and legislation geared toward the use of hydropower has completely disregarded the sentiment and needs of Indigenous residents—a reality that is only starting to be addressed. This is a shocking example of the government implicitly relying on technological determinism as the dam system in the Columbia River Basin has expanded over time. The United States has a dark reputation of committing egregious acts of genocide against Native Americans and ostracizing them from their settlements and homelands. If the present disenfranchisement of Native Americans because of the dams in the Columbia River Basin continues to go unaddressed, the nation is setting a dangerous precedent about the sacrifice of human rights for the sake of technology. An important contradiction in this system however is that the expansion of hydropower and creation of these dams has been both economically motivated—reducing the price of energy in the region—and environmentally motivated—slowing climate change. These objectives are beneficial to our society, which makes establishing reparations for the effects that hydropower advancement has had on Native Americans such a complicated subject.

Improving the CAPOW hydropower optimization model of the electricity market in the Columbia River Basin

Can we adapt the existing CAPOW hydropower optimization model for the electricity market to include renewable energy storage and additional objectives to make informed recommendations on hydropower operations in the region?

With contemporary trends in climate change, there is a greater need to modify power systems to become completely reliant on renewable sources of energy as opposed to natural gas. The Columbia River Basin, with more than four hundred dams, is home to the largest renewable

energy power grid in the United States. It serves many key functions to the region such as providing clean, reliable energy and flood protection, while the reservoirs in the region are also responsible for flood prevention, water quality and water assurance, and salmon reproduction. The region's energy supply depends on hydropower operations from the Columbia River Basin due to the variability in wind and solar energy production. Existing hydropower operations do not enable a power grid supported by 100% renewable energy yet due to energy supply and demand needs. If hydropower operations can be optimized, however, then the idea of a power grid supported by 100% renewable energy sources may become a reality. Hydropower is among the easiest renewable energy sources for humans to control through dam systems as opposed to wind and solar energy. If, at a smaller geographical scale, we can discover such optimizations that sustain a renewable energy power grid while balancing important environmental and social metrics, we can apply this to power systems across the world and reduce society's reliance on fossil fuels and natural gas as an energy source; this would be a major achievement toward slowing the rate of climate change and global warming.

Previous work done in this field uses the California and West Coast Power System (CAPOW) optimization model–a python model that represents the effects of hydrometeorological processes on energy demand and production–to represent the Columbia River Basin, outputting energy prices under different energy demand and climate change scenarios. These scenarios are quantified by Shared Socioeconomic Pathways (SSP)--scenarios of projected socioeconomic global changes which can be used to derive greenhouse gas emission scenarios--and Representative Concentration Pathways (RCP)--trajectories for greenhouse gas concentrations. Prior research has shown that energy demand pathways have a greater impact on the energy price and energy production outputs of the CAPOW model.

Our work this year attempts to expand on this prior research to determine robust reservoir operating policies in the Columbia River Basin using the CAPOW optimization model, with the goal of achieving a 100% renewable energy reliance in the power system. Upon integrating other objectives into the CAPOW model such as flood mitigation and salmon population management, we can develop economically and environmentally optimized reservoir operating policies. Thus, we are attempting to derive a hydropower-based solution to enable 100% clean energy at the Columbia River Basin. This solution, while still having a large enough energy production, must not impact the local ecosystems and waterways negatively. The design must balance the electrical needs of consumers and businesses, while protecting the environment, and decarbonizing the electricity sector in the Pacific Northwest.

To address the problem, there are certain key activities that we must accomplish:

1. We need to refine and improve the CAPOW optimization model to include pump storage and an alternative financial objective function. Our project seeks to use a reservoir simulation model, water level model, and direct policy search–which extends the prior research done in this field.
2. We need to develop various scenarios depending on current and prospective socioeconomic, environmental, and technical factors. This will incorporate projected climate change pathways.
3. We need to use the model outputs of electricity prices from these scenarios and conduct risk analysis based on economic/environmental metrics. Other outputs include performance metrics such as environmental spill violations, hydropower production, and the 100-year flood. An optimization algorithm will loop back into the system to converge at an optimal solution.

