Impact of Glen Canyon Generation Loss

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Study Motivation

- The Western United States, including the Colorado River Basin, is experiencing a historic drought
- Ongoing drought can impact the water levels at reservoirs, such as Lake Powell, which feeds Glen Canyon Dam (GCD) and can impact downstream ecosystems
- **This study aims to understand the consequences of the loss of power generation at GCD**

Impact of Loss of Glen Canyon Generation

Research questions

- What will be the impacts to the electricity system for different level reductions in GCD energy and capacity?
- What are alternative resources to provide energy and reserves to support grid reliability?
- Will there be sufficient transmission grid capacity to federal delivery points?
- Will there be an increased risk of load interruptions?

Upper Colorado River Basin (CRB)

- CRB water resources are managed for multiple purposes
- Federal hydropower capacity of 1,827 MW from artificial reservoirs and dams

Upper Basin:
Colorado River Storage project (CRSP) power marketed by WAPA Salt Lake City/Montrose Offices

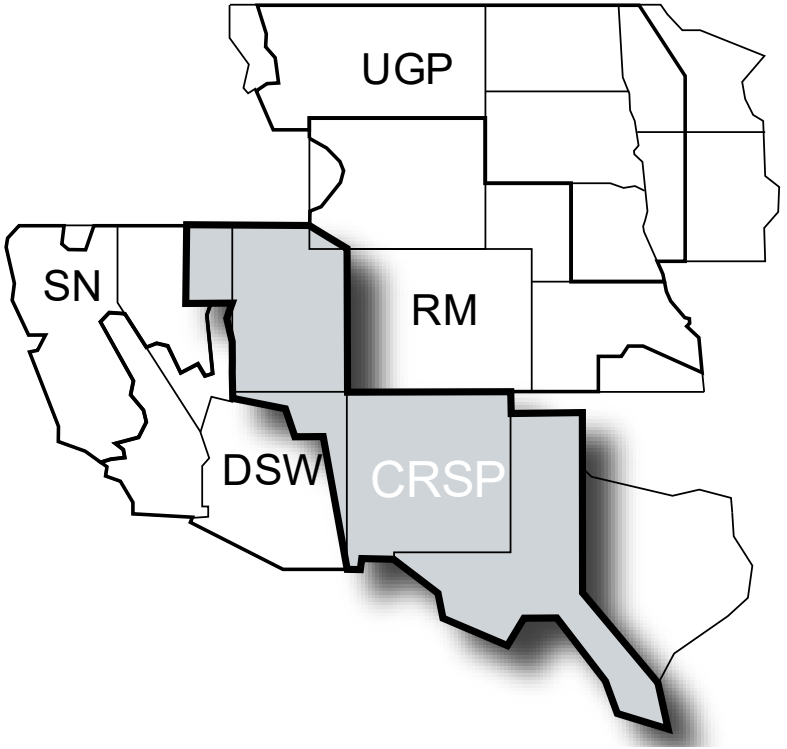
- Glen Canyon
- Blue Mesa
- Morrow Point
- Crystal
- Flaming Gorge
- Fontenelle
- Other small hydro

Ref: (1) https://www.wapa.gov/wp-content/uploads/2023/11/22-StatisticalAppendix-.pdf; (2) https://d9-wret.s3.us-west-2.amazonaws.com/assets/palladium/production/s3fs-public/thumbnails/image/coloradoriverbasinviausgs_0.png

Colorado River Storage Project (CRSP)

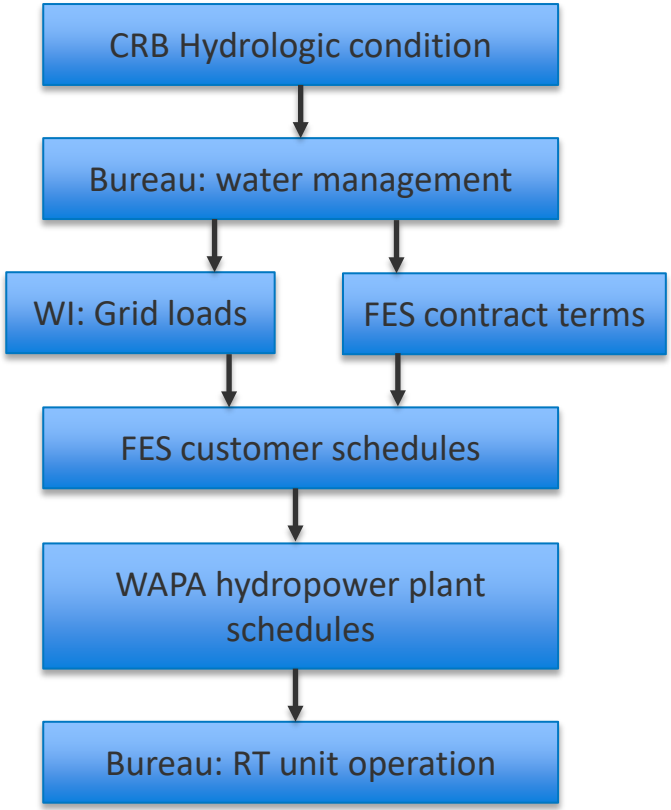
A Western Area Power Administration Management Center

- WAPA: one of the four power marketing administrations within DOE, Market hydropower generated by federal dams (Reclamation, Army Corps)
- CRSP: one of WAPA's five regions
- Federal hydropower is sold through firm electric service (FES) contracts to preference power utility customers that provide electricity to millions of end-use customers
- Historically, CRSP office delivered FES customers a base amount of ~5,300 GWh of energy annually
- Additionally, CRSP participates in market transactions and buys/delivers energy to FES customers on cost pass-through basis
- More recently, CRSP has linked FES energy deliveries to seasonal projections of CRSP hydropower production, typically resulting in base annual deliveries of less than 5,300 GWh



Current Power System and Hydrology Business Processes

- 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

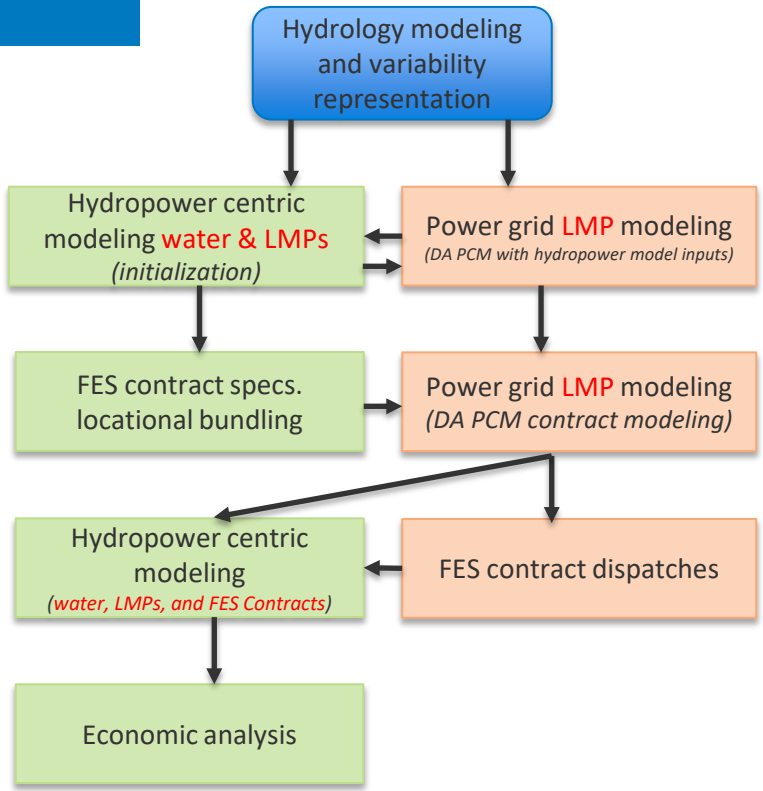


CRB water and hydropower operation planning process

Ref: Thushara De Silva, Thomas Veselka, Jennie Jorgenson, et al. "Projecting Future Colorado River Basin Water and Hydropower Operations" AGU 2022, https://www.osti.gov/biblio/1908951

