January 3, 2018

MEMORANDUM

TO: **Council Members**

FROM: **John Ollis, Power System Analyst**

SUBJECT: **Marginal Carbon Emissions Rate Study Draft**

BACKGROUND:

Presenter: John Ollis

Summary: This presentation will update the Power Committee on the revised results of the Marginal Carbon Emissions Rate Study, per the methodology recommendations of stakeholders and staff. Staff will be seeking release of the draft study in a following Council presentation.

Relevance: The study of avoided carbon dioxide production rates of the northwest power system will evaluate what the implied avoided emissions rate is in the WECC by reducing 100 MW of Pacific Northwest load in every hour of four test years (2016, 2021, 2026 and 2031), and the implications for regional conservation replacing the need for that production. The results will summarize the findings into an annual avoided carbon dioxide emissions rate (lbs per MWh) for the years of the study for two scenarios analyzed in the 7th Power Plan: Existing Policy and Average Social Cost of Carbon.

Workplan: N/A

Background: The cost of future carbon dioxide regulation has been a significant factor in resource planning in the Pacific Northwest. To avoid making higher cost resource choices, a direct evaluation of this risk requires an estimate of the carbon dioxide emissions avoided by purchasing conservation or another resource. The Council has periodically produced this study using the AURORAxmp model to help inform Council staff and regional stakeholder analysis.

Per the discussion in the January and February 2017 Power Committee, and April Council Meeting, AURORAxmp has been used as the Council's wholesale market electricity price forecasting model. The first draft of the study was released for public comment in April 2017. In response to that public comment, staff developed, in conjunction with the System Analysis Advisory Committee, a slightly different methodology for calculating the best estimate for an avoided carbon dioxide emissions rate. This updated draft reflects the new methodology and results.

More Info: The second 2017 Marginal Carbon Emissions Study Draft will be available for preview before the meeting.

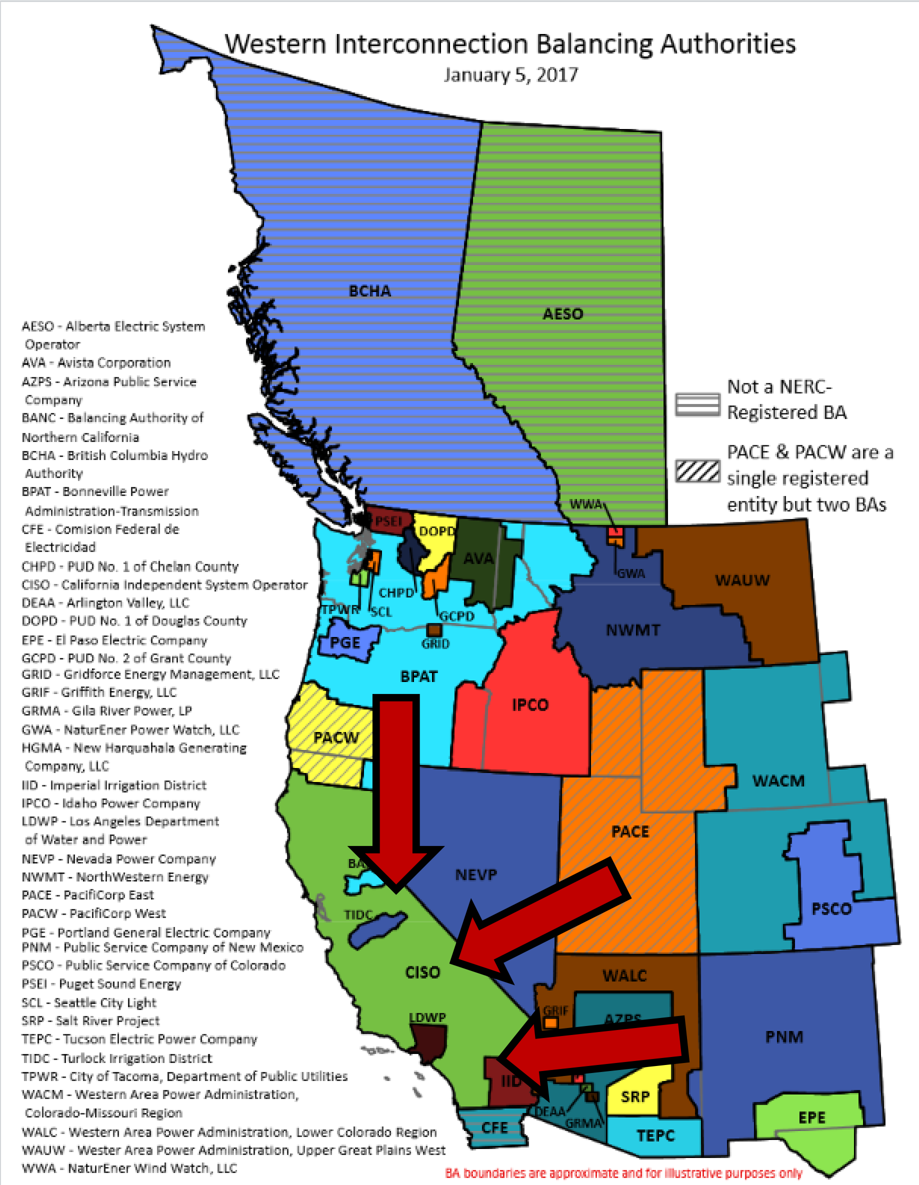
For SAAC discussion of study, see
https://www.nwcouncil.org/energy/saac/meetings/2017_10_06-webinar/

For initial paper, see
https://www.nwcouncil.org/energy/2017-04-marginal-carbon-draft/

For initial paper, see
Marginal Carbon Emissions Study initial scope

2008 Marginal Carbon Emissions Study:
https://www.nwcouncil.org/media/29611/2008_08.pdf

For more information please contact John Ollis.



Marginal Carbon Dioxide Production Rate Report: Methodology Discussion

Power Committee
John Ollis
January 9th, 2018

Northwest **Power** and
Conservation Council

Why We Are Having This Discussion Again.

1. Stakeholder response to first draft asked for more involvement and input on methodology.
2. Multiple meetings with SAAC resulted in updated methodology.
3. Similar average results, but larger ranges and different reasoning.
4. Approval to release second draft of study.

Similar Results, But Different Methodology

Annual Avoided Emissions Rate (lbs. of CO_2 per kWh)

Scenario	Existing Policy	Social Cost of Carbon
2016	1.83	1.40
2021	0.91	0.58
2026	0.93	0.70
2031	0.97	0.55

- *Modern natural gas-fired combined cycle unit emits 0.8 to 0.9 lbs. of CO2 per kWh.*
- *Conventional coal-fired steam unit emits roughly 2.1 to 2.4 lbs. of CO2 per kWh.*
- *Peaker gas units have a larger range of emissions rates 1.1 to 1.7 lbs. of CO2 per kWh.*
- Initial methodology (April 2017): 1.16 to 1.75 lbs. per kWh for existing policy scenario

Why the Methodology Change?

Draft Study Response

- Staff released its updated draft marginal carbon study in April 2017
- Significant stakeholder response
- Concerns included:
  1. Metric used for evaluation
  2. Low prices in spring not implying hydro as marginal
  3. Less stakeholder involvement than most Council processes

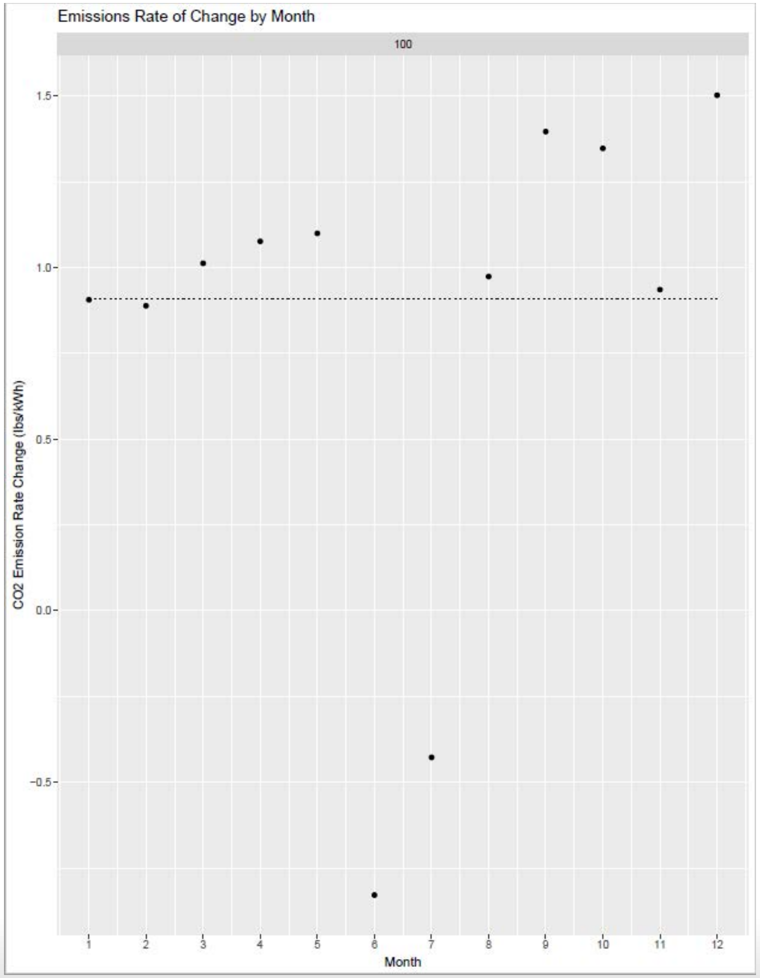
SAAC Direction on Methodology Change

- In August, System Analysis Advisory Committee meeting members suggested the following:
  - WECC-wide look at Avoided Carbon Emissions Rate
  - Look at deltas in emissions for flat load decreases of 1, 10, 100 and 250 MW, see if there is a major difference in results
  - Use delta emissions to calculate avoided emissions rate

October 2017 SAAC Discussion: Delta Test Conclusions

- The delta tests for flat demand reduction, yield similar results with 100 MW determined to be the best choice by the SAAC:
  1. The change in load effects has the biggest effect on the dispatch of coal units in Arizona, Colorado, Nevada, Utah, and Wyoming, and gas units in California and the PNW.
  2. The major driver of the emissions change is the change of dispatch in the coal units.
  3. The difference in load change yields hourly and monthly results that may move emissions up or down, but in general on an annual basis and long-term, reduction in load reduces emissions.
- Key finding: 1 and 10 MW pretty insignificant in terms of the total output of the WECC, the results from this study were noisy and inconclusive.

