Regional Resource Adequacy Program Footprint PRM Study

COMPARATIVE IMPACTS ON PLANNING RESERVE MARGIN (PRM) OF ALTERNATIVE REGIONAL RESOURCE ADEQUACY FOOTPRINTS

PREPARED BY

John Tsoukalis
Kai Van Horn
Linquan Bai
Evan Bennett
Bo Li
Jack Kalinski
Alison Savage Brooks
Drew Kassman

PREPARED FOR

- PacifiCorp
- NV Energy
- PGE
- PNM
- Idaho Power, An IDACORP Company
- Seattle City Light
- SMUD
- Los Angeles Department of Water & Power (LADWP)
- Balancing Authority of Northern California

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Brattle

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Study Overview

Regional RA Programs Create Value by Unlocking Regional Diversity

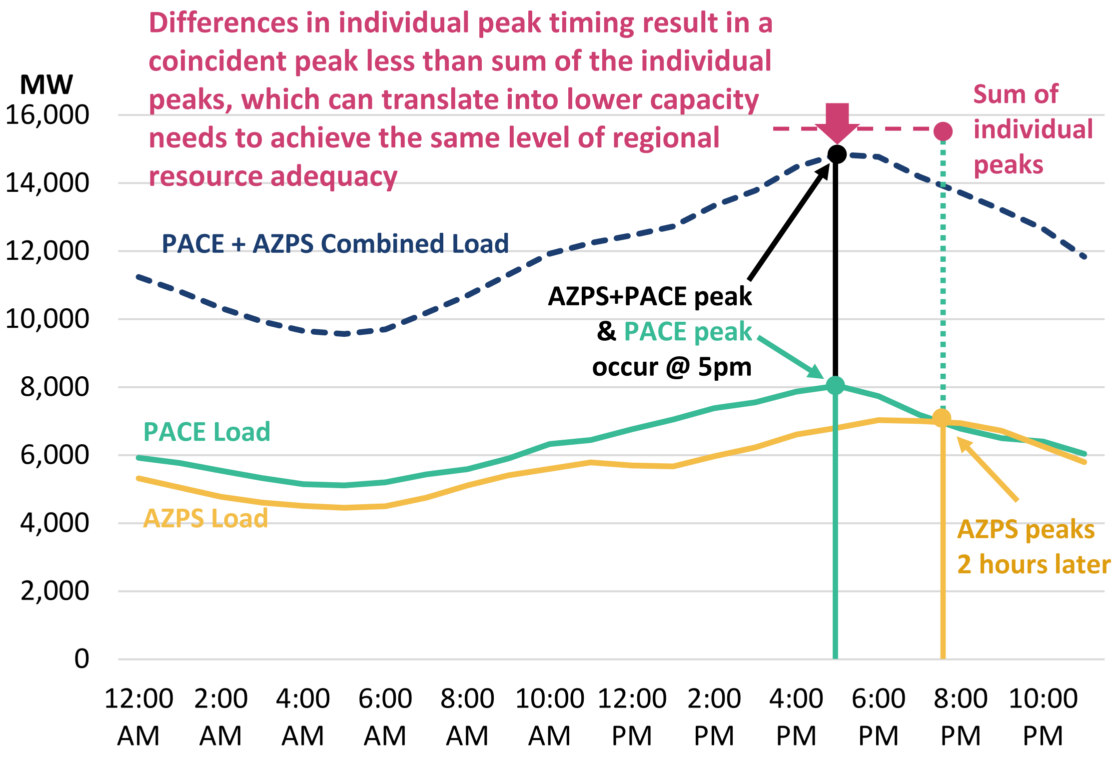
Regional Resource Adequacy (RRA) programs can reduce capacity requirements for participating utilities by leveraging load, or net load **diversity savings** achieved with increasing geographic scope:

- Regional diversity savings represents the potential reduction in needed capacity to meet peak load or net peak load due to the non-coincidence of individual utility peaks and resource diversity in a region
- Diversity savings tends to increase with the size of the region
- Greater diversity may reduce PRMs while maintaining the same level of resource adequacy (e.g., 1 event-day in 10 years)

Diversity Savings Example

For a Single Day With Two Balancing Authorities

Actual Gross Load for July 10th, 2024



Source: EIA 930 BA-level load data

Notes: Example shows gross peak load diversity only for clarity; higher renewables diversity across a regional RA program footprint can also produce PRM reductions through peak net load diversity savings.

Summary

The Study Group engaged the Brattle Team to assess potential impacts on Planning Reserve Margins (PRMs) of the WRAP vs an alternative RA program footprint to answer the question:

Would a regional RA program that included the study group be likely to yield lower planning reserve margins (PRMs) for those entities than they would be subject to under WRAP (i.e., in the WRAP subregions)?