Methods

- Analyze an ensemble of CRB hydrology and hydropower futures
- Select multiple representative hydropower conditions from the ensemble for detailed analysis
- Create VRE scenarios
- Simulate WI day ahead scheduling at the bus levels to compute DA Locational Market Prices (LMPs)
- *Input FES customer contract terms by locations*
- *Optimizing customer DA request in WI and get customer scheduling and LMP*

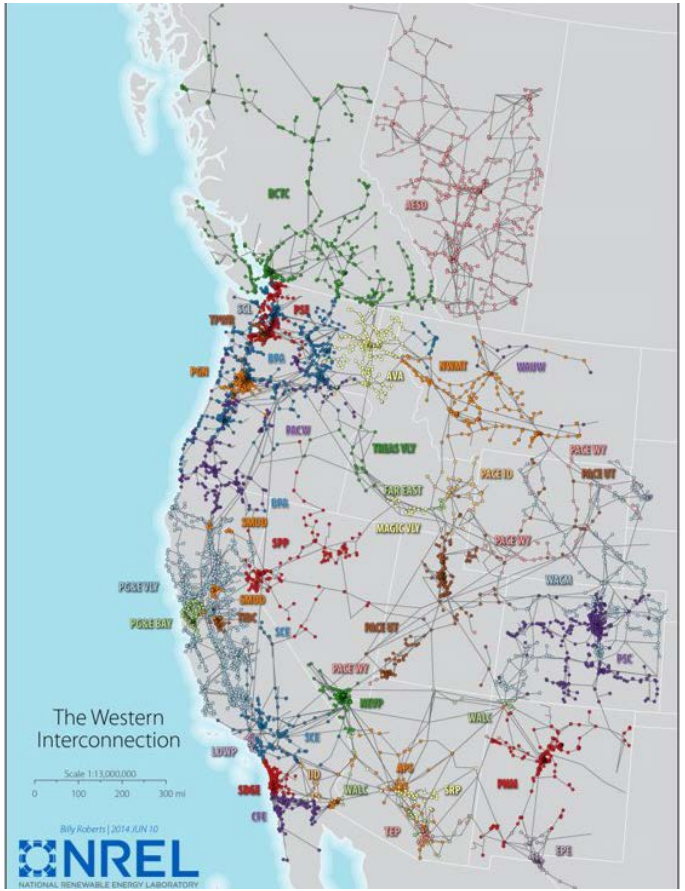


Study methodology for CRB water and hydropower operation planning

Ref: Thushara De Silva, Thomas Veselka, Jennie Jorgenson, et al. "Projecting Future Colorado River Basin Water and Hydropower Operations" AGU 2022, https://www.osti.gov/biblio/1908951

Methods

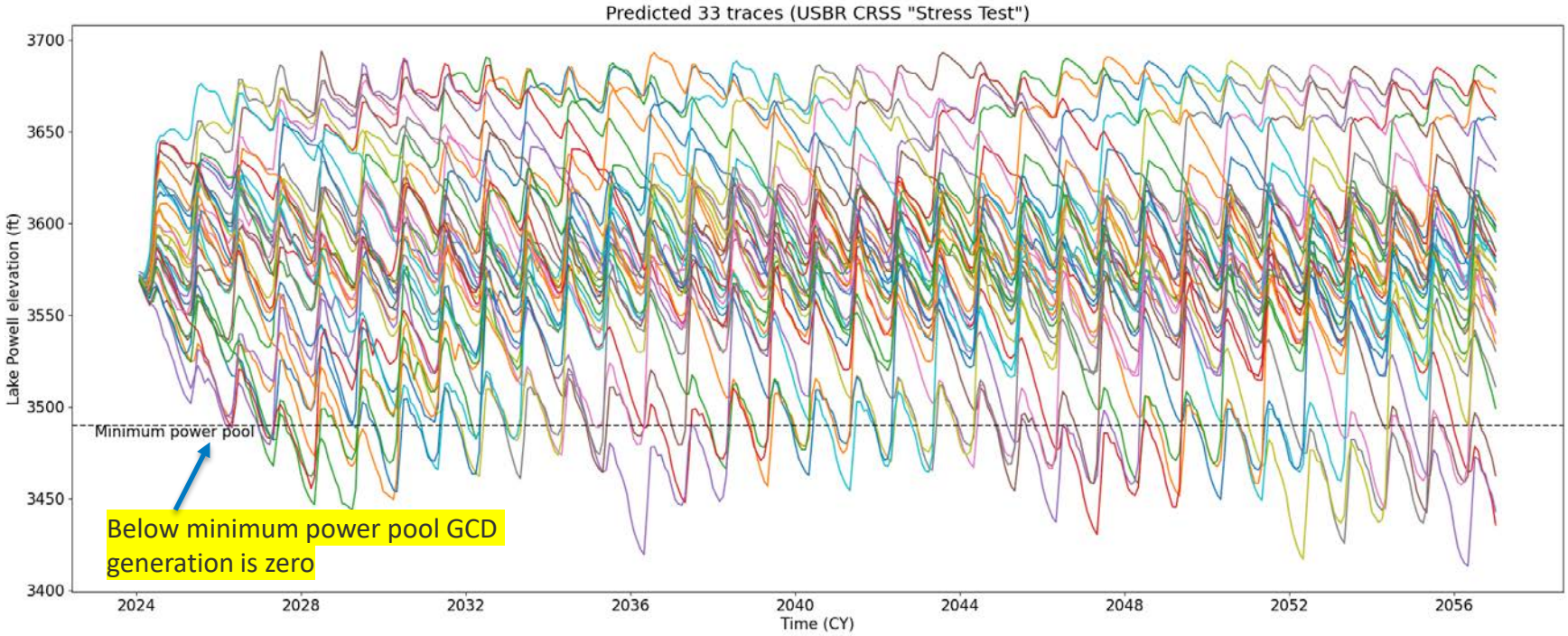
- Western interconnection power system is simulated using a production cost model (PCM), PLEXOS. PLEXOS determines:
  - Use of bulk transmission system
  - Unit commitment and economic dispatch of all generators in the footprint
  - Locational marginal price (LMP) calculations at each node
- Hydro scheduler “GTMaxSL”/”CRiSPPy” (ANL):
  - CRSP hydropower generation
  - Determine CRSP market transaction