WECC Avoided CO2 Emissions Rate for 2021: Updated Methodology

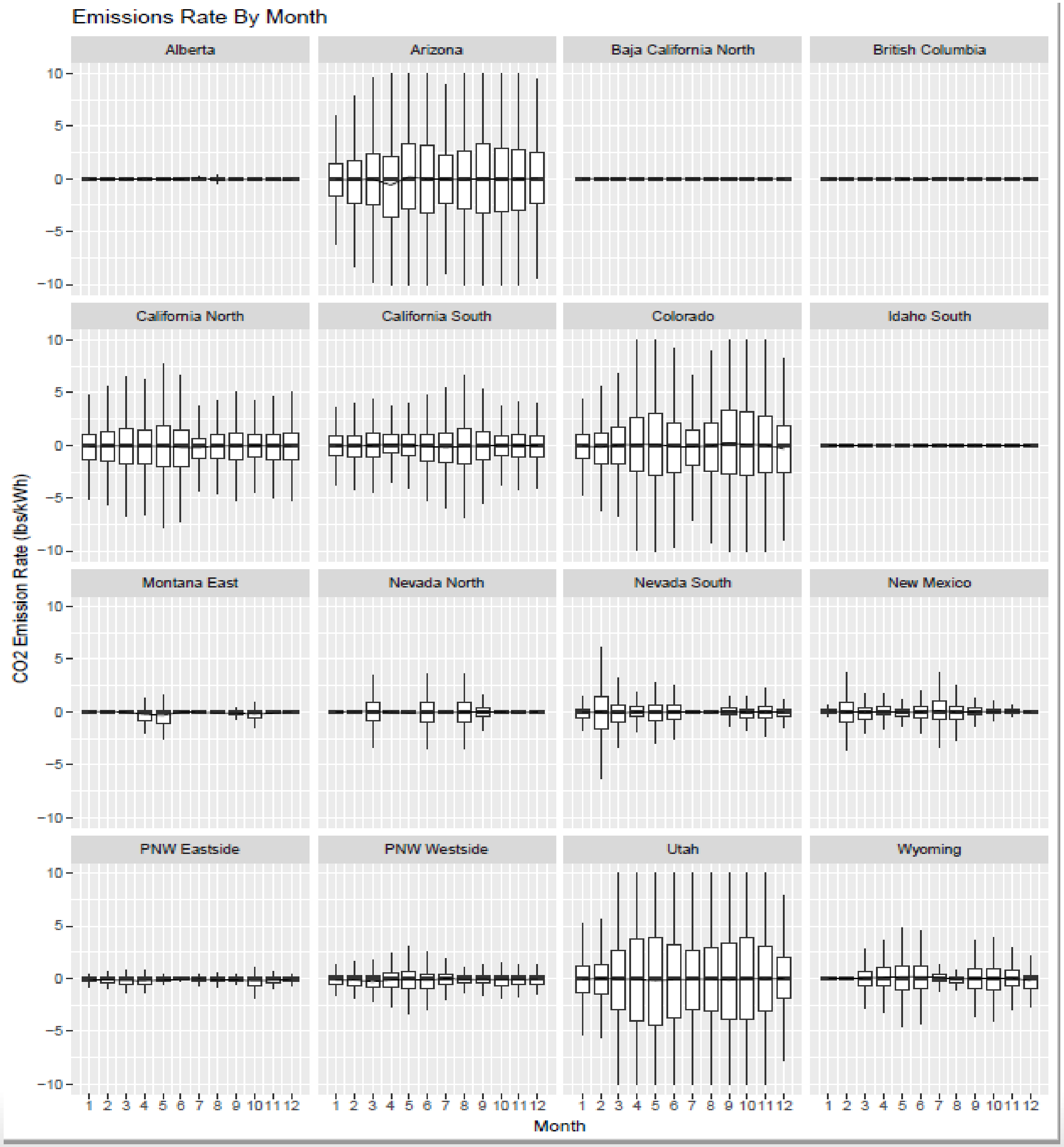


The *average avoided emissions rate* over the output changed in the WECC from the flat drop of 100 MW is

$$\frac{Emissions_{100} - Emissions_0}{Output_{100} - Output_0} = .91 \text{ lbs/kWh}$$

Variable Definition:

1. $Emissions_{100}$ is the emissions in the WECC with 100 MW less load run
2. $Emissions_0$ is the emissions in the WECC in the base run
3. $Output_{100}$ is the output in the WECC with 100 MW less load run
4. $Output_0$ is the emissions in the WECC in the base run



WECC Emissions Rate Changes by Zone

Notice the spreads are large but the net effect may still be small depending on how much output is increased or decreased at that emissions rate

WECC-wide data questions

- Change in fuel usage at plants
  - What types of plants are driving the emissions rate?
- Change in delta emissions and output
  - Where are plants changing output?
  - What is driving the large emissions changes?
  - Is this driven by regional exports?
  - Variability in production from the hydro system?

Box Plot Review

Since we need to look at distributions of results...

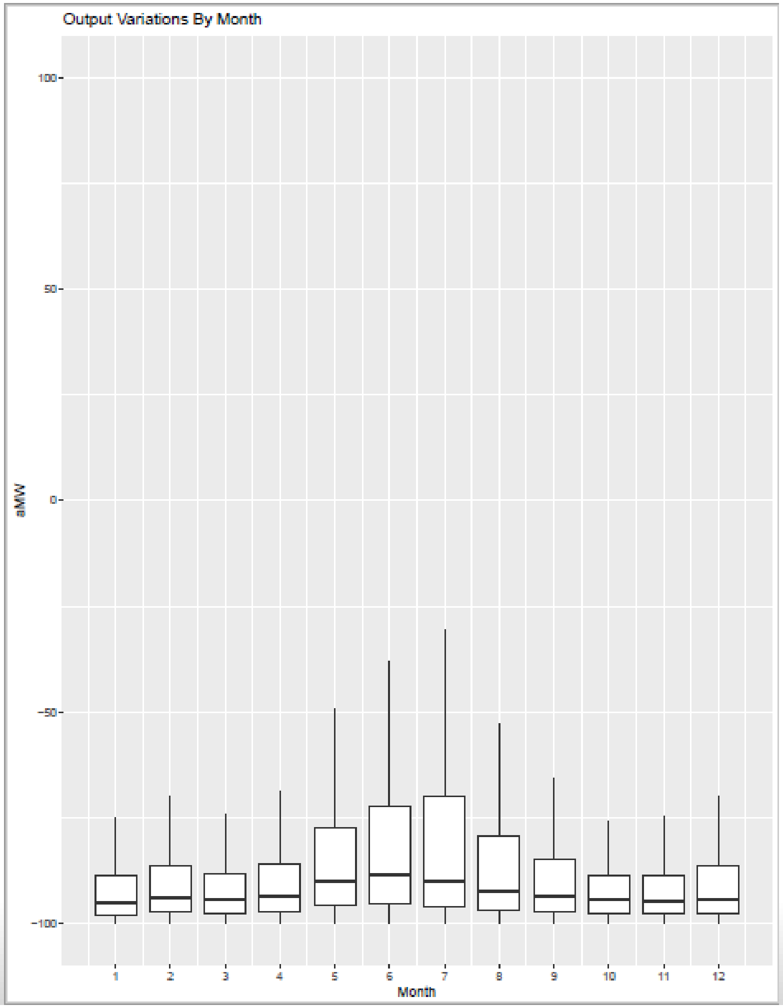
- Lower boundary on box: 25% quantile
- Middle line: 50% quantile
- Upper boundary on box: 75% quantile
- Min and max whiskers:

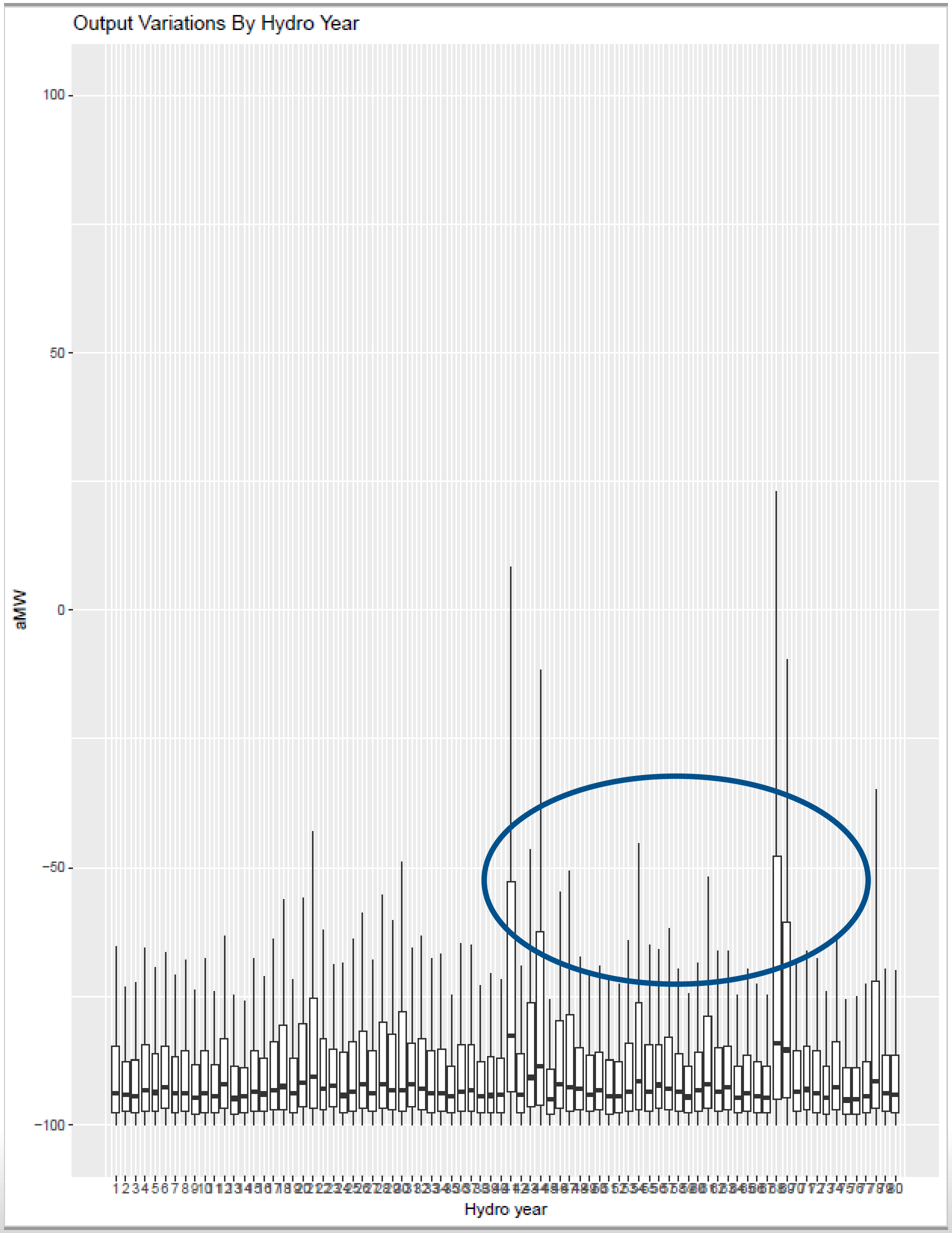
(Min Observation-1.5*IQR, Max Observation+1.5*IQR)