To do so, we conducted a detailed PRM Analysis for four regional RA footprints:

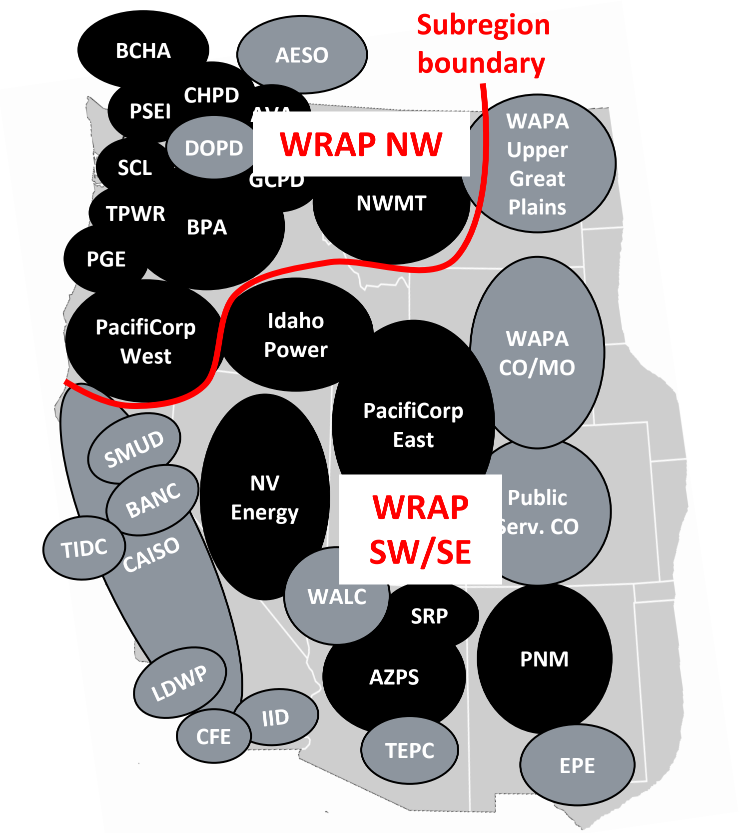
- Undertook RA modeling and analysis of historical data to replicate the WRAP approach to assessing Qualified Capacity Contribution (QCC) and PRM
- Used the results of the RA simulations and historical analysis to assess the impact of program footprint on participant PRMs for the Winter 2027/2028 and Summer 2028 binding seasons

Regional Resource Adequacy (RRA) Footprint Scenarios

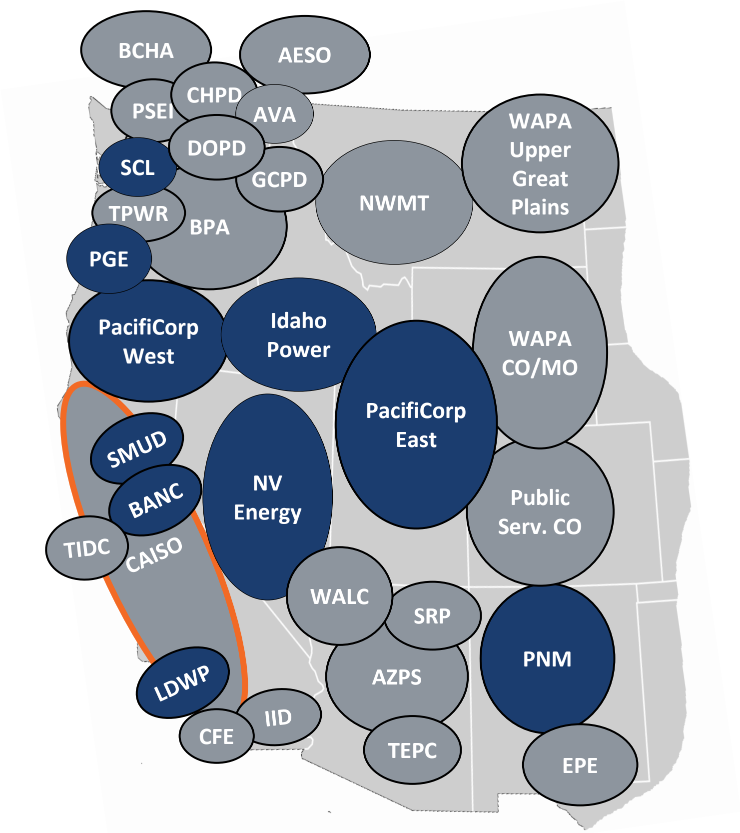
We assessed PRM for four RRA footprints:

- **WRAP (3 footprints)**: WRAP NW and WRAP SW/SE subregions, and the full WRAP footprint
- **EDAM-focused (1 footprint)**: All study participants together (Non-CAISO EDAM)