Western interconnection power grid map

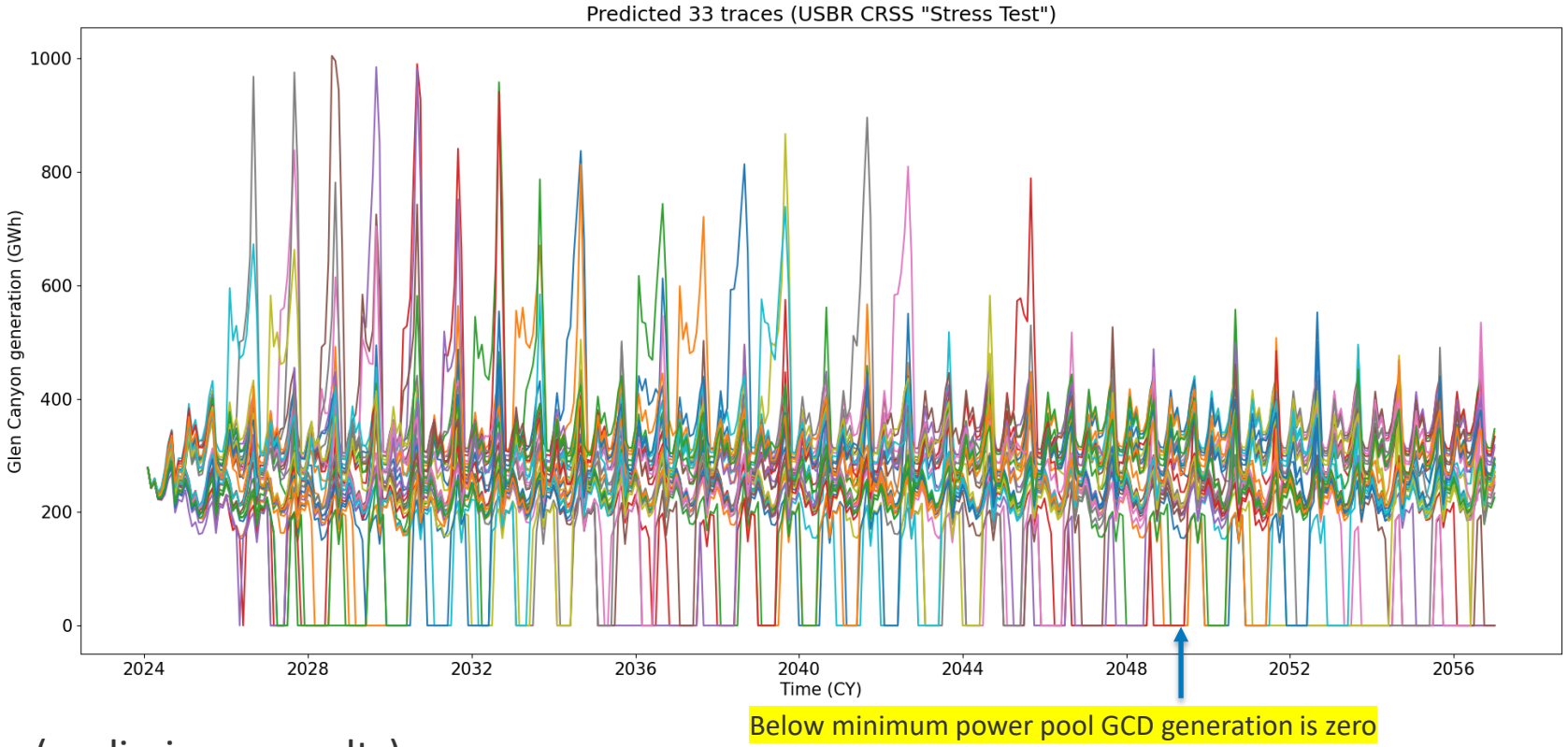
Lake Powell Reservoir Elevation for 33 Hydrology Traces

Ensemble of Lake Powell Reservoir elevation projections (end-of-month)



(preliminary results)

Glen Canyon Dam Generation for 33 Hydrology Traces



(preliminary results)

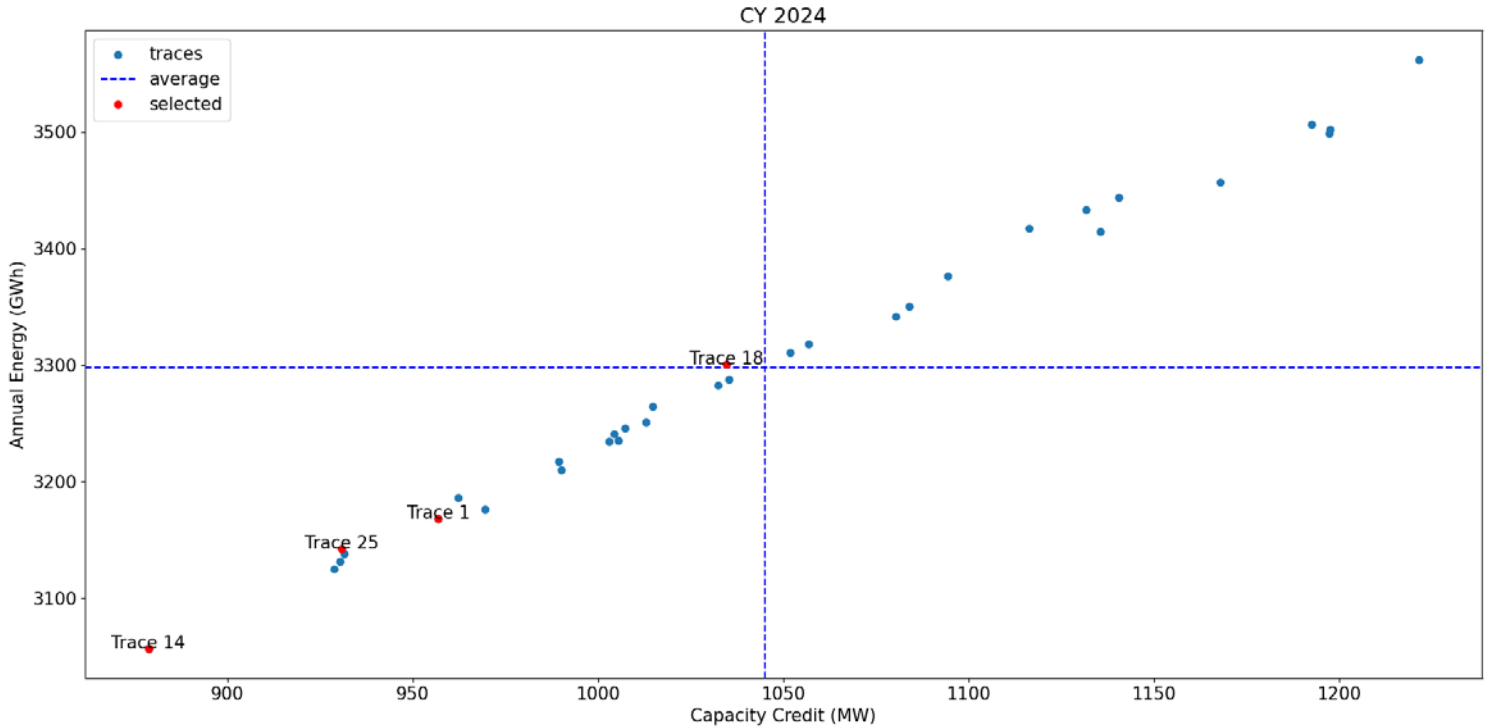
Capacity Credit of GCD

Definition

- We use the concept of capacity credit for the purpose of selecting hydrologically traces/conditions that are of interest
- Capacity Credit is an estimate of the maximum physical output of GCD based on Lake Powell's Reservoir elevation level