  - IQR is Interquartile range

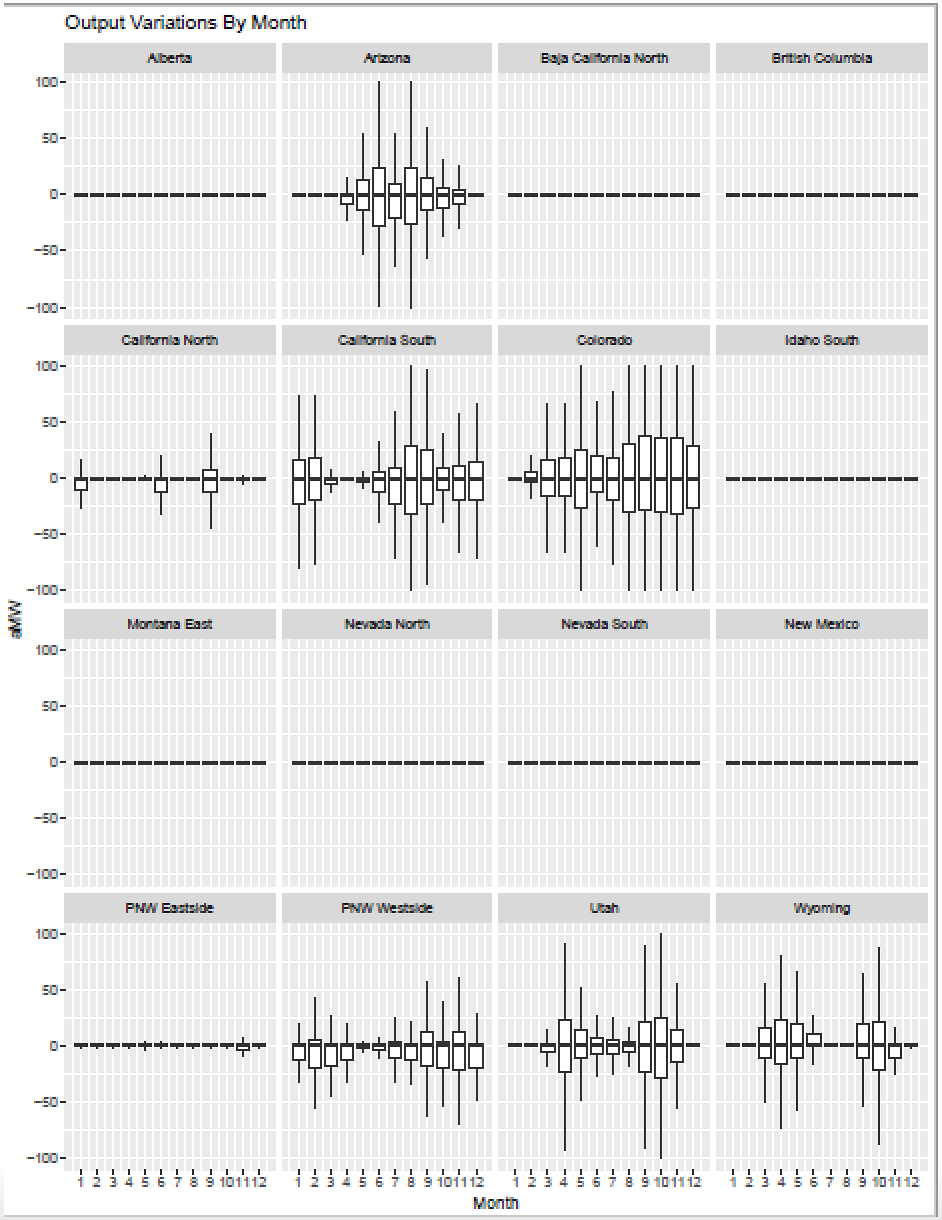
WECC Output Change

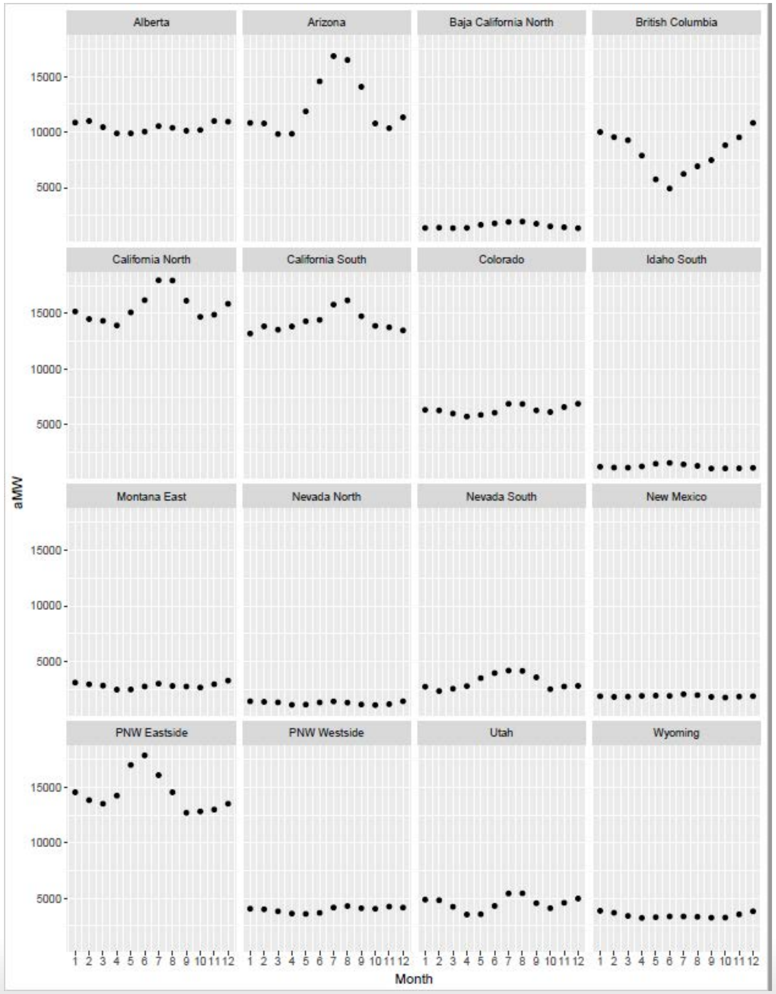
As expected, this is close to 100 MW less output in the WECC corresponding to the flat load drop of 100 MW in the PNW Westside.

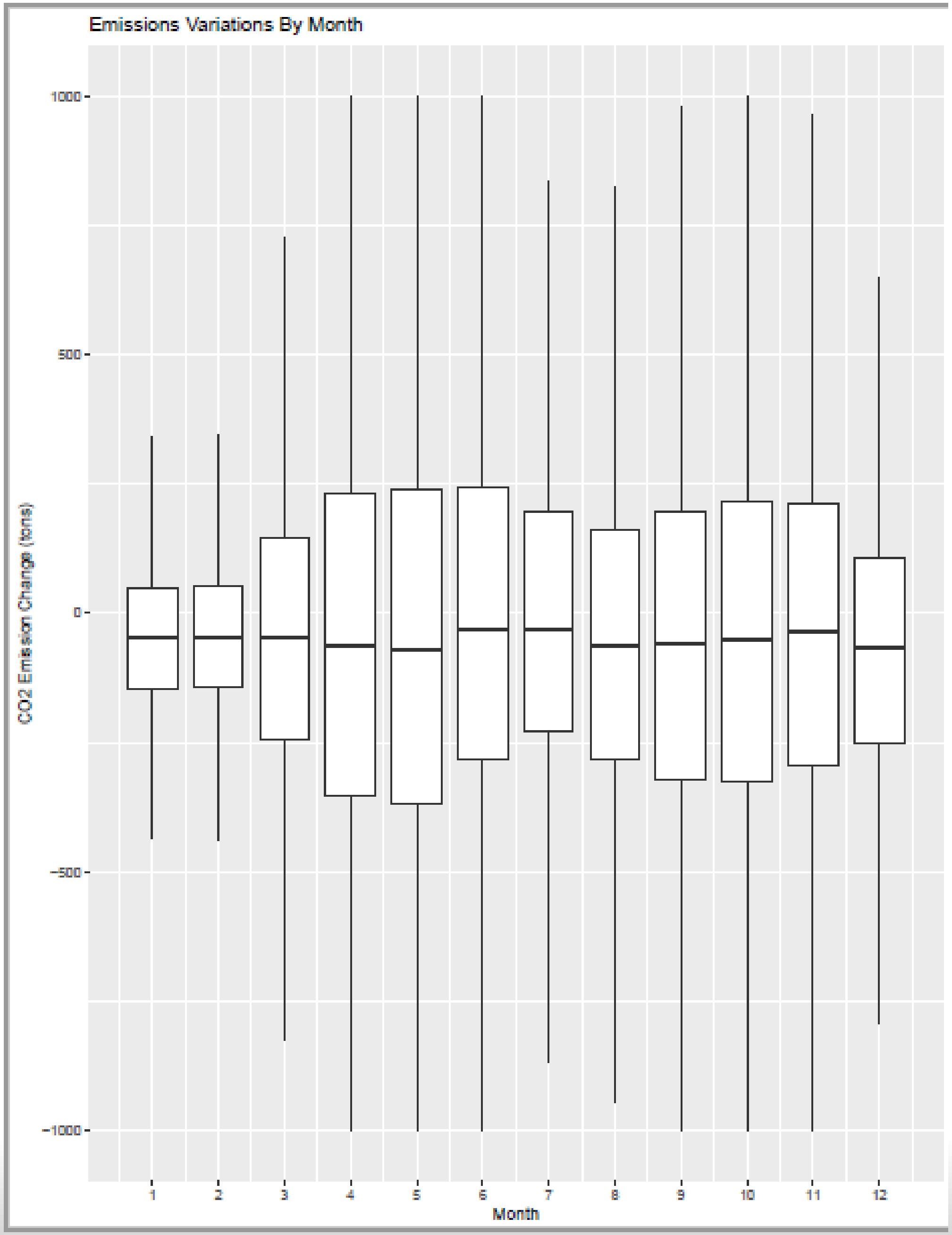




WECC Output by Zone





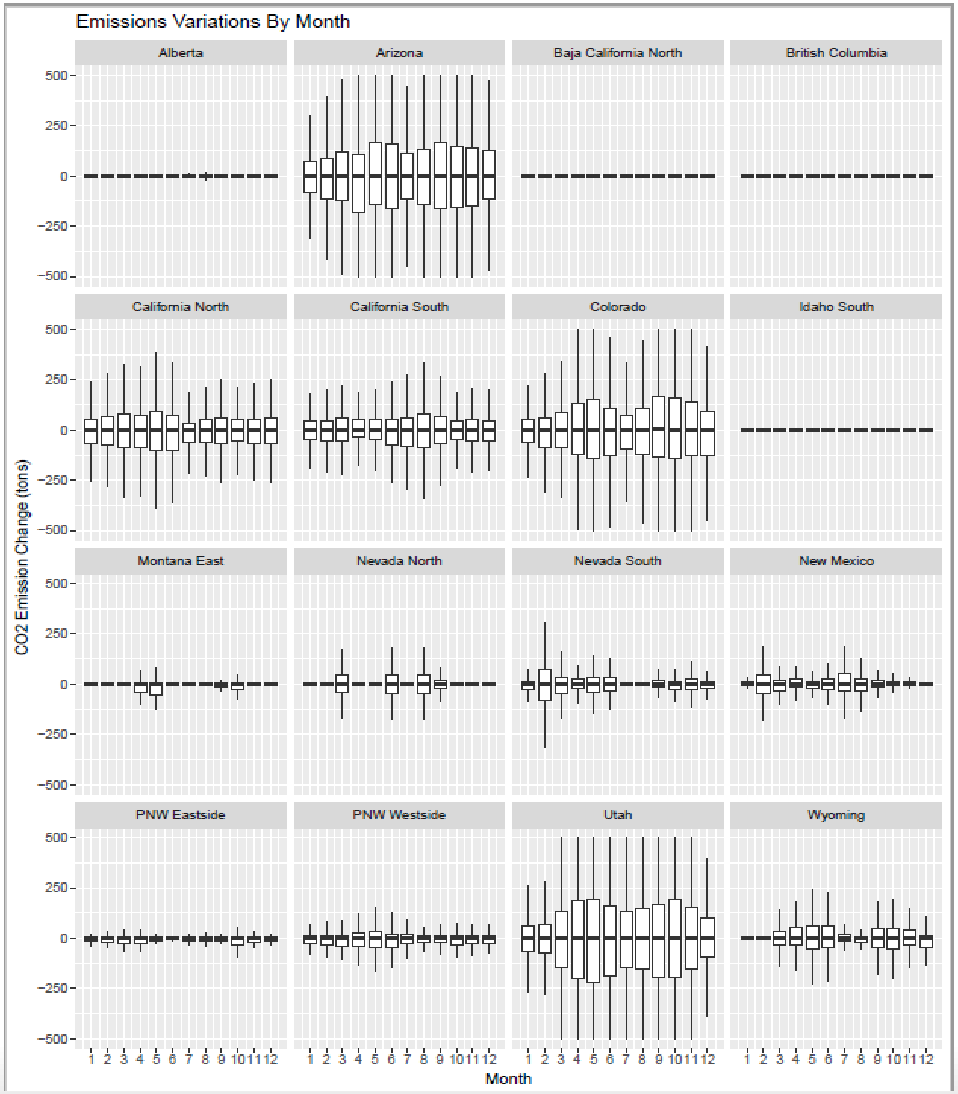


WECC Emissions Change

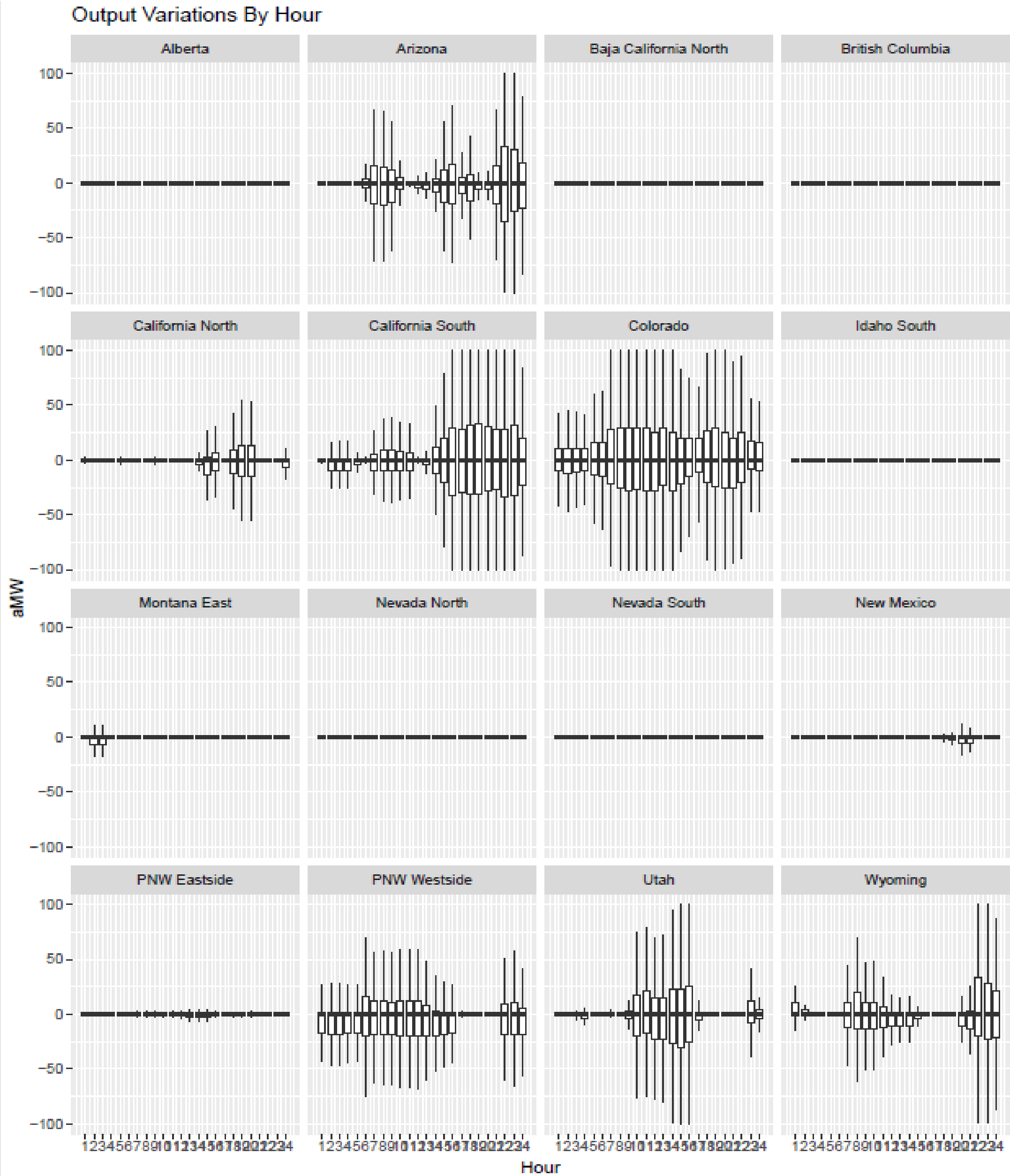
For context, all the changes in emissions are very small (<<1%) in comparison to the total amount of WECC Emissions in a month.