By accomplishing these steps in succession, our goal is to discover operating policies through simulation that enable a power grid entirely reliant on renewable energy given the socioeconomic and environmental context in the Columbia River Basin. These policies can then be implemented and enforced across the existing dam system to achieve reduced emissions from natural gas in the area over time.

Designing a hydropower system that is commensurate with the Indigenous way of life and survival by analyzing the impact of federal projects and legislation on Native American residents in the Columbia River Basin

How can we use the historic relationship between the federal government and Native American tribes regarding hydropower to understand how policy and mutual governance can protect the way of life of Indigenous tribes in the Columbia River Basin?

Since the 1930s, dam construction projects mandated by the federal government have been dominating the Columbia River Basin. Major stakeholders on the federal side of such projects under different presidential administrations include the US Army Corps of Engineers, the Department of Energy, Congress, and the Supreme Court. Dam construction projects between the 1930s and the 1980s in the Columbia River Basin have had detrimental effects on the Indigenous tribes' way of life in the Columbia River Basin up to the present day. The major consequences that these dams have had on Native Americans is a gradual disruption to their food supply in current settlements and historic displacement from their sovereign territory to poor living conditions. Regarding their food supply, the dams' operations continue to disrupt the local salmon populations' runs with salmon being a vital source of food, economy, and culture for Native Americans. Regarding historic displacement, tribal villages have lost vital fishing sites

and territories because of the dams' reservoirs consuming them—often resulting in relocation to poor living conditions by the federal government which many tribes are still operating in today. Notable Pacific Northwest tribes that have been impacted in such ways include the Nez Perce, Warm Springs, Yakama, and Umatilla—all of whom settled with the federal government in the 1950s for their lost sites, unaware of the long-term consequences to their food supply and way of life. It was only until recently that the federal government made considerable progress toward preserving the way of life of Native Americans in the region. This progress, however, is still nowhere close to awarding Native American tribes the human rights that they are entitled to not only as residents of the California River Basin, but as sovereign nations within the United States of America. The rights of Indigenous populations have long been an issue that the federal government has deprioritized due to expansionism and industrialization.

This research project seeks to analyze the evolution of legislation and projects geared toward Native American preservation and environmental flow restoration to understand what deficiencies still exist in the current system and what has proven successful over the years. This information will come from academic literature on efforts made by both the federal government and Native Americans to address these problems in the Columbia River Basin and from documented testimonies of Native American tribes in the region on the issues they continue to face despite what reparations have been made. With a comprehensive understanding of the progress that has been made in addressing Native American preservation and environmental protection, we can then highlight and combine the most promising approaches and frameworks that balance the interests of both the federal government and Native Americans in order to achieve the rapid progress that is still needed from an environmental and territorial standpoint for Native American tribes in the Columbia River Basin. Through innovative public policy, we can

move in a direction that better balances technological advancement, environmental concerns, and the prosperity of Native Americans.

The basis for the historic discord that has occurred between Native American tribes and hydropower projects in the Columbia River Basin is the idea of rapid technological advancement without a regard for the societal and environmental impacts in the system. Hydropower projects mandated by the government were motivated by utilizing hydropower to meet the energy demands of the region, while doing so in a cost-effective manner. Furthermore, the government has the added climate change objective of decarbonizing the energy sector and moving toward more renewable sources of energy. With all these objectives, it has been difficult over time for the government to satisfy environmental considerations like salmon populations and the deeply connected social considerations like the way of life of Indigenous tribes.

The government's efforts in the past regarding compensating Native Americans for their lost territory due to hydropower projects were highly insufficient. Today, many tribal members still live in the plots of land set aside by the government during the dam construction period, characterized by makeshift, overcrowded, and unsafe conditions. The government had only built fifteen houses for tribal use in the Columbia River Basin Gorge (Phillips). In 2016, however, under the Obama Administration, the United States Army Corps of Engineers developed plans to construct a Native American village in the region to create more permanent housing. Congress also passed the Water Infrastructure Improvements for the Nation Act, which gave additional financial assistance for long-displaced tribal members (Phillips).