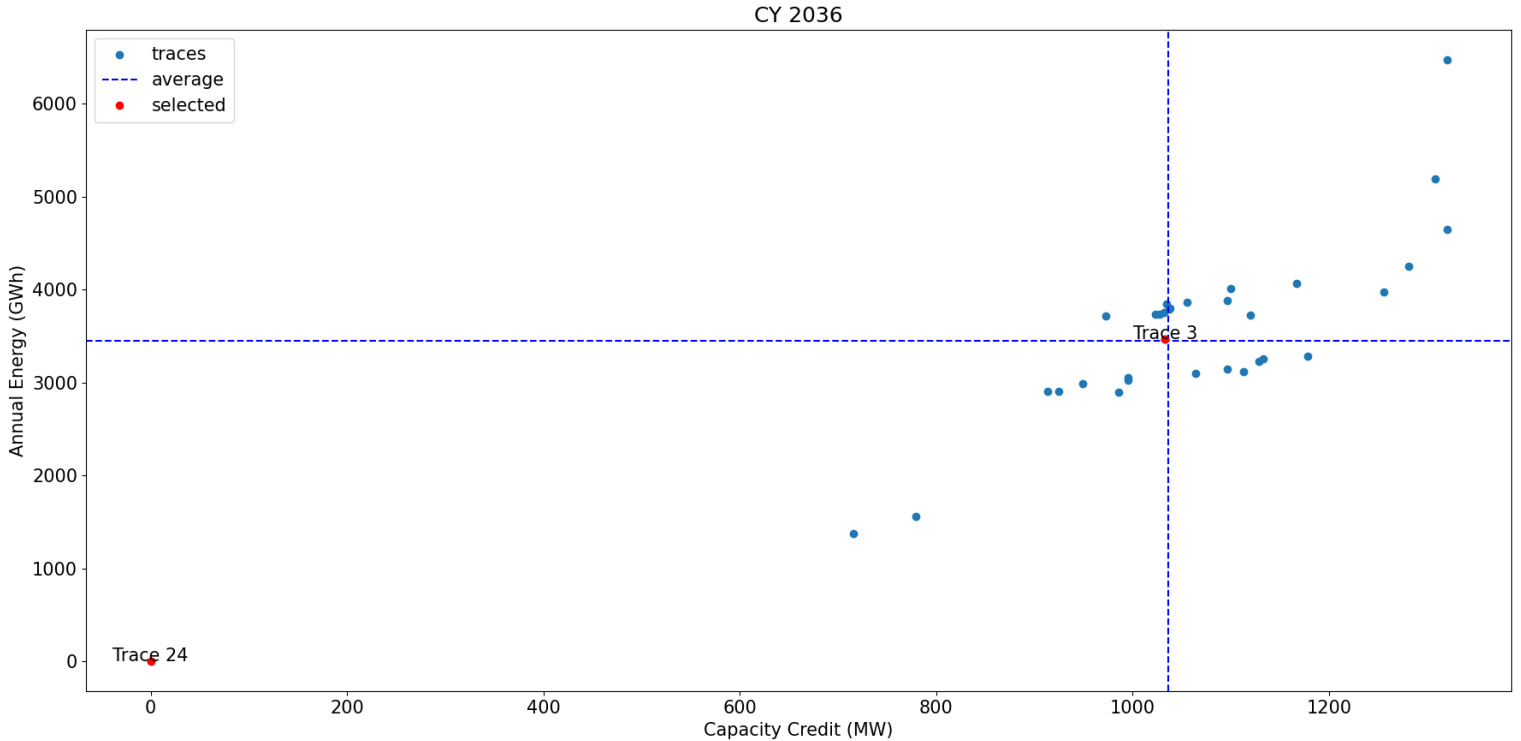
  Capacity credit estimates **exclude** the impacts of environmental operating criteria that has historically changed in the past and it is expected to change in the future
- This quantity is used to select representative average and worst traces
- Representative traces are selected by plotting them on a 2-dimensional space: annual energy generated, and capacity credit
- Although future changes are expected, future operating criteria are currently unknown. Therefore, we used current operating criteria in all other aspects of this analysis

Selected Hydrology Traces (CY 2024)



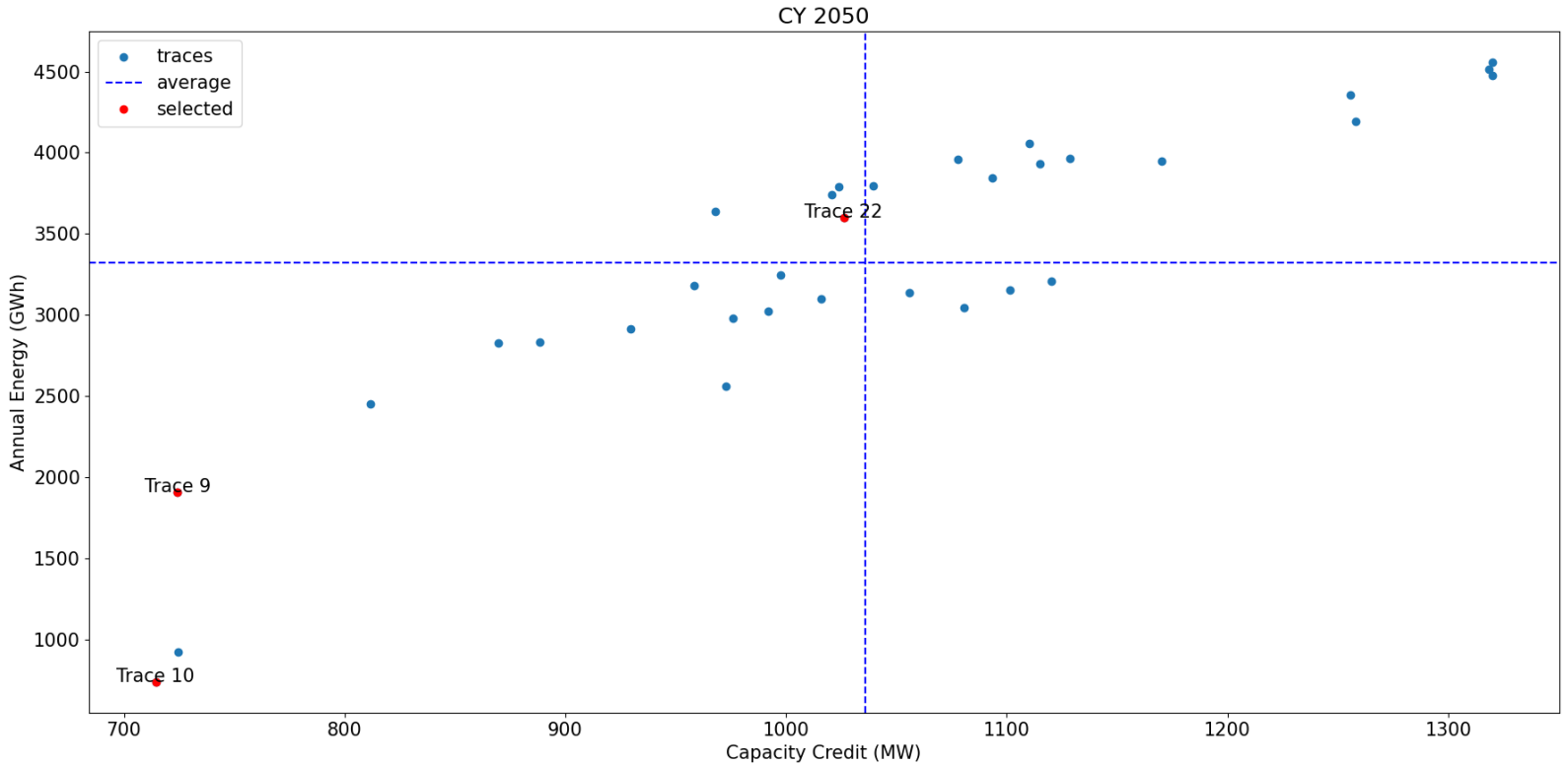
(preliminary results)