	Report_Month	Amount
1	1	61319815
2	2	54787489
3	3	55211064
4	4	47719302
5	5	52770715
6	6	56887022
7	7	67330810
8	8	67567049
9	9	58443896
10	10	54794026
11	11	56928405
12	12	62391053

WECC Emissions Change by Zone

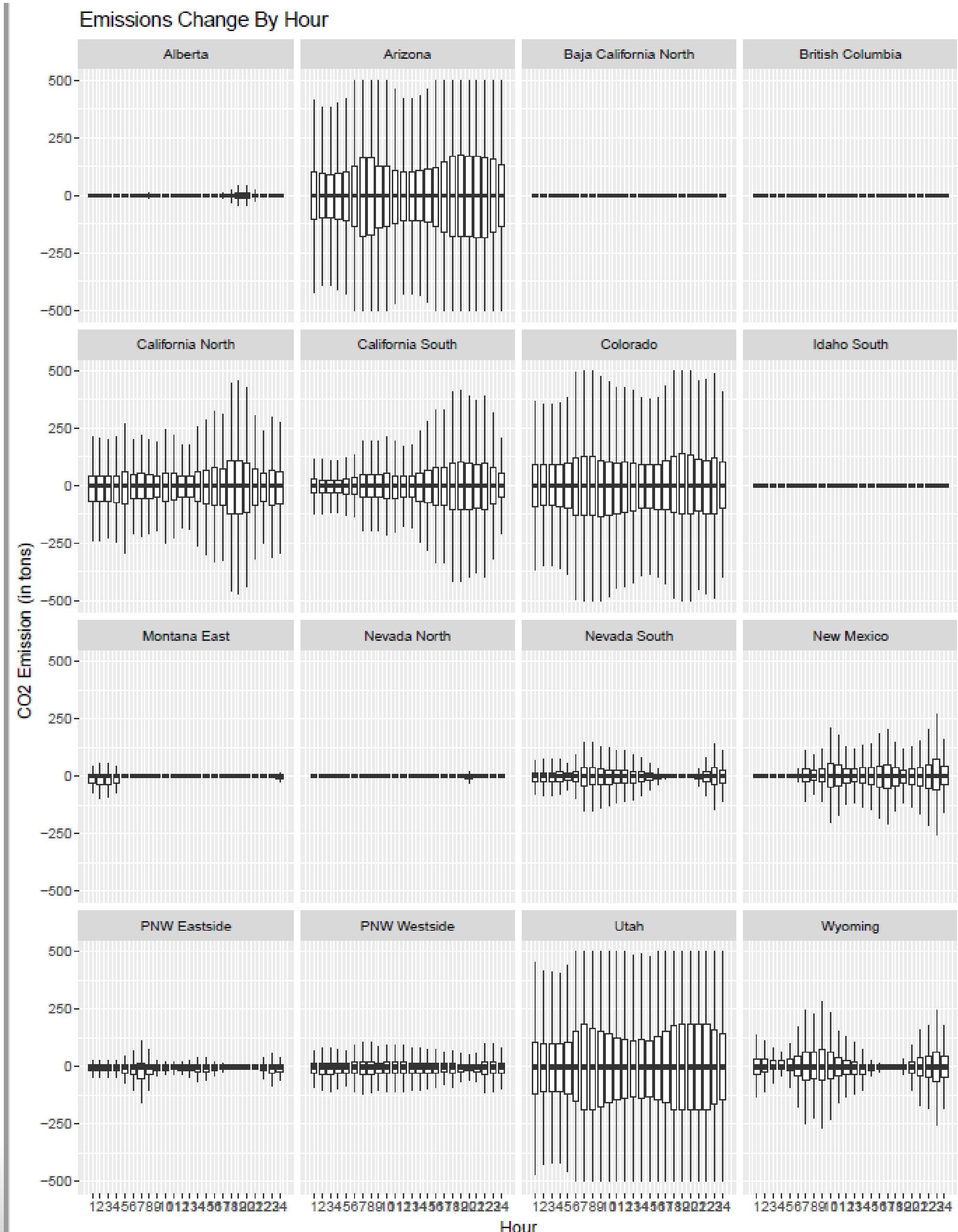


Notice that most of the emissions change happens in a few zones and not much in the NW



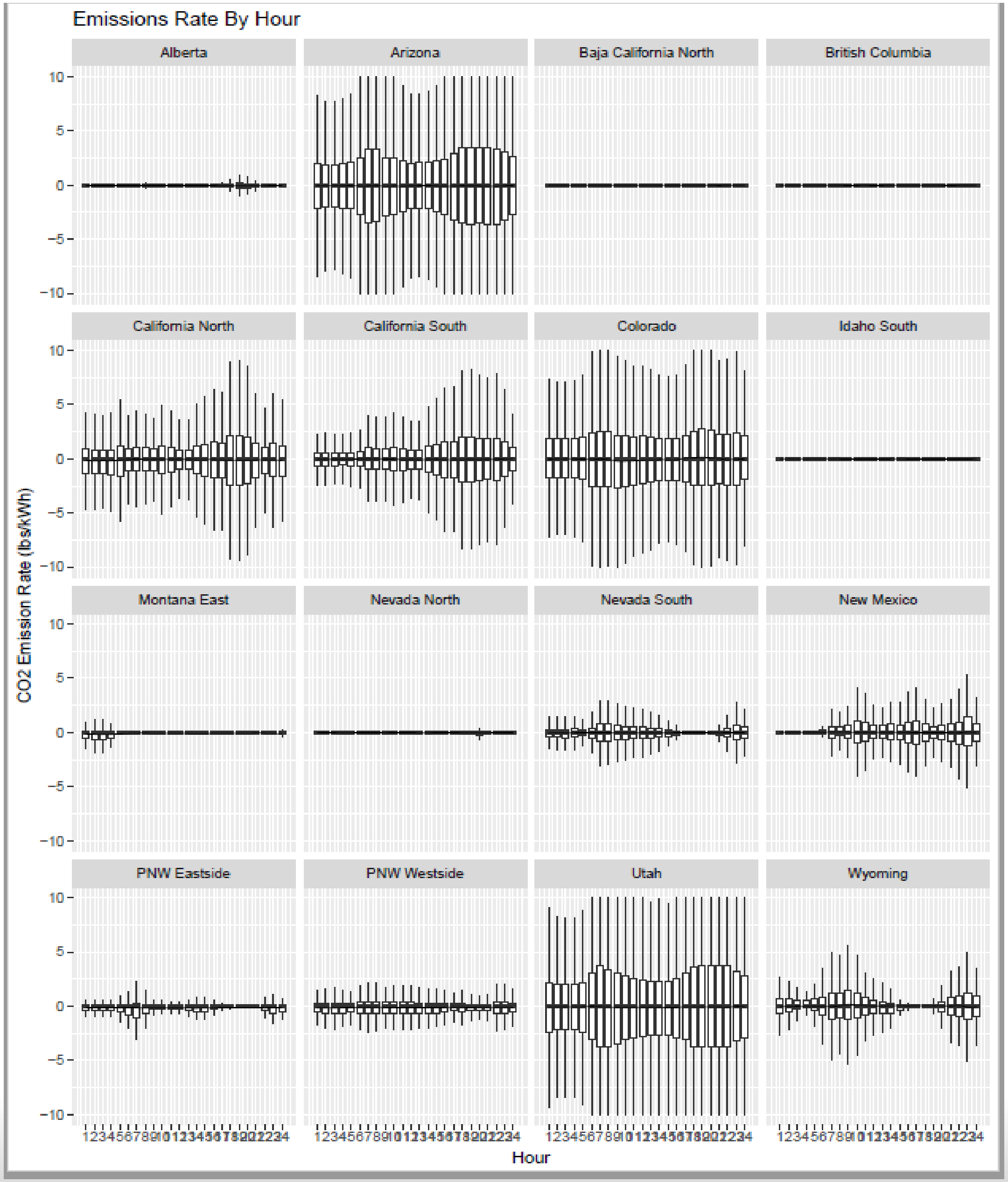
Output Change By Hour

There are some patterns here, like more variation around the daily load shape in certain zones.



Emissions Change By Hour

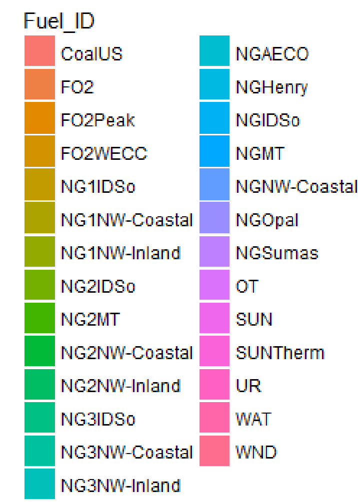
There are some similar patterns here, like more variation around the daily load shape in certain zones.

