Adapting Hydropower Operations to Support Renewable Energy Transitions and Freshwater Sustainability

Applying the Social Construction of Technology to Study the Influence of the Media on the Adoption of Nuclear Energy in the United States

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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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Introduction: Energy Sector Risks to Climate Change

There is unequivocal evidence that Earth is warming at an unprecedented rate, and the scientific consensus is that human activity is the principal cause. The planet's average surface temperature has risen about 2 degrees Fahrenheit since the late 19th century, and the ocean has absorbed much of this increased heat, with the top 100 meters of the ocean having warmed by more than 0.6 degrees Fahrenheit since 1969. Between 1993 and 2019, Greenland and Antarctica lost an average of 279 billion and 148 billion tons of ice per year, respectively, and global sea levels have risen about 8 inches in the last century. Since 1950, the number of record high temperature events has been increasing, while the number of record low temperature events has been decreasing (Shaftel, 2022). Furthermore, the effects of human-caused global warming are only expected to worsen in the decades to come, leading to an increase in the intensity of hurricanes, more frequent droughts and heat waves, a longer wildfire season and more land consumed by wildfires overall, and an ice-free Arctic Ocean before mid-century if current projections hold (Callery, 2022). There is agreement that climate change presents immediate concerns for the global community.

The primary mechanism behind climate change is the greenhouse effect, whereby the release of aptly named greenhouse gases like carbon dioxide, methane, and nitrous oxide into the atmosphere creates an insulating layer which traps the sun's heat and increases global temperatures (European Commission, 2021). The energy sector is responsible for approximately two thirds of global CO_2 emissions, representing by far the largest source of greenhouse gas emissions (European Environmental Agency, 2021). Within the energy sector, burning fossil fuels like oil, coal, and natural gas generates 84.3% of global primary energy and is therefore a massive contributor to climate change; nuclear accounts for 4.3% of global production, and only

11.4% of the global energy demand is met by renewable sources like hydropower, wind, and solar (Ritchie et al, 2020.). According to the United Nations Economic Commission for Europe (UNECE), if the current composition of the global energy production landscape does not change and energy demands double by 2050 as forecasted, emissions will greatly surpass the amount of carbon that can be emitted if the global average temperature rise is to be limited to 2 degrees Celsius above the pre-industrial average (Foster et al., 2015), the upper limit established by the Paris Agreement in 2015 in order to prevent "large and escalating risks to human life as we know it on Earth" (Fendt, 2021).

As an energy source, hydropower uniquely facilitates a transition to renewable energy in an effort to meet global decarbonization targets. As the global energy sector shifts away from fossil fuels and the energy supply becomes more variable and out of phase with demand, the ability of hydropower plants to rapidly increase or decrease the rate at which they generate electricity will become invaluable in balancing supply and demand to allow for greater efficiency of energy usage. My technical project will examine how hydropower plant operations in the Columbia River Basin can be optimized to simultaneously support decarbonization without impacting environmental or ecological outcomes.

Adapting Hydropower Operations to Support Renewable Energy Transitions and Freshwater Sustainability

Hydropower will play an important role in meeting global carbon mitigation targets and eventually achieving net-zero carbon emissions by facilitating the integration of variable renewable energy sources such as solar, wind, and geothermal. This is especially true of the California Independent Systems Operator (CAISO) power grid and the connected Mid-Columbia (Mid-C) energy market: In California, where solar energy comprises 75.0% of its renewable energy supply, the production of renewable energy peaks during the day when sunlight is available, while peak demand does not occur until much later in the evening, creating an imbalance between the supply of renewable energy and energy demand overall (California ISO, 2022). However, hydropower combats this problem, balancing supply and demand to increase grid resiliency through its ability to quickly ramp up electricity production to meet increasing demands and even store energy in anticipation of future needs by pumping water into reservoirs at a higher elevation.

Given the importance of hydropower in integrating renewables and decreasing emissions, my technical project will center around the optimization of existing hydropower plants to better support increasing production from renewable energy sources while mitigating flood and draught risks and preventing ecological effects to native fish species and their habitat. The project will focus on hydropower operations in the Columbia River Basin in the Pacific Northwest. With 31 federal dams that provide 65% of the Mid-C energy market's power and over 55.3 million acre-feet of storage for flood protection, this region meets all criteria to examine the effects of various changes to hydropower operations.

Several models as well as a complex optimization algorithm will be utilized in order to derive a hydropower-based solution to build towards complete decarbonization in the Columbia River Basin. A reservoir simulation model inputs relevant climate data to quantify the environmental impacts of the resulting water flows from one reservoir to another within the hydropower system. A California and West Coast Power (CAPOW) model inputs energy demands, exports, and imports as well as hydropower, solar, and wind production to produce energy prices in the CAISO and MID-C energy markets. The outputs from each of these models are combined within an optimization algorithm to minimize negative environmental outcomes while maximizing energy generation and integration between each of the two markets.

The aforementioned models and optimization algorithm will be run repeatedly under a variety of climate and energy pathways. The various climate pathways represent possible future scenarios in which climate patterns are altered to varying degrees due to global warming, while the various energy pathways account for uncertainty in how the composition of the energy sector will change in the future in pursuit of complete decarbonization. In doing so, an optimal policy of hydropower operations will be identified according to not only an optimized tradeoff between electricity generation and environmental impacts, but also its resilience to future uncertainty from changes in climate patterns and the energy mix.