Selected Hydrology Traces (CY 2036)



(preliminary results)

Selected Hydrology Traces (CY 2050)

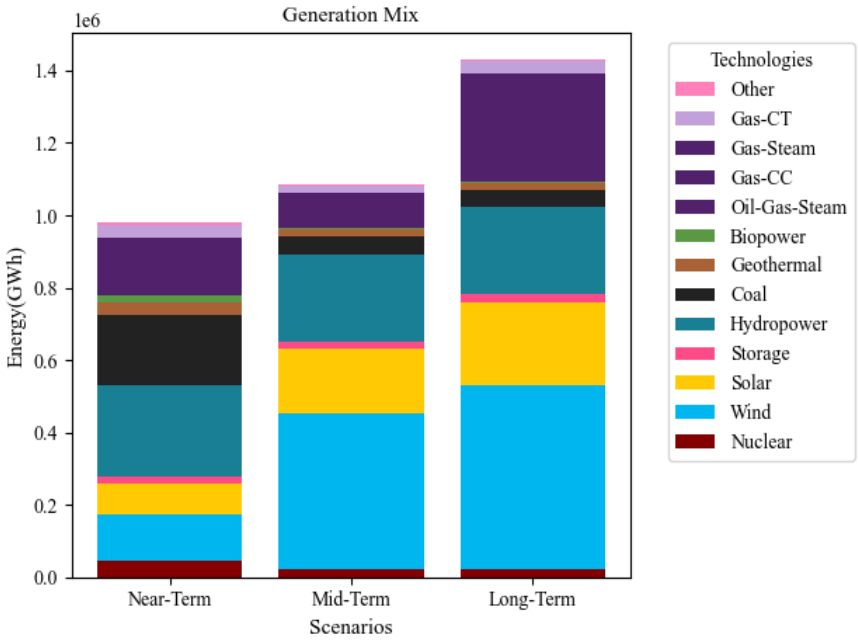


(preliminary results)

Changing power grid and hydrologic conditions

No	Description	VRE (PV + wind) share
1	Historical	20%
2	Near-term grid (Hydrology traces 3)	26%
3	Mid-term (Hydrology traces 3)	51%
4	Long-term (Hydrology traces 3)	51%

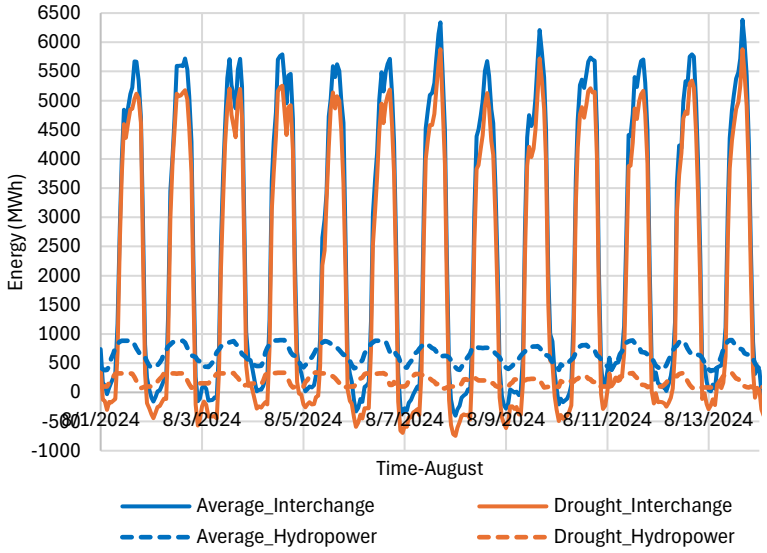
Multiple combinations of power grid and hydrology traces are used to represent the full Western Interconnection (WI)



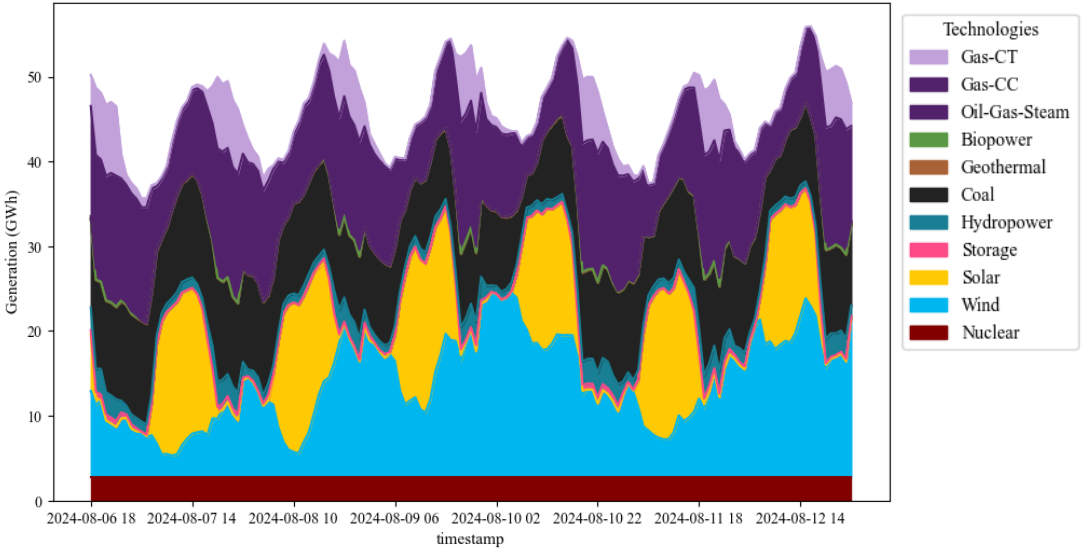
Western Interconnection generation mix by energy type (preliminary results)

Ref: Thushara De Silva, Thomas Veselka, Jennie Jorgenson, et al. "Projecting Future Colorado River Basin Water and Hydropower Operations" AGU 2022, https://www.osti.gov/biblio/1908951

CRSP Hydropower Generation Variation Impacts



CRSP hydropower and BA's energy interchange for midterm grid scenario



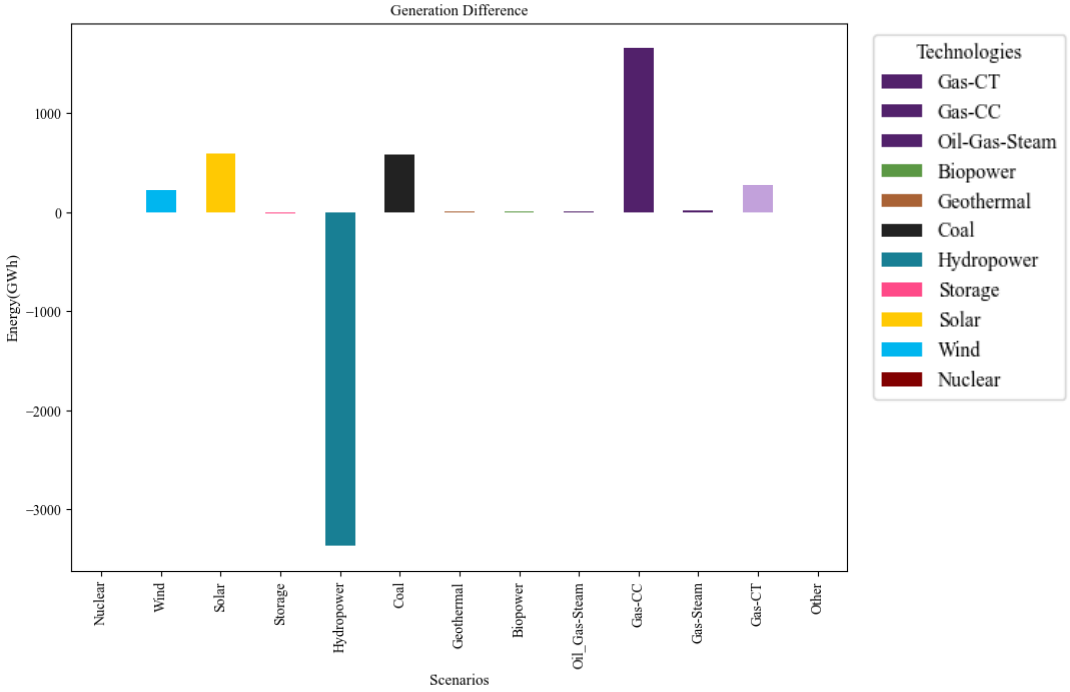
Focus regions' generators dispatch, August midterm grid scenario

