

Projecting Future Colorado River Basin Water and Hydropower Operations

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Colorado River Basin (CRB) and the Grid

- CRB water resources are managed for multiple purposes
- Federal hydropower capacity 4200MW located at the two largest artificial reservoirs and other dams
- Federal hydropower sold through firm electric contracts (FES) to millions of electricity consumers
- Drought, Variable Renewable Energy (VRE) resources, and power markets can impact hydropower operation



Fig 2. Map of Reliability Coordinator areas in the Western Interconnection footprint.

Fig 1. Map of the Upper and Lower Colorado River Basin¹

Power system and hydrology interactions

- Bureau (water management), WAPA (hydropower scheduling) and FES customers are all involved in CRB operation planning.
- WAPA FES contracts give customers a wide degree of scheduling flexibility
- Hydropower scheduling and operation are informed by several factors
- Study focus on how drought, power grid VRE share, and power markets may impact on CRB hydropower operation and economics

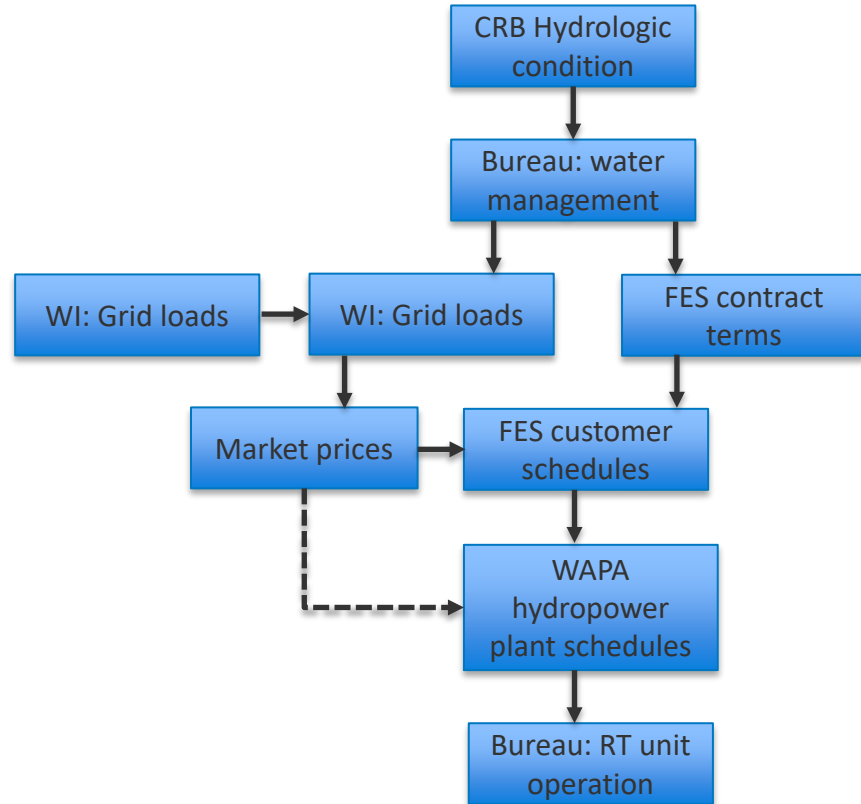


Fig 3. CRB water and hydropower operation planning process

Changing power grid and variable hydrologic conditions

Four combinations of power grid and water release conditions are used to represent the full Western Interconnection (WI)

No	Description	VRE (PV + wind) share
1	Base VRE-normal hydropower condition	26%
2	Base VRE-dry hydropower condition	26%
3	High VRE-normal hydropower condition	51%
4	High VRE-dry hydropower condition	51%