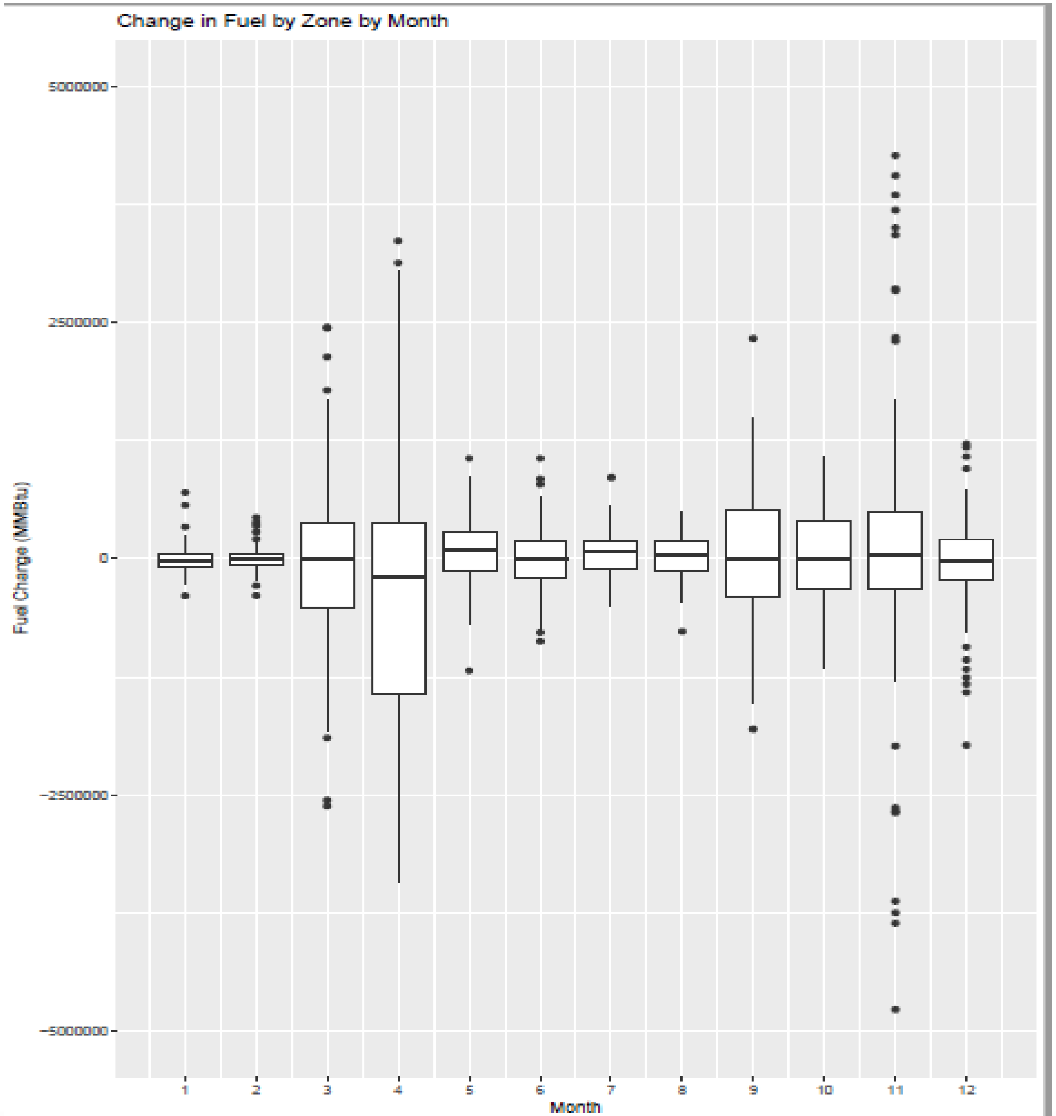


Emissions Rate Change By Hour

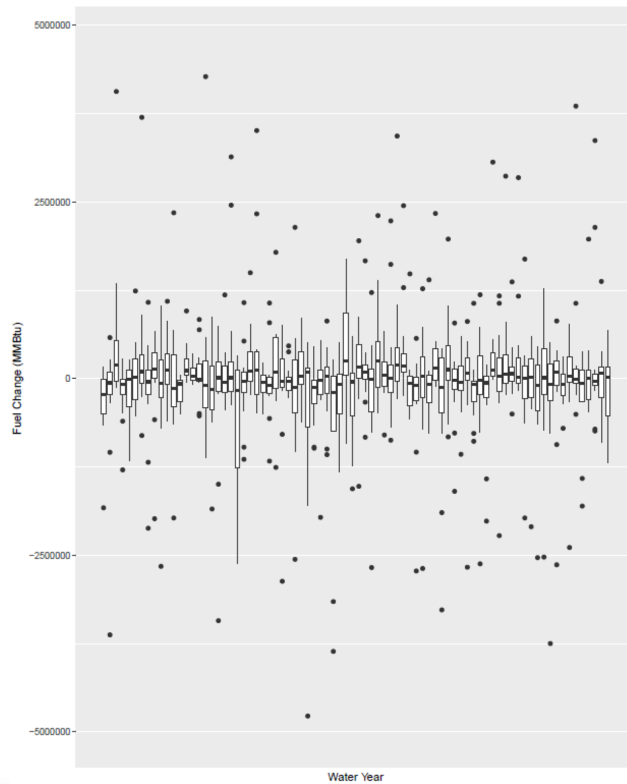
There are some similar patterns here, like more variation around the daily load shape in certain zones.

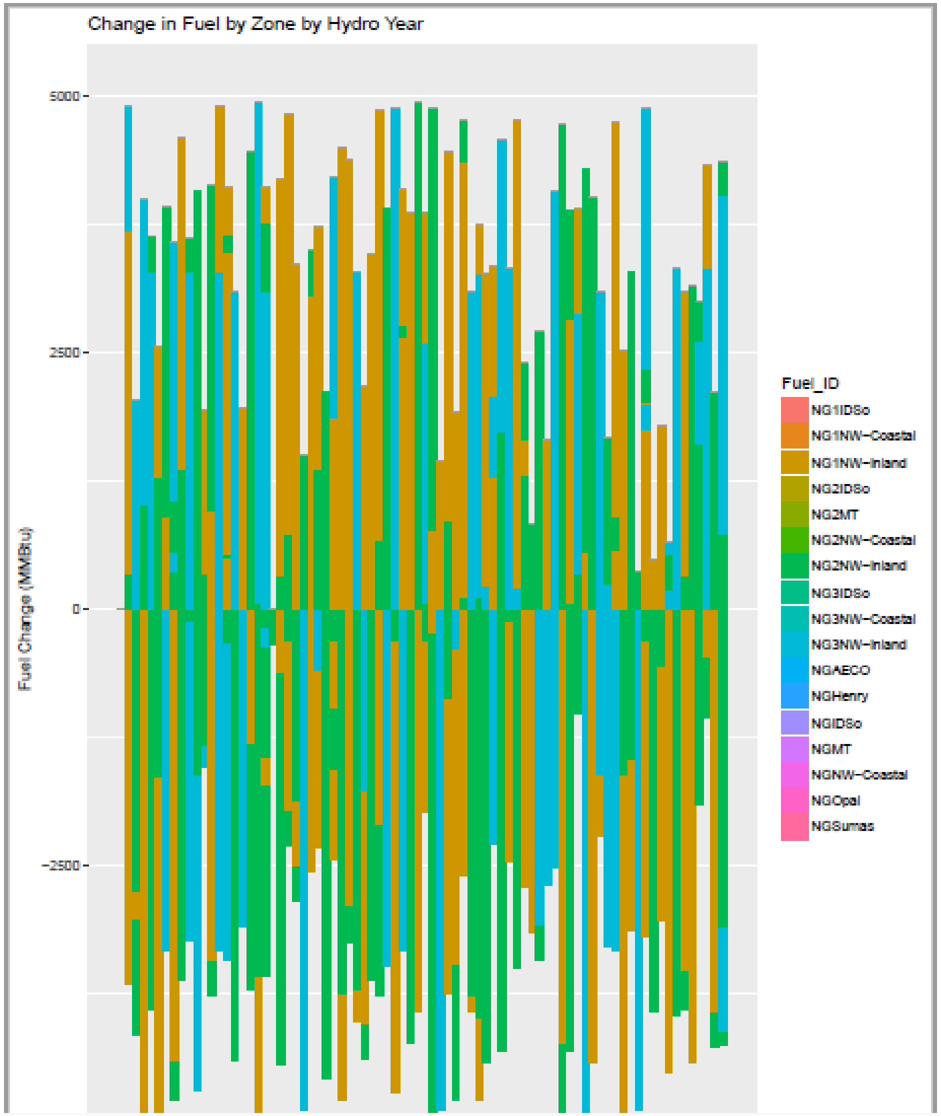
Coal plant fuel usage in Arizona changes the more than any fuel by month, but why?



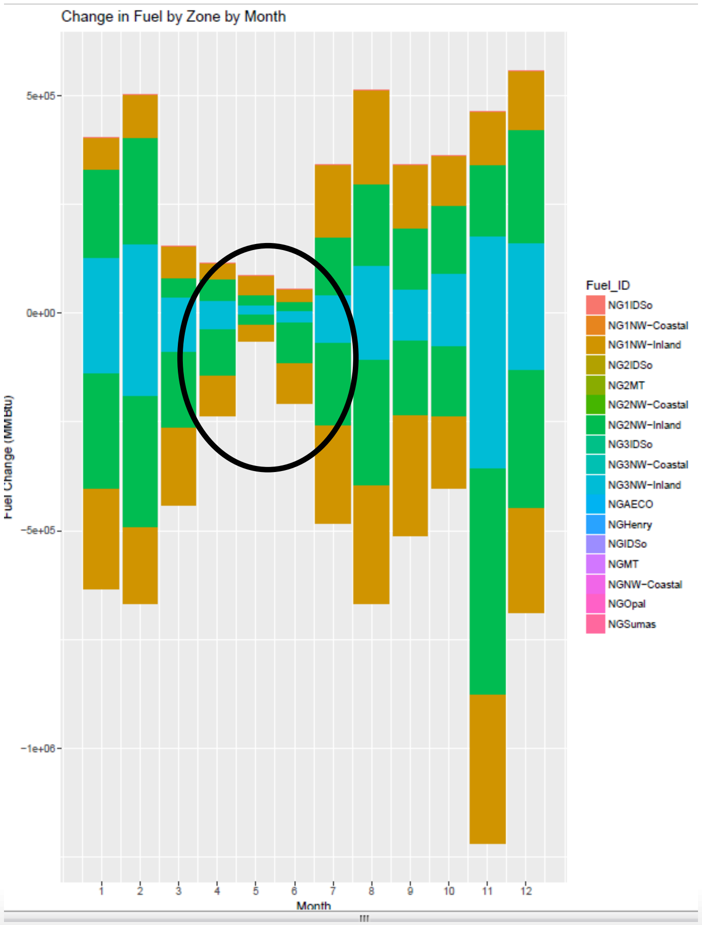


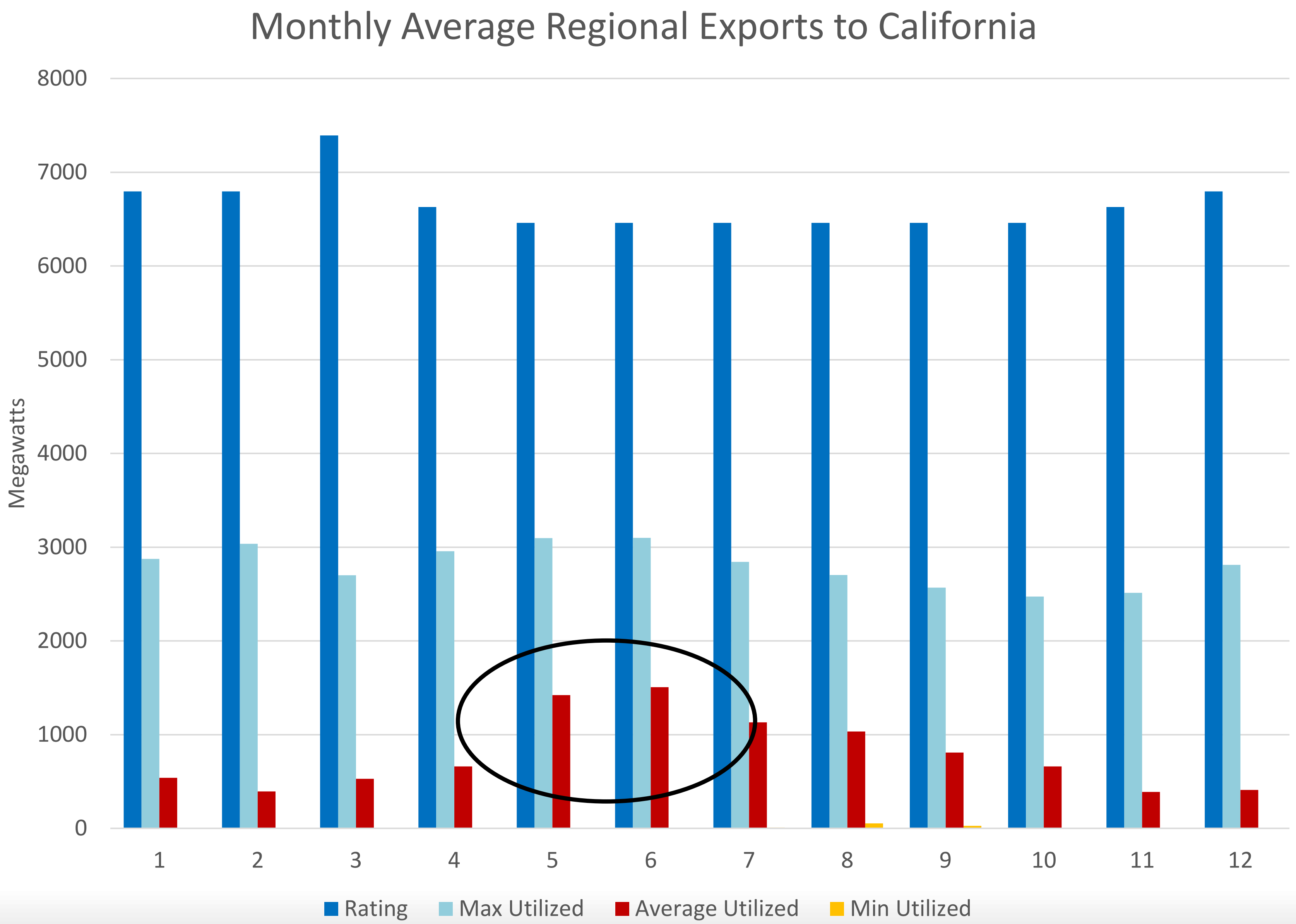
- Coal usage drives WECC emissions change
- Coal usage in Arizona fluctuates by month and by water condition





In the east side of the region, gas usage changes, but not often and not much.