- Balancing authority, where GCD located, is a net exporter majority of time. Exporting energy reduces for dry hydropower conditions
- Regional generator dispatches change according to loss of Glen Canyon energy

(preliminary results)

Which Technologies Made Up the GCD Loss?

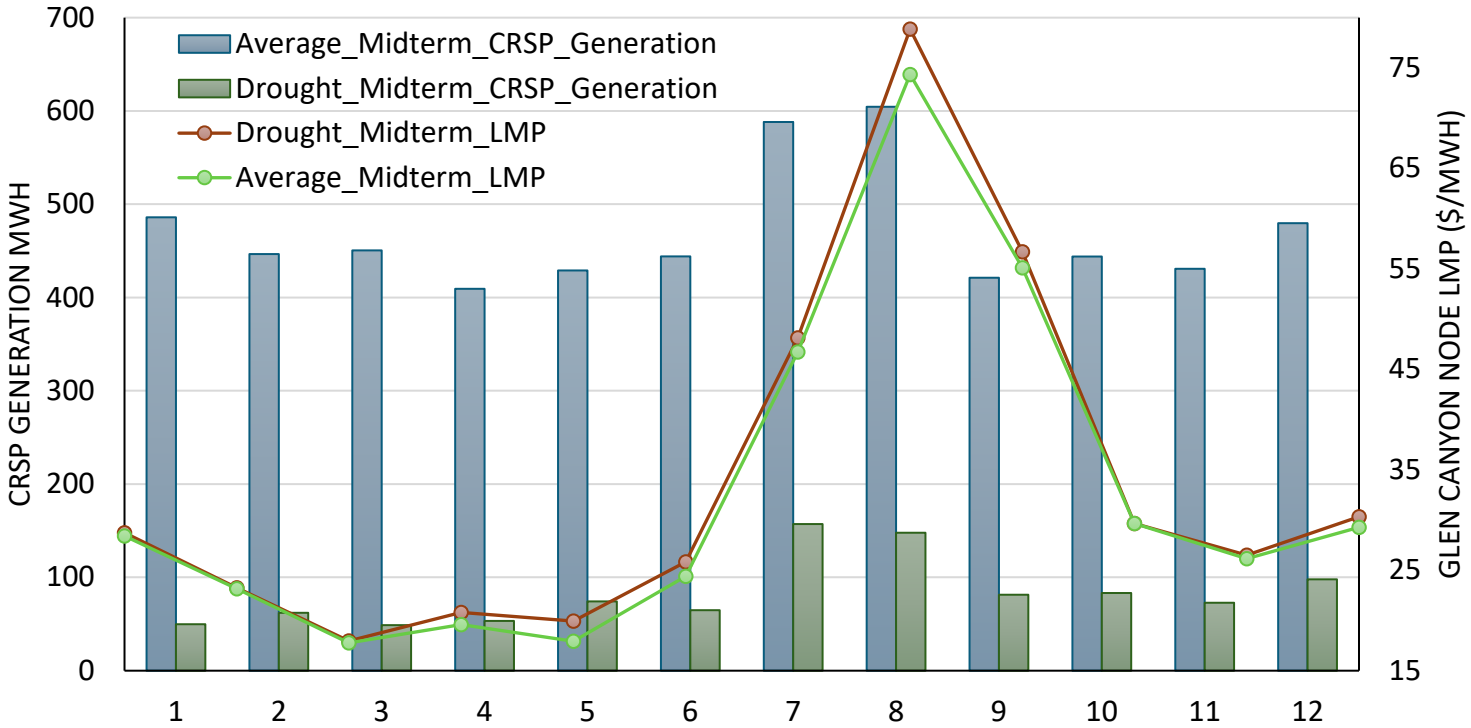
Generation Technology	Drought_2036 (GWh)	Average_2036 (GWh)	Difference (GWh)
Nuclear	23330	23330	0
Wind	428450	428225	225
Solar	180110	179520	590
Storage	20480	20500	20
Hydropower	239800	243200	-3400
Coal	50450	49850	600
Geothermal	17590	17580	10
Biopower	5760	5750	10
Oil-Gas-Steam	1670	1660	10
Gas-Steam	92960	91310	1650
Gas-CC	660	645	15
Gas-CT	20410	20140	270
Other	4330	4330	0



- GCD loss generation come from natural gas, coal, previously curtailed wind and solar energy

(preliminary results)

Hydrology Scenarios and Prices



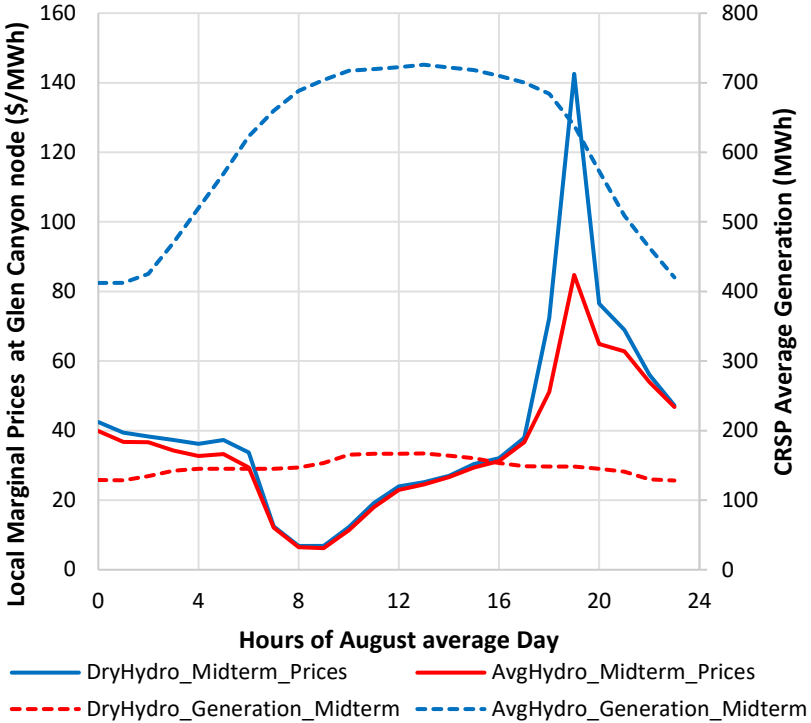
- Glen Canyon node's LMPs increases as Glen Canyon generation loss
- Prices are higher in summer and August is a critical month without Glen Canyon

(preliminary results)