While these legislative actions are a good start to making reparations for the historic displacement of Native Americans, they do not address the problem that poses an even greater risk to the survival of these tribes today—the disruption to salmon runs' resulting from the dams'

operations. Tribes have noted the gravity of the issue and the slow progress of the federal government in offering a solution. As a result, as of 2022, Native American tribes have been taking environmental restoration efforts into their own hands; Native American tribes like the Coeaur d'Alene, Colville, and Spokane tribes are attempting salmon restoration efforts and are doing so successfully through cultural and educational salmon releases. Their efforts have provided a harvest opportunity for salmon for the first time in 60-110 years for some areas. The tribes are employing a scientific approach to go about their salmon release process which has enabled them to collect data regarding survival, travel time, and behavior that will assist in designing future experiments (Baldwin et al.). While they have made decent progress, progress toward restoration has also come from certain past legislation. One large-scale program by the federal government that has proven effective over time in securing environmental flows and supporting freshwater biodiversity is the 2002 Columbia Basin Water Transactions Program in the Pacific Northwest. This initiative is responsible for helping restore environmental flows in dewatered tributary habitats for salmon over the past decade. One group of authors defines a four-part framework that tracks the implementation of water transactions for adaptive management as well as the impacts of this tool (McCoy et al.). To date, the Columbia Basin Water Transactions Program has restored 1.59 million megaliters of flow and completed more than 450 water rights transactions, resulting in the watering of over 2,414 stream kilometers in the Columbia River Basin (McCoy et al.). By analyzing this successful framework, it may serve as a foundation for understanding what type of approach can be used to resolve remaining conflicts attributed to dam construction and the impacts on Indigenous tribes. Furthermore, it is a useful source for understanding what ways we can quantify the impacts of policy through metrics

such as megaliters of flow restored and stream kilometers in the Columbia River Basin that are watered because of the framework.

Another means of facilitating more legislative solutions to issues like reparations for Native American displacement and the disruption to the salmon in the Columbia River Basin is to use formal and informal bridging organizations. This is important because management of rivers is often shared territory among various national and subnational governments and governmental sectors. Native American tribes are trying to assert their legal rights in the system and their view of maintaining river benefits while protecting the ecosystem. Governance mechanisms are necessary to facilitate solutions with resident groups like Native Americans; One group of authors discusses an "analytical framework focused on local capacity building and network formation across jurisdictions, sectors, and scales of governance" (Cosens et al.). Their main idea is that networked governance and bridging organizations across the hierarchy of the existing system (jurisdictions, sectors, etc.) combined with new local and indigenous governance would serve to link the various stakeholder interests (Cosens et al.).

Conclusion

Climate change and global warming are considerable threats to the Earth that impact all its inhabitants socioeconomically and environmentally. Therefore, there is no denying that measures must be taken to curtail greenhouse gas emissions. The technical project seeks to employ modern data analysis, modeling, and optimization techniques to generate hydropower operating policies in the Columbia River Basin that can shift the power grid to 100% renewable energy. If successful, this would serve as an energy solution for phasing out greenhouse gas emissions from the energy sector. Furthermore, the policies can be scaled upward and adapted to

fit other regions and countries. The problem, however, is that the implementation of hydropower in the Columbia River Basin has served to disenfranchise Native American tribes in the Pacific Northwest due to unforeseen effects on salmon populations and relocation to poor living conditions by the federal government. The STS research explores the historic dynamic from the 1930s onward between Native Americans and the federal government regarding hydropower. Furthermore, the research delves into the recent progress that has been made in the last 20 years from legislative action and Native American tribes themselves to address the issues of salmon disruption and displacement of Indigenous tribes in the Columbia River Basin. With current reparations to Native American tribes and environmental protection efforts still proving insufficient, this research can help us understand what the most promising solutions and frameworks to address these problems are going forward, likely rooted in cooperation between Native American tribes and the federal government. Ideas like mutual governance may have the most potential to streamline reparations to tribes whose way of life has suffered due to hydropower projects. There does not need to be tradeoffs to the prosperity of Indigenous tribes in the name of technological determinism and advancement. Climate change is an issue that society can address together in a mutually beneficial way through both legislative mechanisms and scientific mechanisms.

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