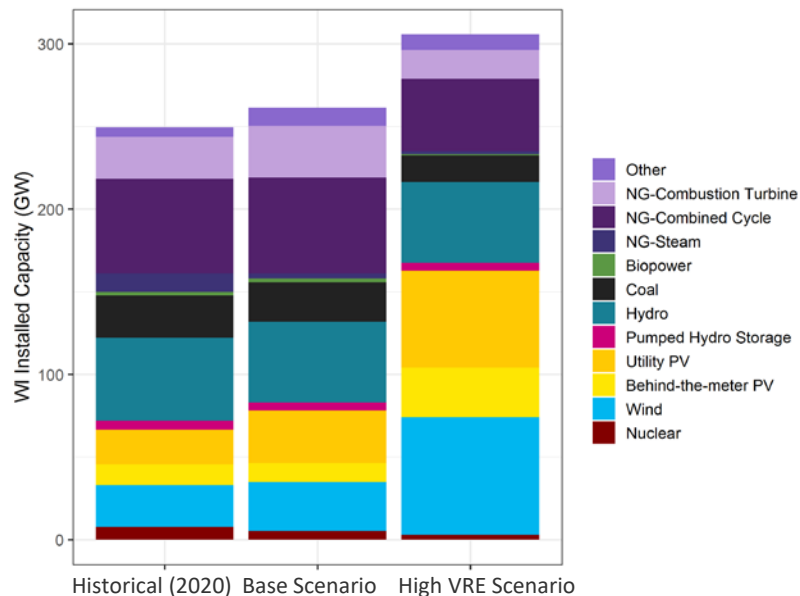


Fig 4. Historical and future WI capacity supply stacks by energy type

Methods

- Analyze an ensemble of CRB hydrology and hydropower futures
- Select two representative hydropower conditions from the ensemble for detailed analysis
- Create VRE scenarios
- Construct FES customer contract terms by locations
- Simulate WI day ahead scheduling at the bus levels to compute DA Locational Market Prices and simulate customer DA request
- Perform detailed CRB water and power operations and
- Compute and compare scenario operations and economics

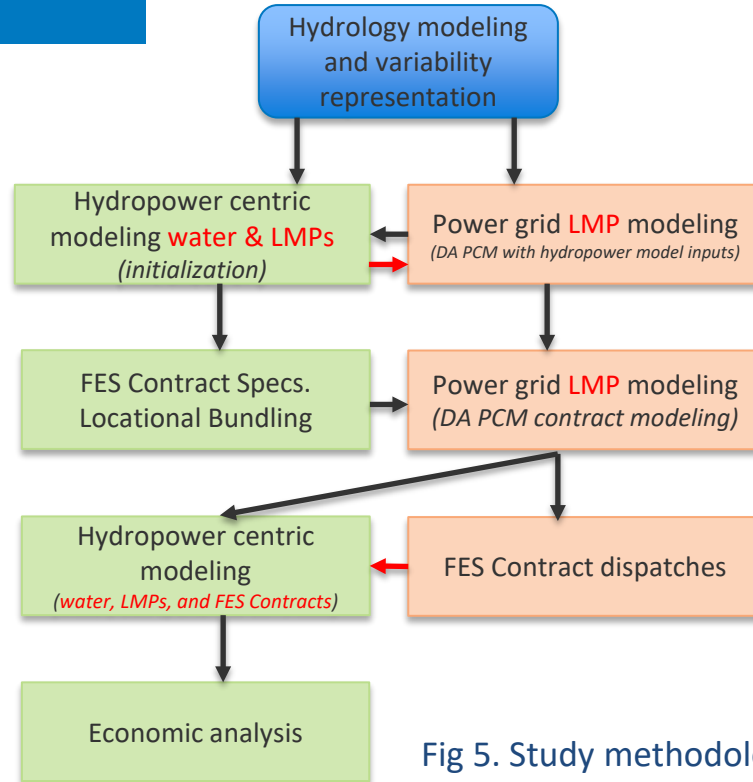


Fig 5. Study methodology for CRB water and hydropower operation planning

Methods

- Western interconnection is simulated using a production cost model, PLEXOS.
 - Production cost models optimize the scheduling and dispatch of all WI power plants including hydropower limited energy (water) constraints
- Reservoir operation for hydropower optimization is carried out using water centric tool, GTmax SL for given monthly water release volumes as specified under a hydropower condition (ensemble selections)