Glen Canyon Generation and Prices

- Two hydrologic scenarios simulated in Midterm grid scenario show generation and prices differences
- Higher energy prices and price differences are noted in summer months for CRSP hydropower generation in Midterm grid scenarios
- Evening peak's expensive thermal generators (combustion turbines) increases LMPs

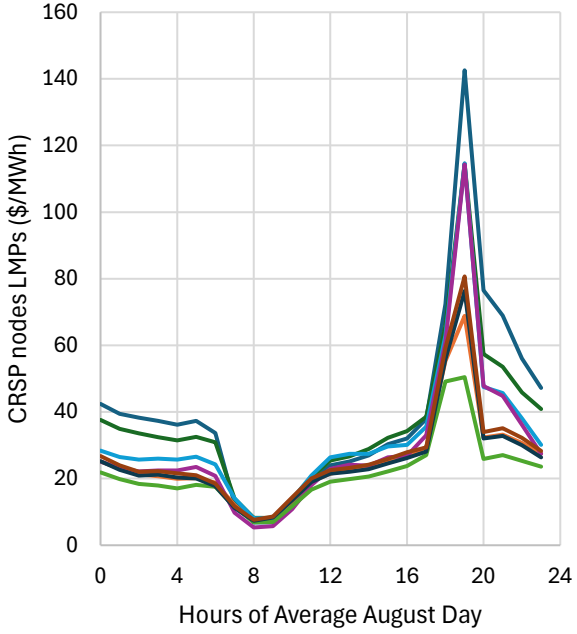
(preliminary results)



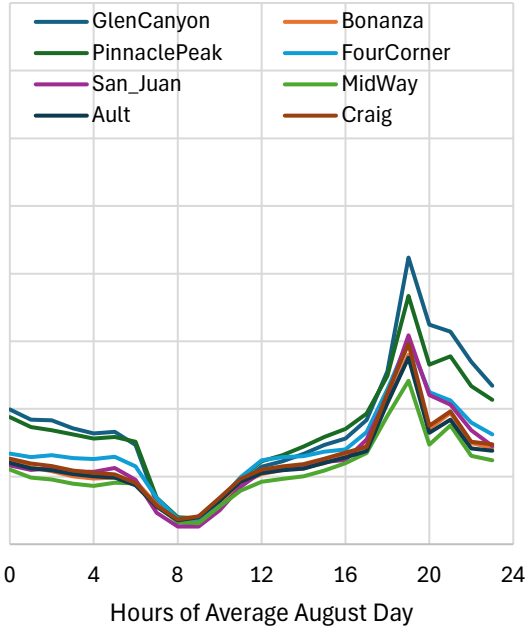
Glen canyon and other CRSP generation and price variation Midterm grid Scenario

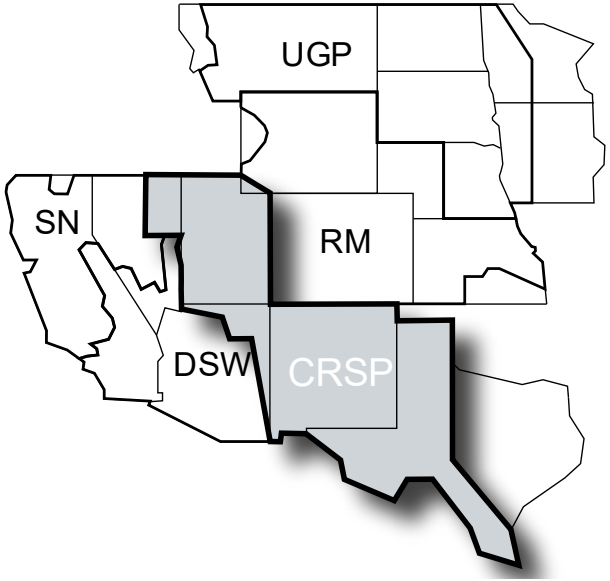
WAPA CRSP project Price changes

Dry hydrology & Midterm grid



Avg hydrology and Midterm grid



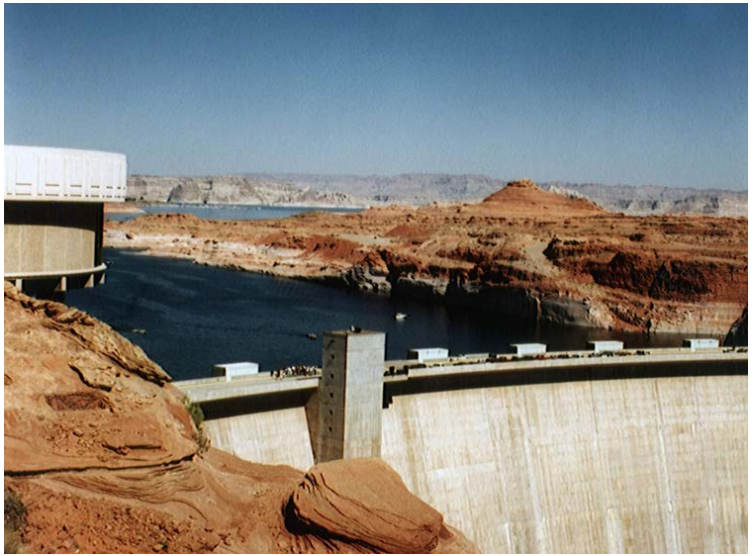


- Glen Canyon node shows the highest price sensitivity for loss of Glen Canyon generation
- Other nodes prices increment is noted peak hours and summer months

(preliminary results)

Summary

- Extremely dry and average hydrology traces in different VRE power grid scenarios were studied assuming FES contracts' load shapes stay as past.
- Energy and reserve prices are high in drought scenarios, specifically evening peak hours and summer months than average hydropower scenario.
- GCD energy loss replaced by thermal generators (coal & NG), and curtailed wind and solar



Glen Canyon Dam, Lake Powell

Next Steps of the project:

- FES contracts will be modeled in the hydropower centric model and PCM to evaluate contract dispatches
- Transmission line overloading to cater contracts' firm energy and grid reserves will be studied.
- Economic analysis of GCD generation loss will be estimated

Future work:

- Explore the potential benefits of working with customers to leverage their generation resources to mitigate the impact of "duck curve" scheduling impacts on GCD.
- Explore the potential benefits of hybrid operation of GCD with other resources including but not limited to solar and batteries to compensate for intermittent or sustained losses in generation from GCD

(preliminary results)

Ref: Glen Canyon dam, Lake Powell, Larry Gordon, Bureau of reclamation

References

1. Thushara De Silva, Thomas Veselka, Jennie Jorgenson, Quentin Ploussard, Clayton Palmer, Stacy Ross . “Projecting Future Colorado River Basin Water and Hydropower Operations” American Geophysical Union 2022, https://www.osti.gov/biblio/1908951
2. Colorado river Basin Map, https://d9-wret.s3.us-west-2.amazonaws.com/assets/palladium/production/s3fs-public/thumbnails/image/coloradoriverbasinviausgs_0.png
3. Thushara De Silva, Jennie Jorgenson, Jordan Macknick, et.al., “Hydropower operation in future power grid with various renewable power integration” Renewable Focus,2022 https://doi.org/10.1016/j.ref.2022.11.001
4. Thomas Veselka, Jennie Jorgenson, Matija Pavičević, Quentin Ploussard, Thushara De Silva, “Impact of Lost Generation at the Glen Canyon Powerplant due to the Environmental Requirements for the Years 2024 to 2027”, 2024 https://doi.org/10.2172/2377679