Northwest **Power** and **Conservation** Council

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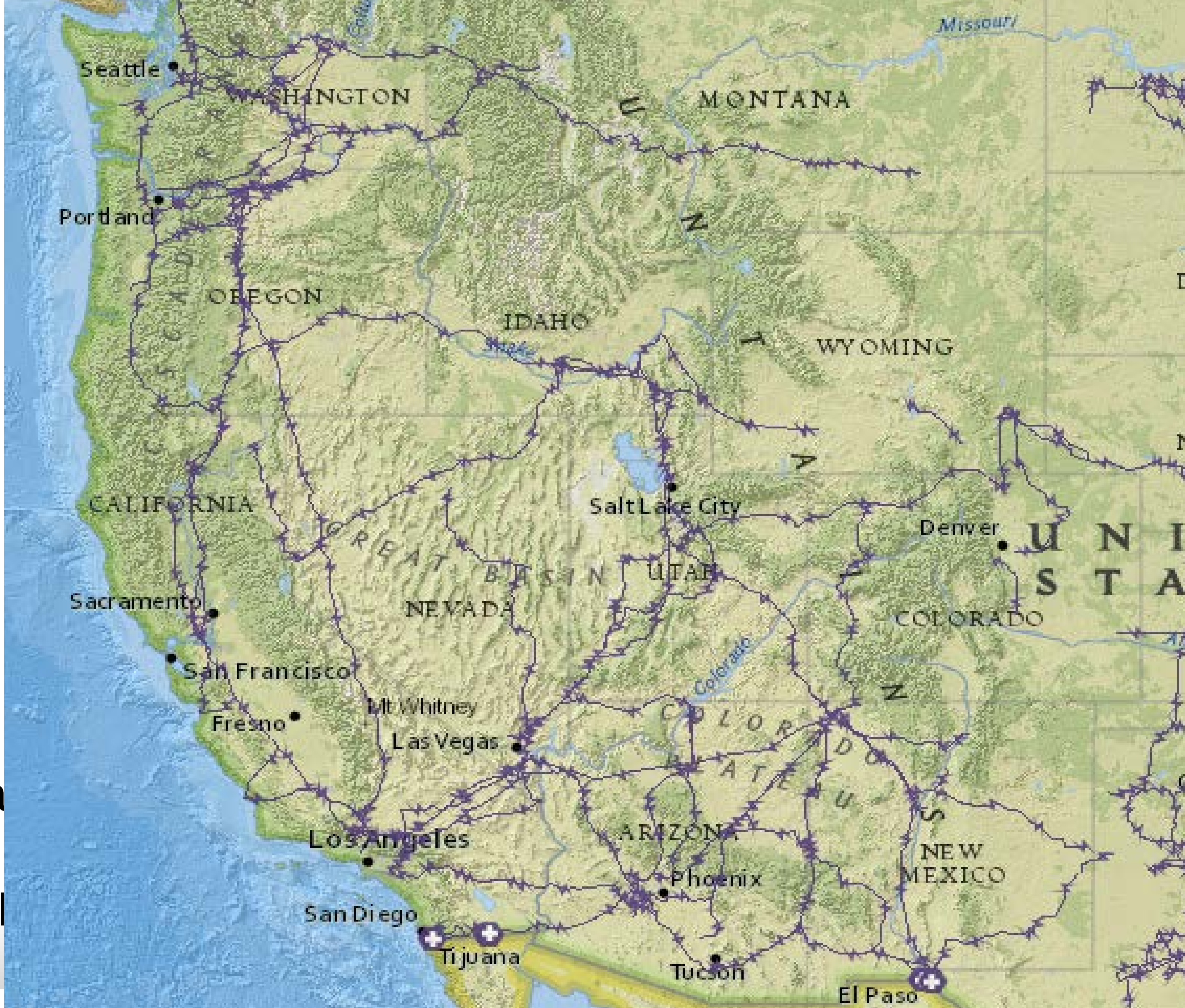

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Sacramento
COLORADO
San Francisco
Colorado
Mt Whitney
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Las Vegas
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San Diego
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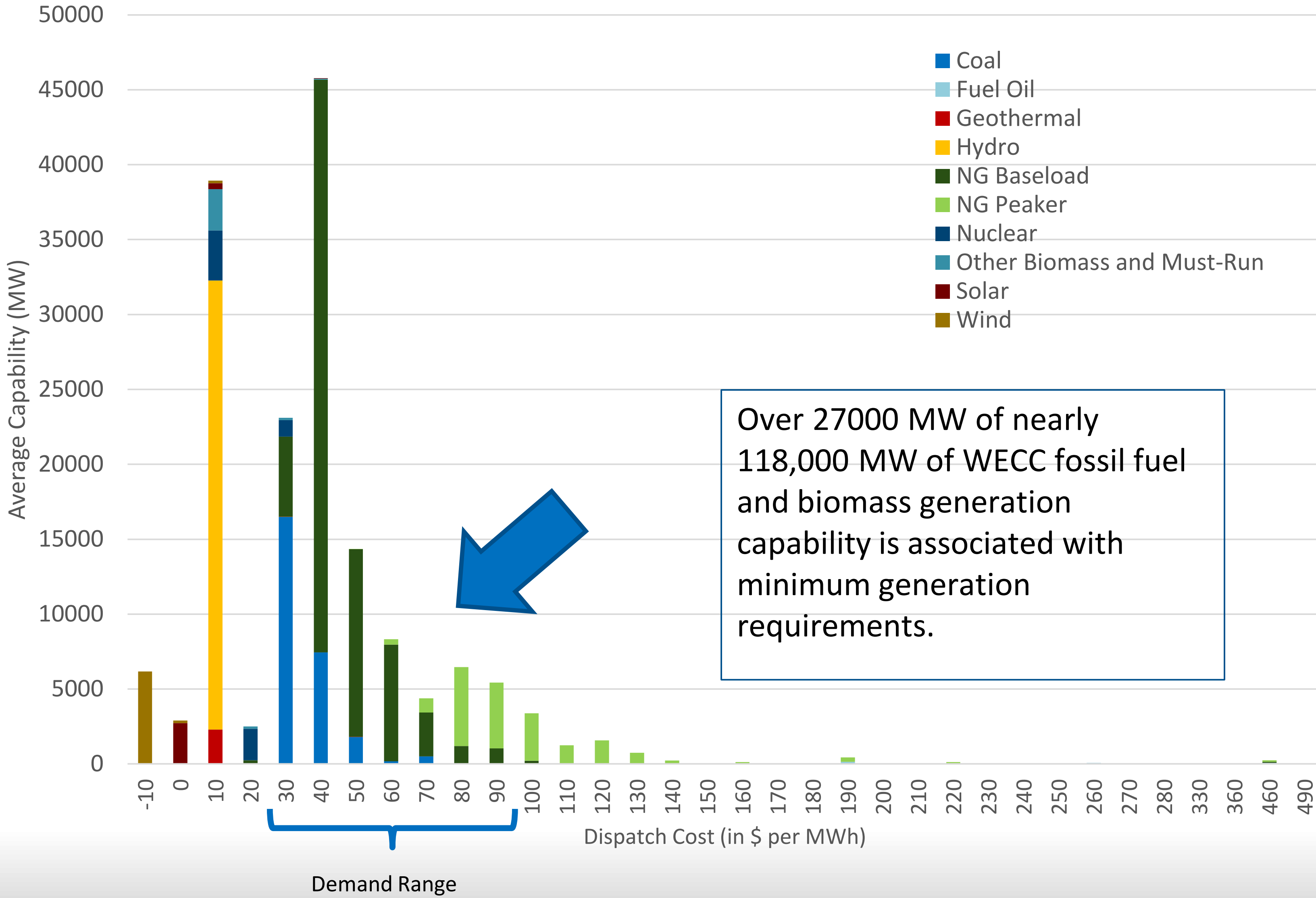
Tucson
El Paso

What are we optimizing?

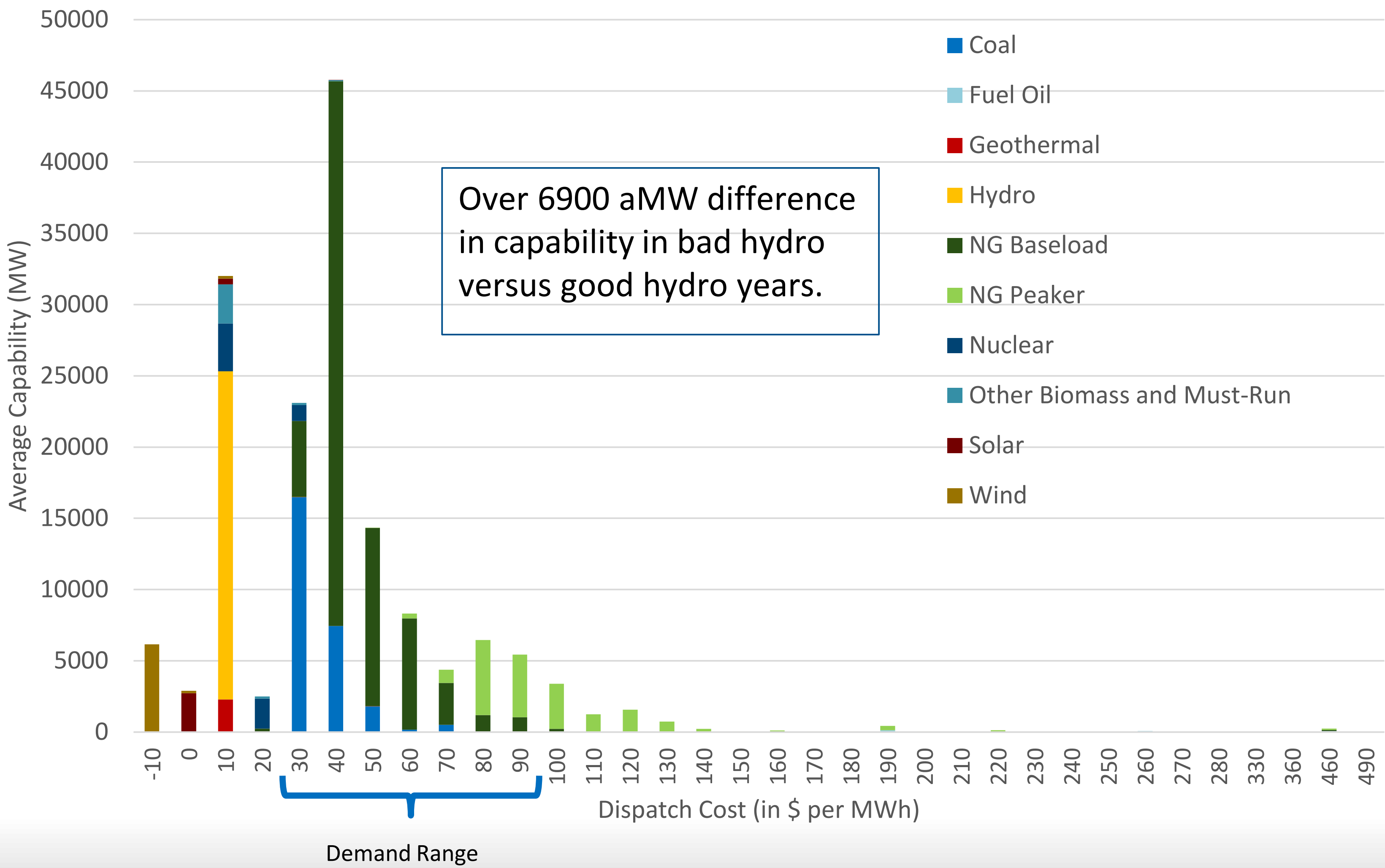
- The optimization in AURORA is focusing on meeting load at the **lowest cost**.
- Optimizing for the **lowest CO_2 emissions** would be a different objective.
- Since the stack is filled with varied fuel types big rate swings may happen hour to hour, but in general there seems to be an avoided carbon rate that is similar to that of a CCCT.