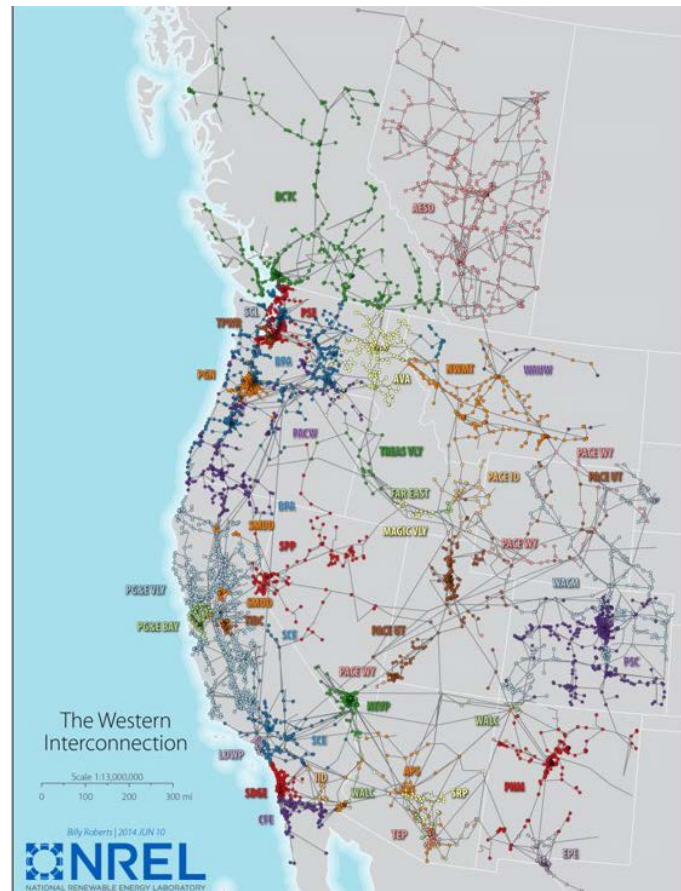
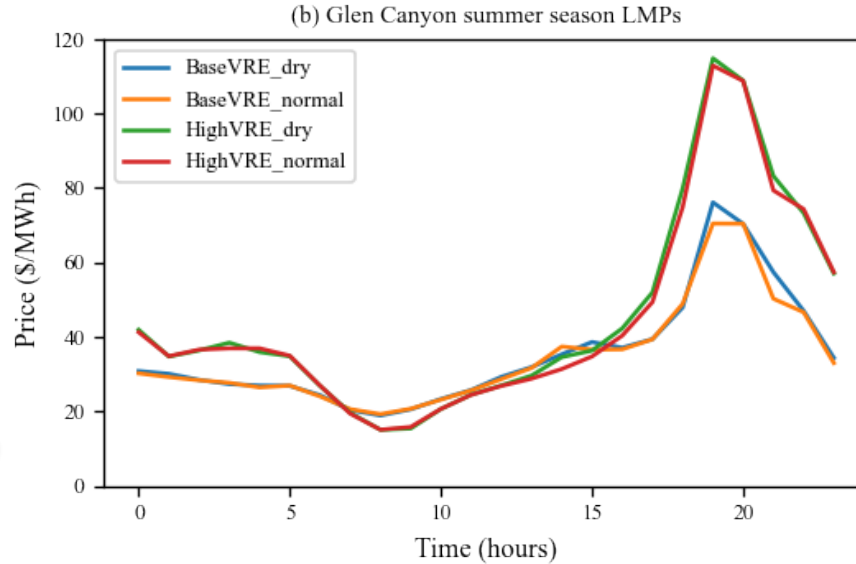
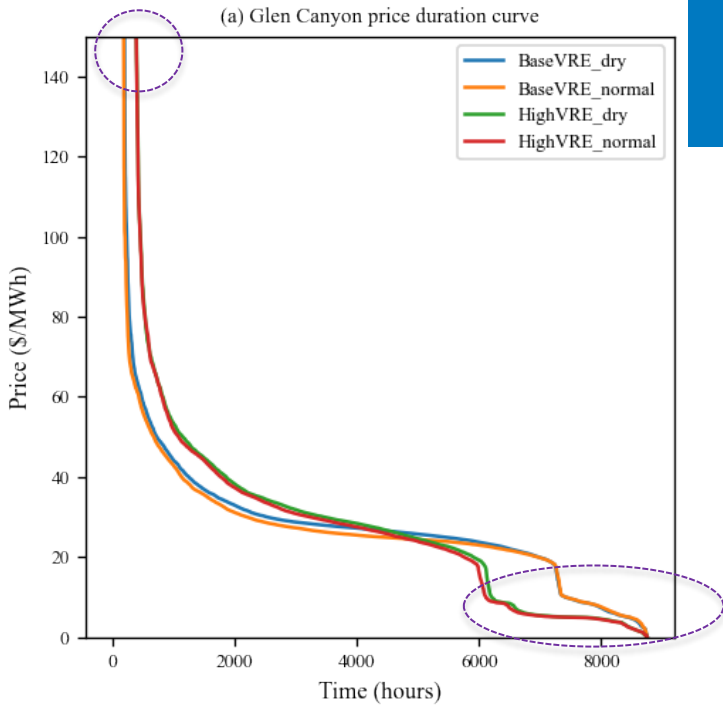