Q&A

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NREL/PR-6A40-91543

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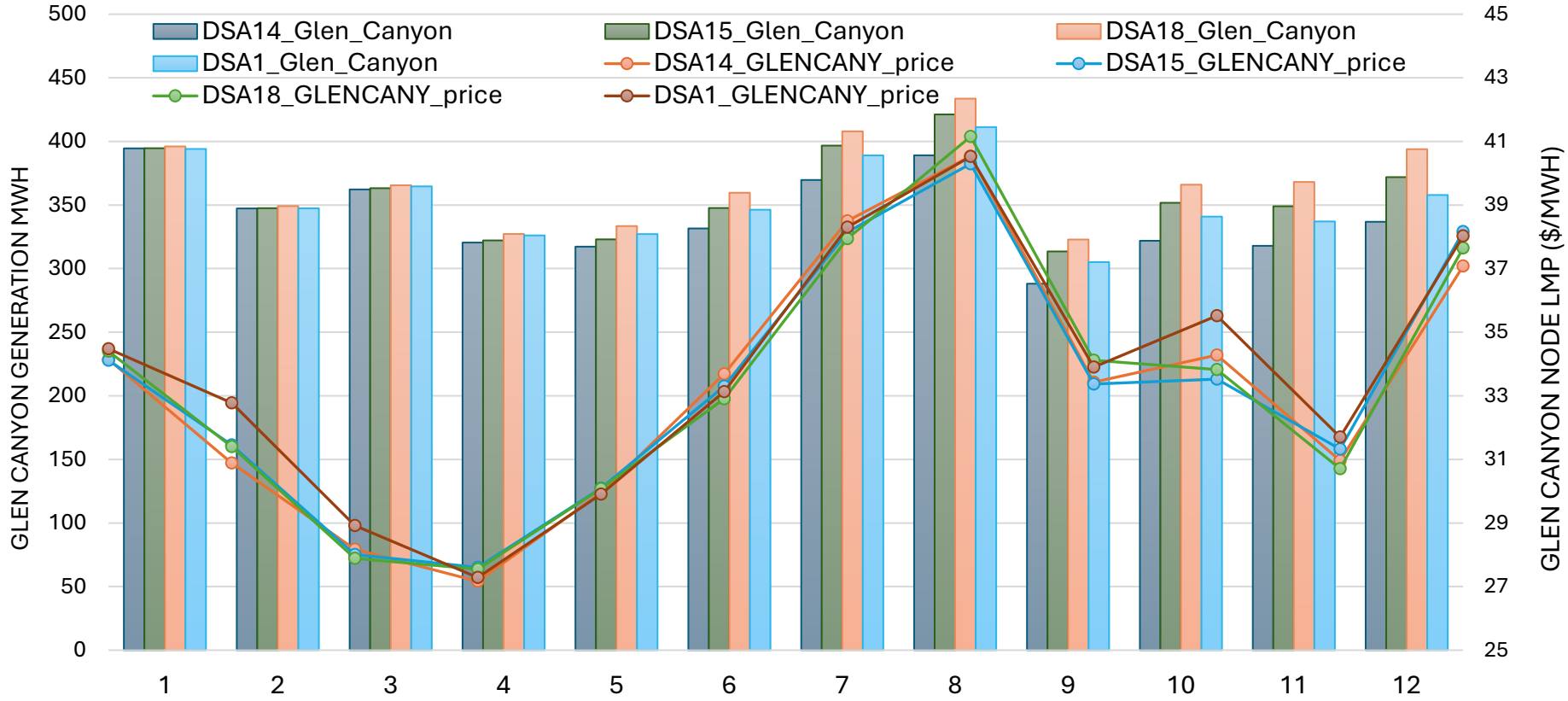
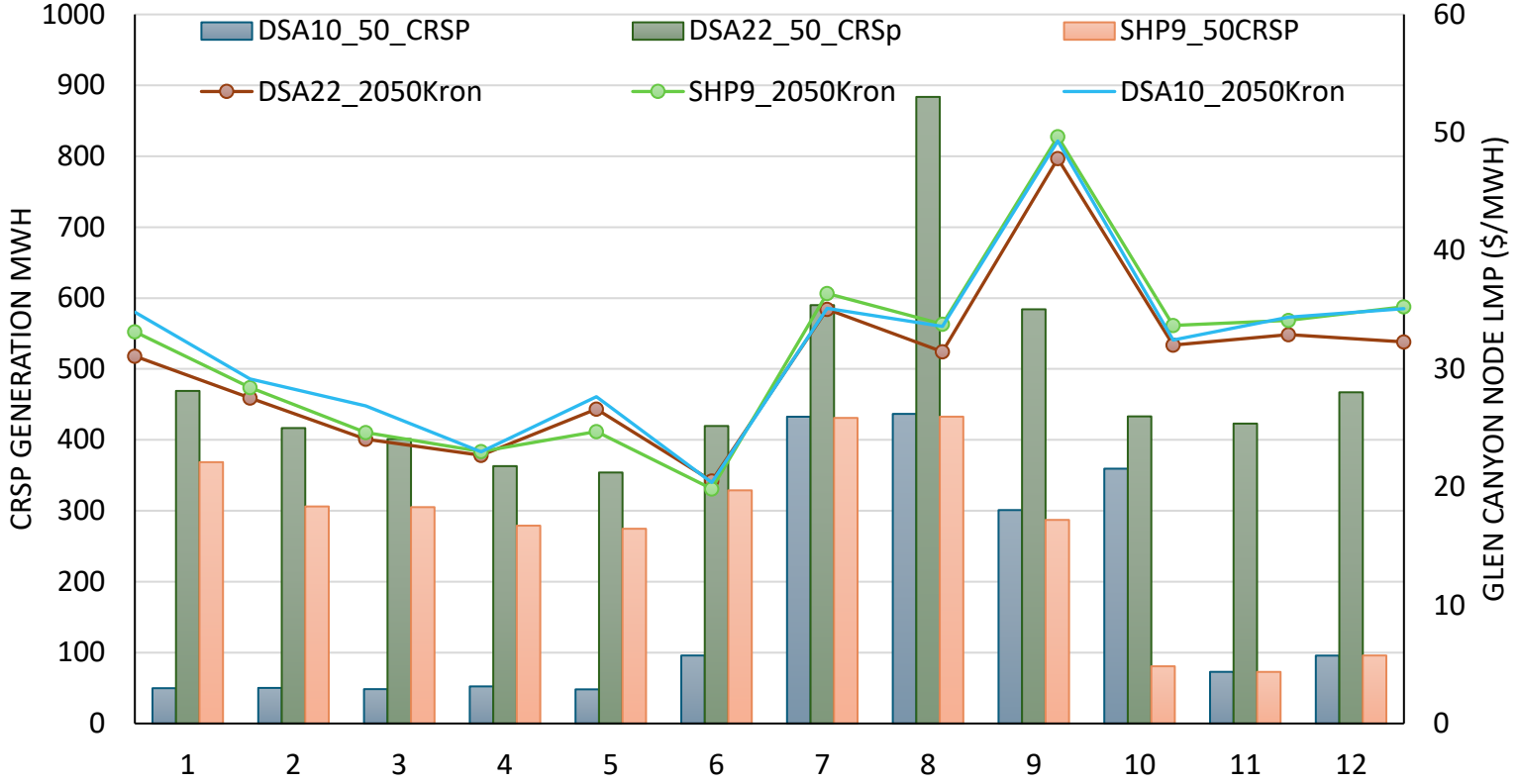
GCD monthly generation and average local marginal prices (Base grid scenario)



(preliminary results)

LMP of Glen Canyon node with generation (Longterm grid scenario)



(preliminary results)