2021 WECC Resource Portfolio - Good Hydro Conditions



Over 27000 MW of nearly 118,000 MW of WECC fossil fuel and biomass generation capability is associated with minimum generation requirements.

2021 WECC Resource Portfolio - Poor Hydro Conditions



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Next Steps

Continue Stakeholder Involvement

- Met with System Analysis Advisory Committee to vet methodology and assumptions, and discuss results.
- Updated report to reflect stakeholder feedback, revised methodology and results.
- Put study out for second round of public comment.

Approval to Release Study?

- Questions?

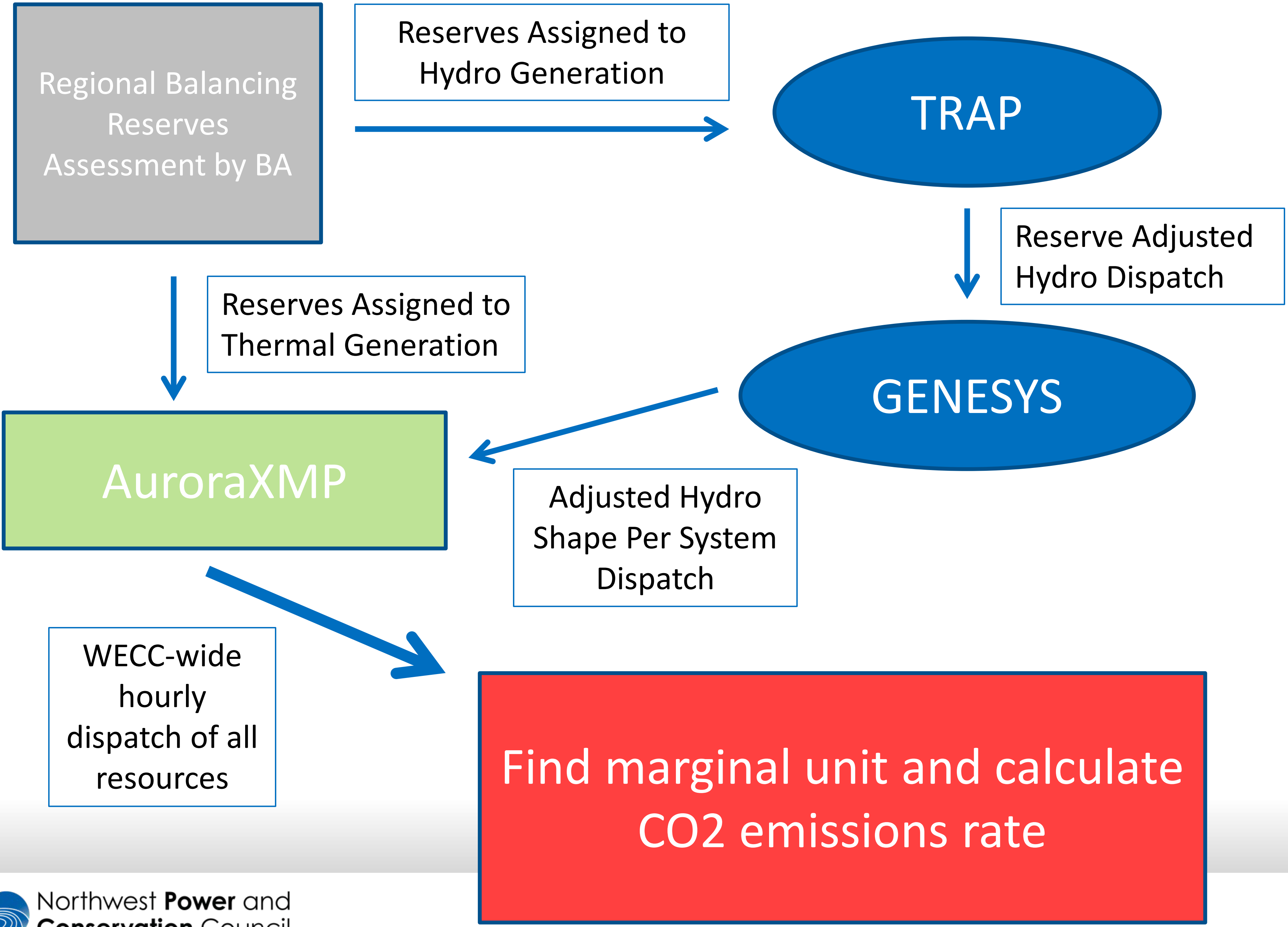
Additional Content for Reference

Review of Methodology

- Similar to 7th Plan Balancing Study setup
- Instead of using AURORAxmp for resource expansion within region, use RPM results from 7th Power Plan.
- Each of 10 scenarios will be considered under all 80 hydro conditions instead of just average hydro conditions.
  - 2016, 2021 (Min and Expected DR), 2026, 2031 run with No Carbon Price and Social Cost of Carbon
- All scenarios will be run with regional reserve requirements and hydro methodology similar to what was used the 7th Power Plan Balancing and Flexibility study.

Review: Capability of Current Models

- **AuroraXMP – Hourly Dispatch**
  - Limited intra-hour reserve accounting capability.
  - Extremely limited hydro dispatch capability
- **GENESYS – Hourly Dispatch**
  - Limited intra-hour reserve accounting capability.
  - Uses hydro shapes from TRAP
- **TRAP – Hydro Shaping Algorithm**
  - Accounts for intra-hour reserves held on hydro


Regional Balancing Reserves Assessment by BA
Reserves Assigned to Hydro Generation
TRAP
Reserve Adjusted Hydro Dispatch
Reserves Assigned to Thermal Generation
GENESYS
AuroraXMP
Adjusted Hydro Shape Per System Dispatch
WECC-wide hourly dispatch of all resources
Find marginal unit and calculate CO2 emissions rate

Determine Amount of Reserves Required by Balancing Authority

- Used the 95% Confidence Interval **load following** requirements for each of the 28 not generation-only BAs (Base Case for the PNNL NWPP EIM Study).
- The data set is described in more detail in the following report

  http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22877.pdf
- This is not the only dataset available, but seemed most reasonable to Council Staff based on data needs:
  1. Monthly and hourly reserve requirement data for all WECC BAs.
  2. Current regional portfolio conditions.
- Some reserves have been modified to reflect utility feedback

Assigning Reserves to Hydro/Non-Hydro Units

- <u>Assumption</u>:

  Total reserve requirements for each BA can be met by resources within each BA (with exception of long term Mid-C hydro Power Purchase Contracts).
- Identify resources that CAN provide reserves.
- Use **commitment optimization** functionality in AURORA to assign reserves to regional resources.
  - Note that BPA reserve requirements are assigned to certain regulated hydro dams in TRAP and GENESYS to ensure hydro shape going into AURORA considers the flow and capability constraints on regulated hydro.

Commitment Optimization

- An commitment/dispatch algorithm that minimizes cost by co-optimizing the assignment of the following to resources in a footprint within the constraints applied to the system:
  1. Energy
  2. Ancillary Services
- Constraints on transmission, ramping, unit capability considered in the commitment and dispatch.

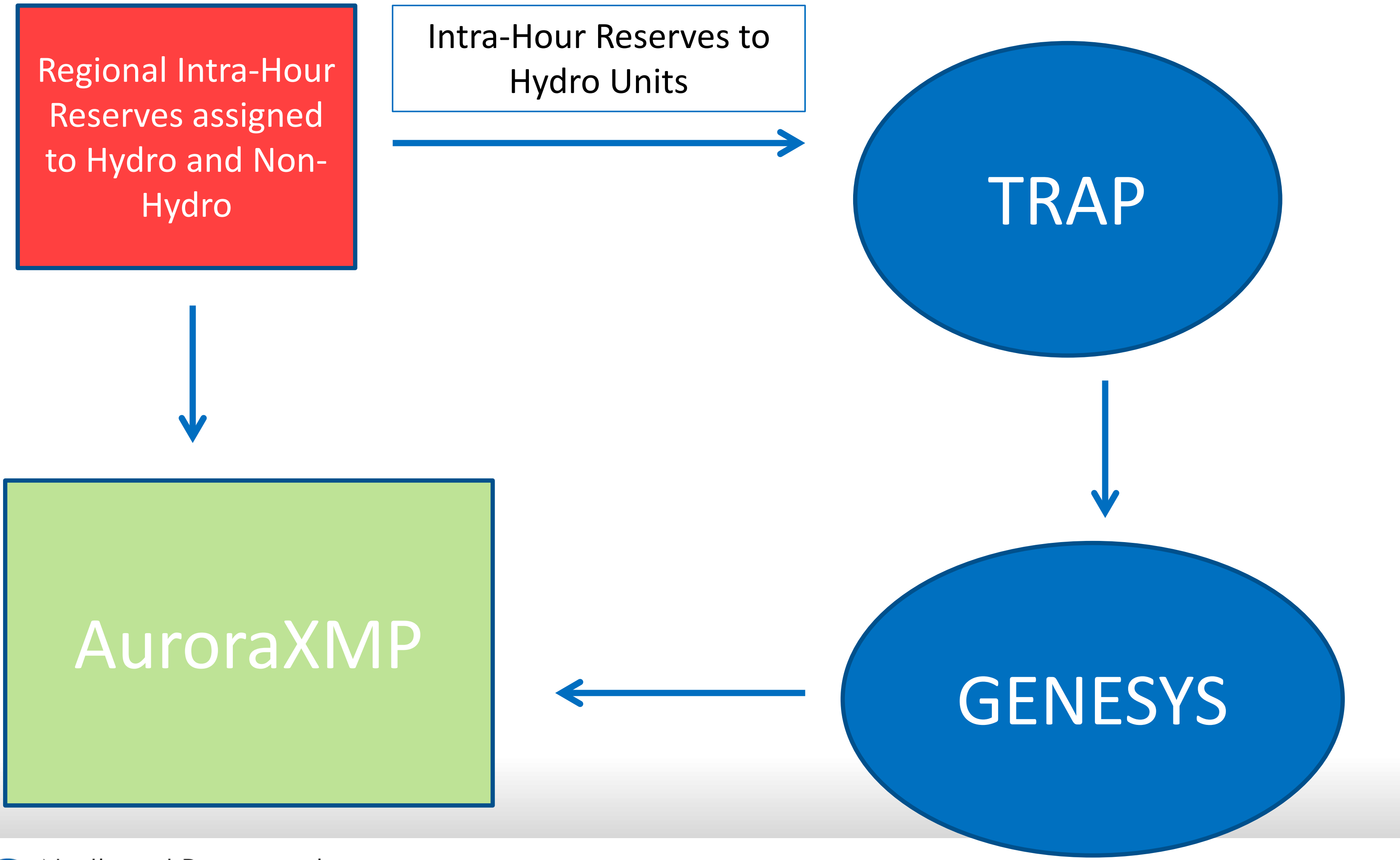
Range Available on Resources to Meet Reserve Requirements

- Hydro and Thermal units have a wide variety of operational capabilities including ramping, fuel supply/constraints, available transmission, and operating range of the generator.