Fig 6. Western interconnection power grid map

Power grid prices and hydropower



LMP:
Local
Marginal
Prices

Fig 7. (a) Glen Canyon LMP duration curves and (b) Glen Canyon summer average diurnal LMP shapes

- Price duration curve indicate higher high and lower price hours for high VRE contribution grid scenarios
- In the future power system, the hourly electricity prices follow “duck curve.”
- Hydropower dispatch follows netload and prices.

FES contract scheduling

- Requests for WAPA customer energy delivered under FES contracts are primarily driven by LMPs
- Contracts delivery requests are steeply ramping in the morning and evening inversely to VRE production profiles (primarily solar)
- These future modeled profiles differ from historical shapes (e.g., 5 years ago), but we have observed that FES requests are evolving toward the model shape

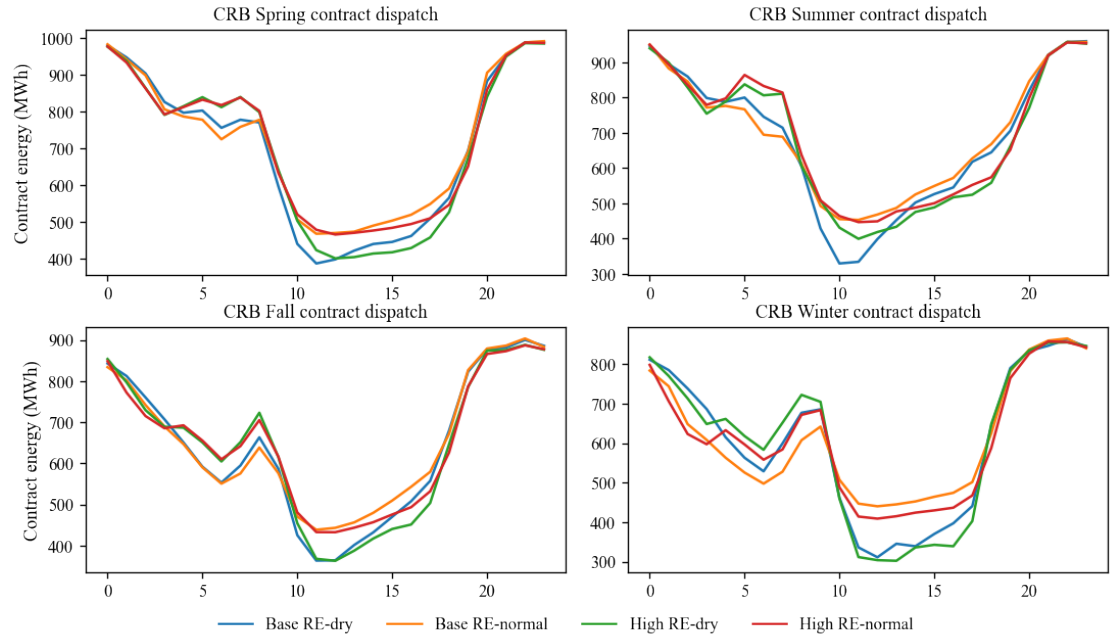


Fig 8. PLEXOS simulation of WAPA FES contract requests vary seasonal as driven by grid supply/demand and hydropower condition