The Influence of the Media on the Adoption of Nuclear Energy in the United States

While hydropower accounts for 6.1% of US energy, nuclear energy provides another 18.9% of the nation's energy. A single nuclear reactor produces enough energy to power 100 million LED light bulbs, equivalent to the production of more than three million photovoltaic panels, while remaining a completely carbon-free energy source (Office of Nuclear Energy, 2021). Indeed, in 2021, the United States avoided more than 476 million metric tons of carbon dioxide emissions by producing clean energy from nuclear power plants across the country (Nuclear Energy Institute, 2022). Nuclear energy is also much safer than fossil fuels, causing only 0.03 deaths per terawatt-hour of electricity generated compared to 32.72 for brown coal, 26.42 for coal, and 18.43 for oil (Ritchie, 2020). For these reasons, the Atomic Energy Commission once anticipated that more than 1,000 reactors would be operating in the United States by the year 2000 (U.S. Congress, 2007). However, despite its seemingly undeniable benefits, only 92 commercial reactors currently operate in the United States, accounting for just 18.9% of U.S. energy production today (Office of Nuclear Energy, 2022). In an effort to build towards the vast amounts of carbon-free energy that the world will need in order to stave off climate change, my senior thesis will investigate this dichotomy between the superior utility of nuclear power understood by the scientific community and its low level of adoption in the United States. Specifically, I aim to determine the extent to which media coverage of nuclear disasters has shaped the public perception of nuclear technology in the U.S. and affected the decisions and regulations which limit the adoption of nuclear energy today.

In order to identify the potential role of the media in the low penetration of nuclear energy in the US, I will apply the framework of the Social Construction of Technology to analyze how human action taken by various social groups, particularly journalists and anti-nuclear protesters, has affected the development of nuclear power as a socio-technical system. Generating a social constructivist account of nuclear power in this way relies upon a multidirectional model which defines the developmental process of a technological artifact as an alternation of variation and selection. Both phenomena are driven by the concept of *interpretive flexibility*, in which the different perceptions of a technology by various social groups create different problems to be solved and distinct prioritizations of tradeoffs in the design of solutions to combat those problems. Therefore, in order to understand the primary drivers behind the acceptance and rejection of nuclear energy throughout its history in the United States, my senior thesis will examine the various interpretations of nuclear reactor technology by social groups such as the media and anti-nuclear activists. In particular, I will analyze how the differing prioritizations by these social groups of the tradeoffs between financial, environmental, safety, and climate concerns has influenced what constitutes of a superior energy-production technology over the course of the development of nuclear energy in the United States. I will also investigate the extent to which negative media coverage of nuclear disasters has collapsed the interpretive flexibility of nuclear technology by aligning public opinion against the adoption of nuclear power.

Research Question and Methods

My research will assess, quantify, and describe the influence of media coverage of nuclear disasters on the adoption of nuclear power in the United States using the case studies of the Three Mile Island, Chernobyl, and Fukushima nuclear disasters. These particular disasters were selected as candidates for analysis due to their inextricable connection to nuclear adoption in the United States: Three Mile Island took place in the U.S. and was a significant turning point in the global development of nuclear power, Chernobyl is the deadliest nuclear disaster in history and "broadened the opposition to nuclear power" (International Atomic Energy Agency, 2004, p. 7), and Fukushima is the most recent deadly nuclear disaster, allowing for better analysis of nuclear adoption in the present day.

In order to analyze my research topic, I will conduct a literature review of these prior case studies on the social effects of nuclear disasters as well as examining counts of anti-nuclear protests in the United States throughout the development of nuclear reactor technology. In the literature review, key findings from journal articles such as "Media, fear, and nuclear energy," which conducts a content analysis of newspaper headlines and connects negative public perception to energy policy decisions, will be provided to determine how media coverage of nuclear disasters has affected the public opinion towards the technology and in turn its adoption. Similar articles can be found in journals such as *Organization & Environment*, *Energy Policy*, and *Public Understanding of Science*, and *The Social Science Journal*. Finally, counting anti-nuclear protests in the periods before and after a nuclear disaster and utilizing the frequency of anti-nuclear protests as a proxy for public sentiment towards nuclear energy will allow me to find the correlation between nuclear disasters and the negative perception of nuclear power.

Conclusion: Hydropower, Nuclear Energy, and Climate Change

The Earth is currently experiencing climate change at an unprecedented rate as a result of increasing greenhouse gas emissions from the energy sector which are overwhelmingly produced through the burning of fossil fuels. With the environmental effects of climate change only expected to worsen in the coming years as energy demands increase, the need to transition to low- and zero-carbon sources is greater now than ever, and both hydropower and nuclear energy will be instrumental in this change. Hydropower supports the transition to renewable energy by supplementing the energy supply of variable sources like solar by quickly ramping up production to meet additional demands. Nuclear energy, on the other hand, provides tremendous upside in terms of energy production compared to renewable sources while being completely carbon-free and much safer than fossil fuels. My senior thesis will determine the role that the media has played in the low adoption of nuclear energy in the United States despite its seemingly apparent benefits.

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