Known Issues with Reserve Assignment

- Reserve Distribution: In Region
  - *Based on anecdotal information in IRP's and Staff judgment.*
  - *Unregulated hydro not counted in reserve provision.*
- Reserve Assignment: Out of Region, in WECC
  - *Probably mostly assigned to Non-Hydro except certain BA's like SMUD that have hydro resources.*
  - *Currently only contingency reserves are held explicitly.*
- Seasonality
  - *In operations, reserves are probably assigned differently by season (Spring Runoff considerations, etc.). Only Winter and Summer seasonal information available in PNNL dataset.*

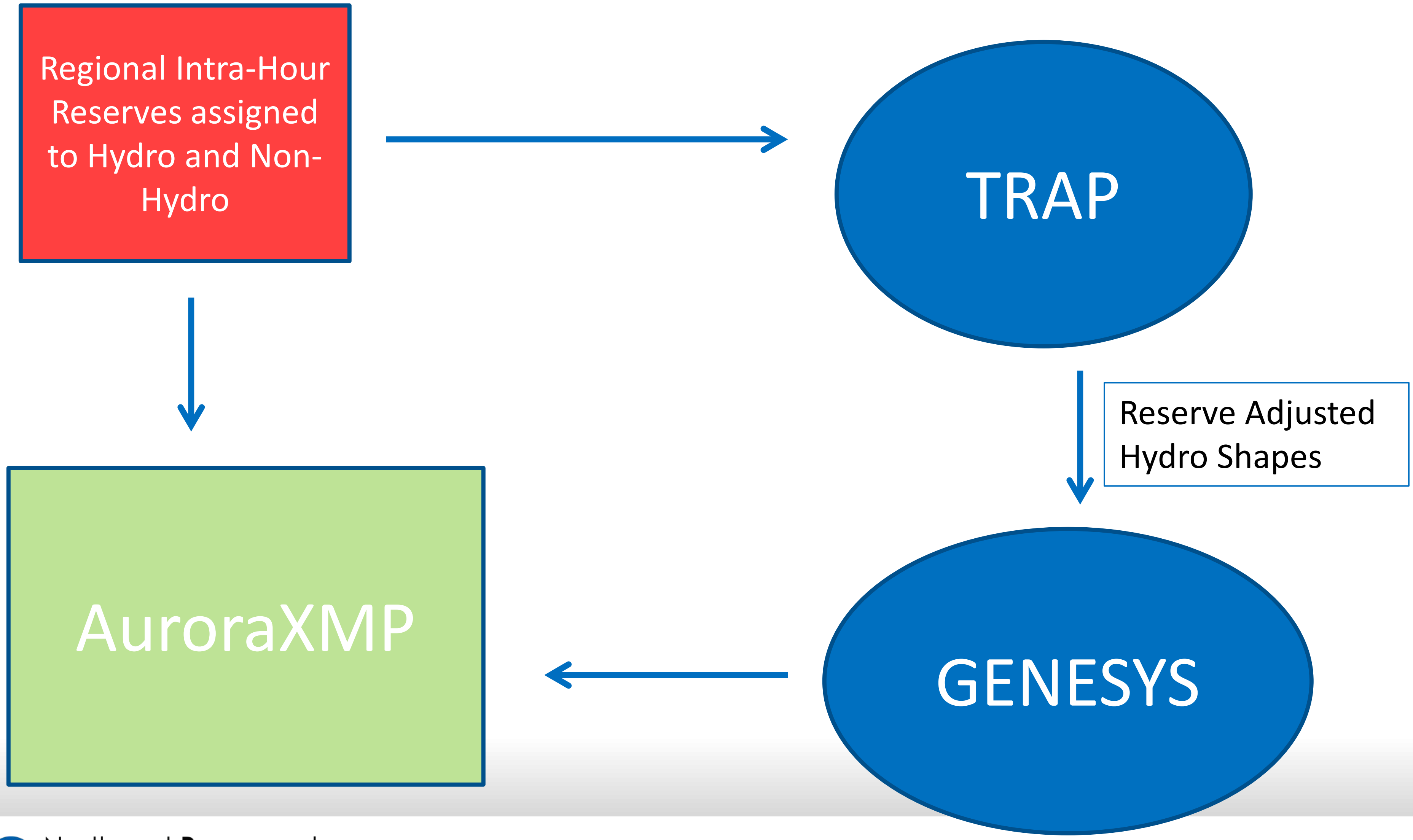
Proposed Methodology



TRAP Data Input and Calculation

- TRAP takes the information about INC and DEC reserve requirements held on particular plants and raises minimum hydro capability to account for DEC and lowers maximum hydro capability to account for INC reserves while pushing as much generation as possible into on-peak hours.
- Calculations repeated to determine 2, 4 and 10 hour max and min generation levels for each of the 14 hydro periods (Monthly, with 2 periods in April and August).

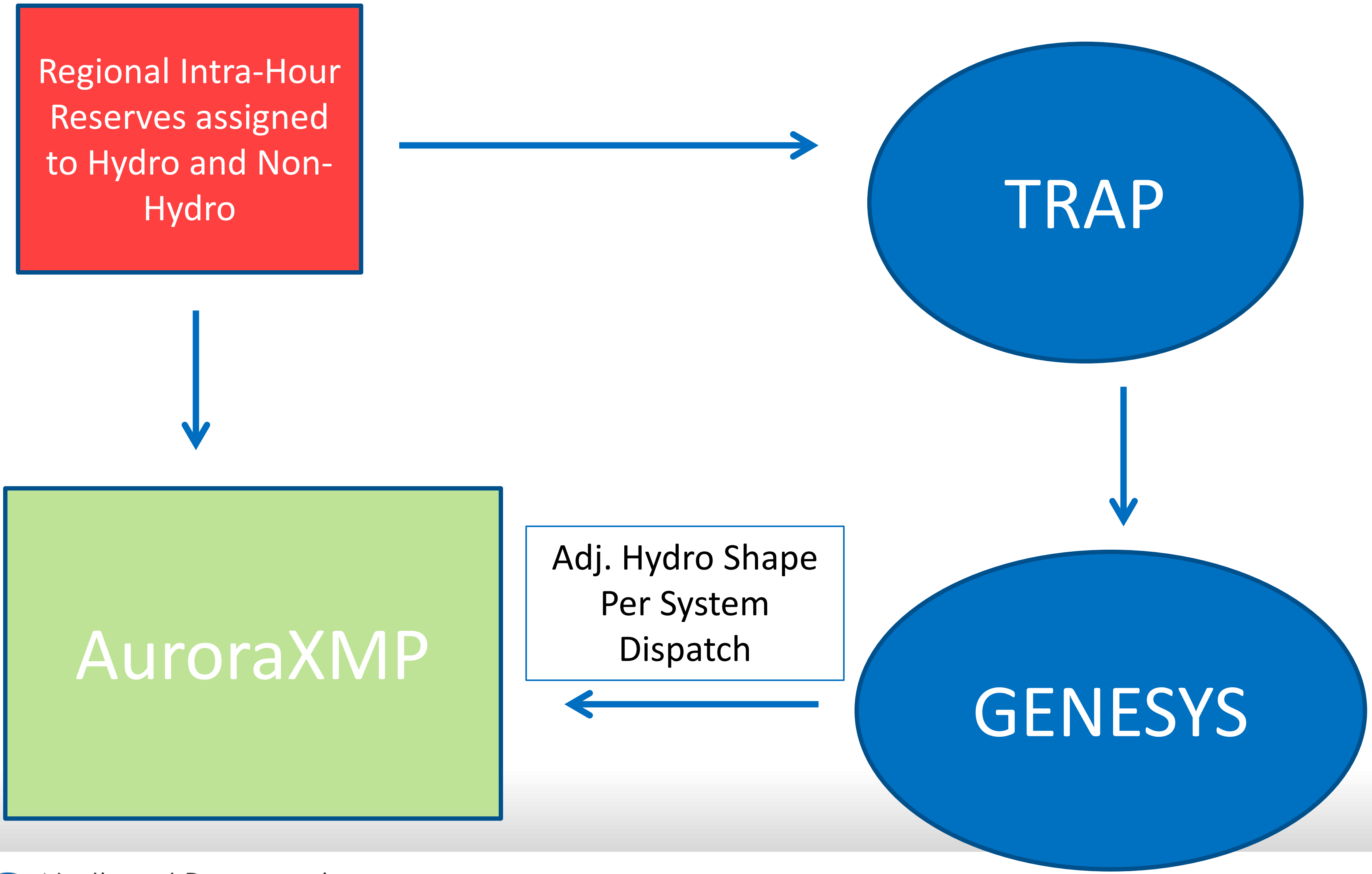
Proposed Methodology



GENESYS Data Input and Calculation

- GENESYS takes the 2, 4, and 10 hour reserve adjusted max and min generation constraints for all 14 periods, and develops hourly hydro flows for each of the 80 water years.
- The hourly hydro shaping for a particular simulation considers the sampled hourly load and wind generation data, a simple resource stack of other non-hydro resources, and any other flow/spill information not in TRAP.

Proposed Methodology



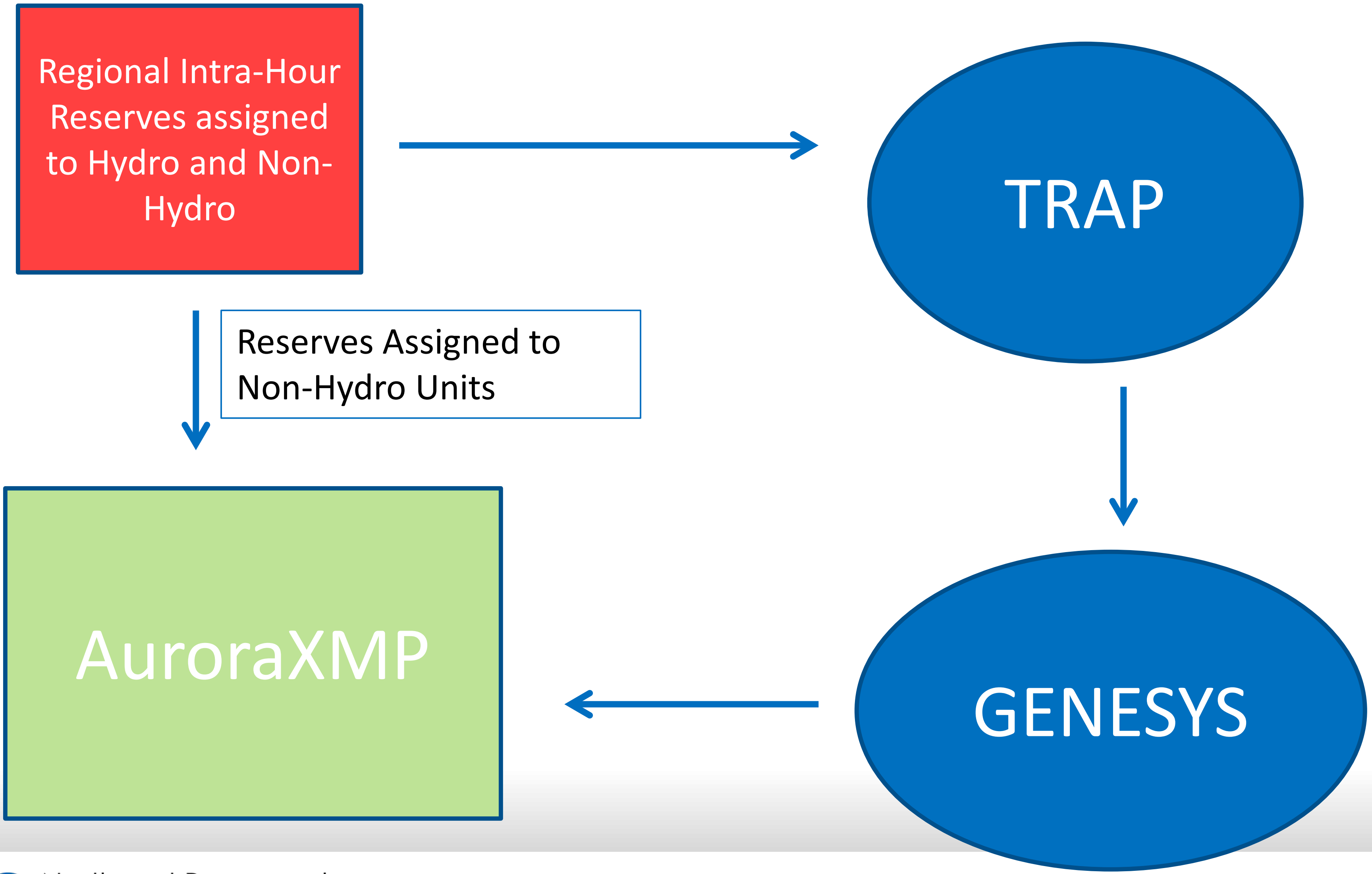
Aurora Inputs from GENESYS

- GENESYS will output an hourly hydro shape for a particular sample year of load, hydro and wind.
  - Staff proposes doing 80 sample years to start.
- Hourly loads and wind data can be input to Aurora, and hydro ranges for Aurora dispatch can be derived by taking the max and min of the hourly hydro generation during each on and off peak period.
  - *This will limit Aurora's ability to dispatch hydro within a tight band, but will still allow for some flexibility in the Aurora hydro dispatch.*
  - *Hourly data sets ($Load_i$, $Wind_i$, $HydroMax_i$, $HydroMin_i$) where,*

    $HydroMax_i = Max(HourlyHydroGen_i \{on/off\ peak\})$

    $HydroMin_i = Min(HourlyHydroGen_i \{on/off\ peak\})$

Proposed Methodology



Aurora Non-Hydro Inputs and Dispatch

- Assign the remaining operating reserve requirements to the previously identified non-hydro reserve carrying units in the region.
- Utilize AURORAxmp to determine *marginal unit* within the region for each of the 80 simulations
  - The *marginal price* is based on the variable cost of any discretionary energy or load following down above the minimum generation segment.
  - During dispatch, Aurora will also assign contingency reserves (spinning and supplemental) to the appropriate units.