Re-designing reservoir operations for a decarbonizing grid under climate change

Samarth Singh[1,3], Julianne Quinn[1], Jacob Wessel[2], Jonathan Herman[3], Jordan Kern[4], Rosa Cuppari[5], Greg Characklis[5]*

[1]*Civil and Environmental Engineering, University of Virginia*
[2]*Princeton University*
[3]*Civil and Environmental Engineering, UC Davis*
[4]*Department of Forestry and Environmental Resources, NCSU*
[5]*Environmental Sciences and Engineering, University of North Carolina*

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***Abstract*:**

Hydropower systems are increasingly exposed to two converging pressures: climate-driven changes in hydrology and the rapid integration of variable renewable energy (VRE) into electricity markets. Historically, reservoir operations were developed under assumptions of climatic stationarity and a primarily fossil-based grid, assumptions that no longer hold in today's evolving conditions. To maintain satisfactory performance of both the water and energy system, operating policies must adapt to ensure robustness across diverse climate and energy futures.

This work evaluates how alternative multi-objective reservoir operating policies perform under 2050 climate and energy system scenarios in the Columbia River Basin. Policies are assessed across key metrics-- hydropower generation, flood risk, system revenue, and fossil fuel displacement-- revealing which strategies generalize well under deeply uncertain conditions. Sensitivity analysis and scenario discovery methods are used to identify the climatic and energy drivers most critical to policy vulnerability and effectiveness.

The results show that robust policies improve tradeoffs by seasonally adjusting the use of inflow forecasts, reservoir storage, and energy market signals to better align hydropower operations with both hydrologic regimes and renewable energy variability. These insights support the development of resilient, transferable water-energy strategies for managing complex multi-objective systems in a decarbonizing grid.

Contact Information for Presenting Author: *samsi@ucdavis.edu*