FES contract scheduling

- Hydropower contracts and hydropower generation have differences
- Winter and spring months have higher hydropower and contract shortage – which must be met by other generation sources on the market
- WAPA purchases energy difference from the power market
- Currently, details of economics and financial implications will be determined

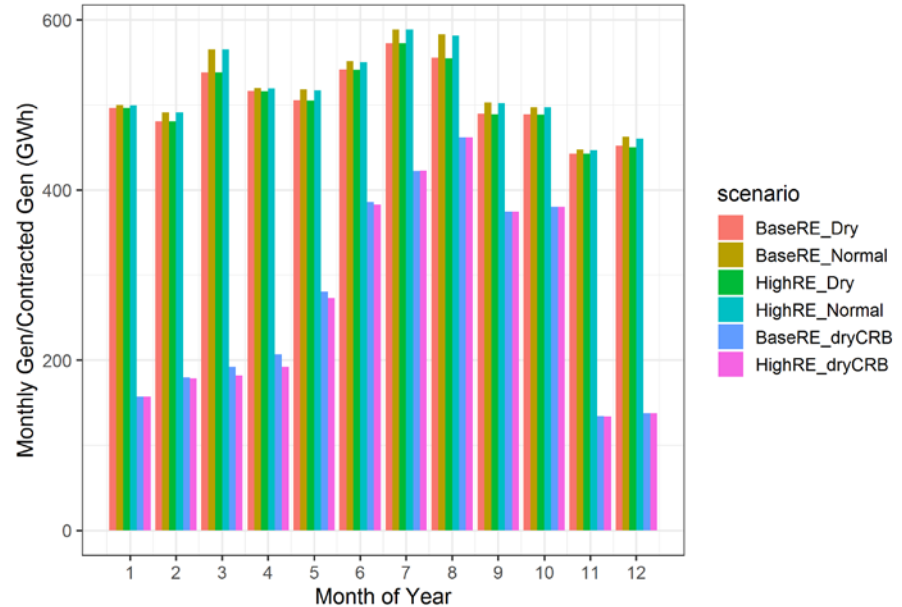


Fig 9. Colorado (CRB) hydropower contracts and hydropower generation monthly values across scenarios.

Summary

- Drought, VRE, FES contract terms and power markets impact hydropower operations
- Power grid net load and prices follow the “duck curve” shape in high VRE contribution scenarios due to PV
- These changes will impact WAPA hydropower FES energy delivery obligations
- Hydropower operation under drought needs to be studied in detail

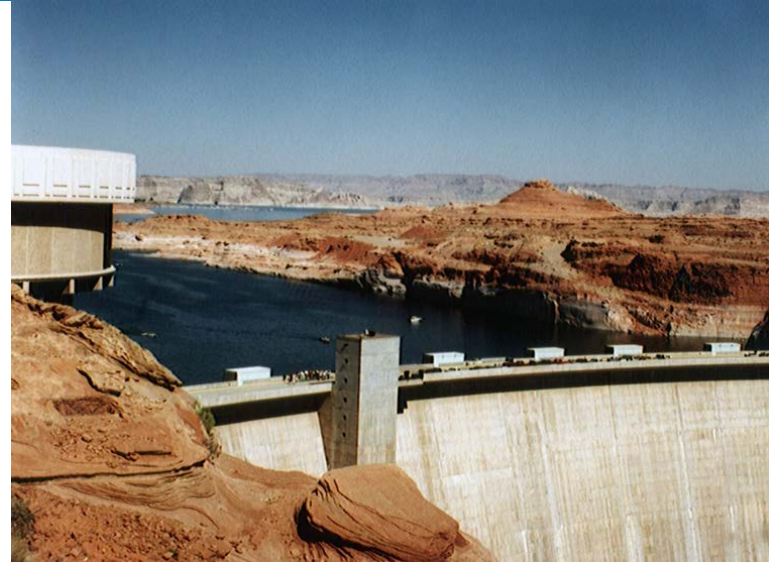


Fig 10. Glen Canyon dam, Lake Powell

Q&A

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