WRAP



Non-CAISO EDAM



WRAP Members
(at time of study)

Study Participants

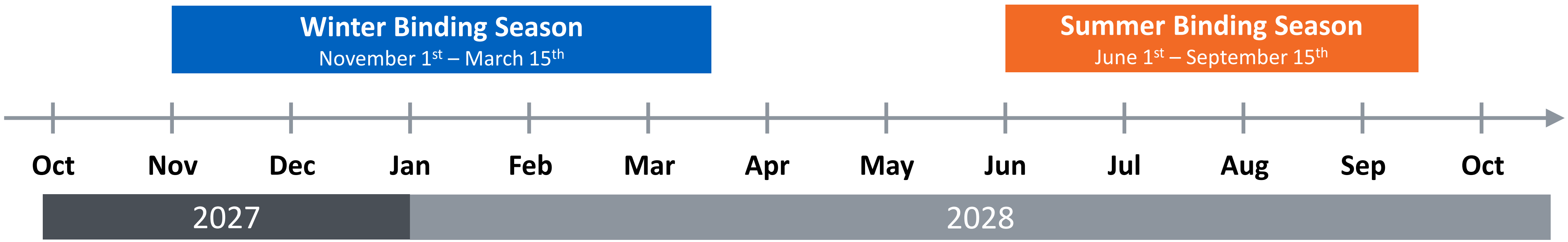
Other BAAs

We also simulated 18 subregional "VER zones" for our QCC analysis (see appendix for details).

Time Scope of Analysis

We simulated the Winter 2027/2028 and Summer 2028 binding seasons, with modeled load and resources reflecting those periods

- We conducted all analysis on an hourly basis, with metrics calculated monthly or seasonally (as appropriate) to align with WRAP-defined methodologies*
  - We conducted hourly PRM and ELCC simulations for each of the WRAP-defined summer and winter binding seasons to establish perfect capacity needs to meet seasonal LOLE target
    - Monthly perfect capacity adjusted in PRM simulations to target monthly minimum LOLE
  - We calculated regional PRMs on a seasonal and monthly basis
  - We calculated Unit-level QCCs on a monthly basis using hourly historical data and the results of ELCC simulations



* Note: We have adopted the WRAP approach for this study but note that the approach could be improved to more accurately measure resource adequacy requirements.

Our PRM Analysis Replicated the WRAP PRM Methodology

We conducted a combination of historical analysis and detailed RA simulations to assemble the needed QCC and peak load values that underly the WRAP PRM calculation

Capacity Critical Hours
95th percentile of regional net capacity need
Net load = load – wind – solar – RoR - interchange

ELCC Simulations
Target: 1 event-day in 10 years per binding season

PRM Simulations
Targets:
- *1 event-day in 10 years per binding season*
- *Minimum 0.1 event-days in 10 years in each month in binding seasons*

Forecasted Load
Monthly load forecasts for each month in the binding seasons, for each footprint and BA

RA Simulations

Historical-based data analysis

PRM calculations

Unit & Class-Level QCCs
Unit performance during CCHs and adjusted ELCC

Regional PRMs

Areas for Improvement in the WRAP methodology

We identified areas where the WRAP forward showing study methodologies include simplifications that may over- or under-state RA risks:

- **Transfer of capacity within each studied region is unrestricted**
  - I.e., each simulation focuses on a single "bubble", with no internal transmission limits
  - Applies to WRAP subregions and VER zones
  - May understate transmission-driven RA risks
- **Non-firm imports into studied regions *not* considered in PRM and ELCC simulations**
  - Only firm capacity contracts into or out of studied regions are considered
  - Non-firm transfers are considered when identifying CCHs and resource QCCs, but only as a second order effect—the RA value of non-firm imports is not specifically assessed in simulation, which may overstate resource adequacy risks
- **Uses static outage rates for thermal plants**
  - Static outage rates may understate RA risks (e.g., due to higher outages during heat waves or cold snaps)
  - Actual forced outage rates for thermal generators can vary considerably with temperature
- **ELCC study regions for wind and solar differ from the PRM study regions (VER zones vs WRAP subregions)**
  - The RA contributions of wind and solar to meeting PRM criteria may differ from those calculated in the ELCC simulations
    - Wind/Solar RA values tend to be lower in the VER zones vs in the WRAP subregions due to lower regional diversity
  - This can lead to inconsistency in the PRM calculation between the perfect capacity need to meet the RA criterion and the QCC of wind & solar
- **Represents pondage hydro as available at monthly qualified capacity in all hours**
  - May understate hydro flexibility and the ELCC of hydro, and consequently overstate the ELCC of other flexible resources, e.g., battery storage
  - Does not capture correlations between water availability and other weather scenario variables, which may over- or under-state RA risks

Summary of Findings

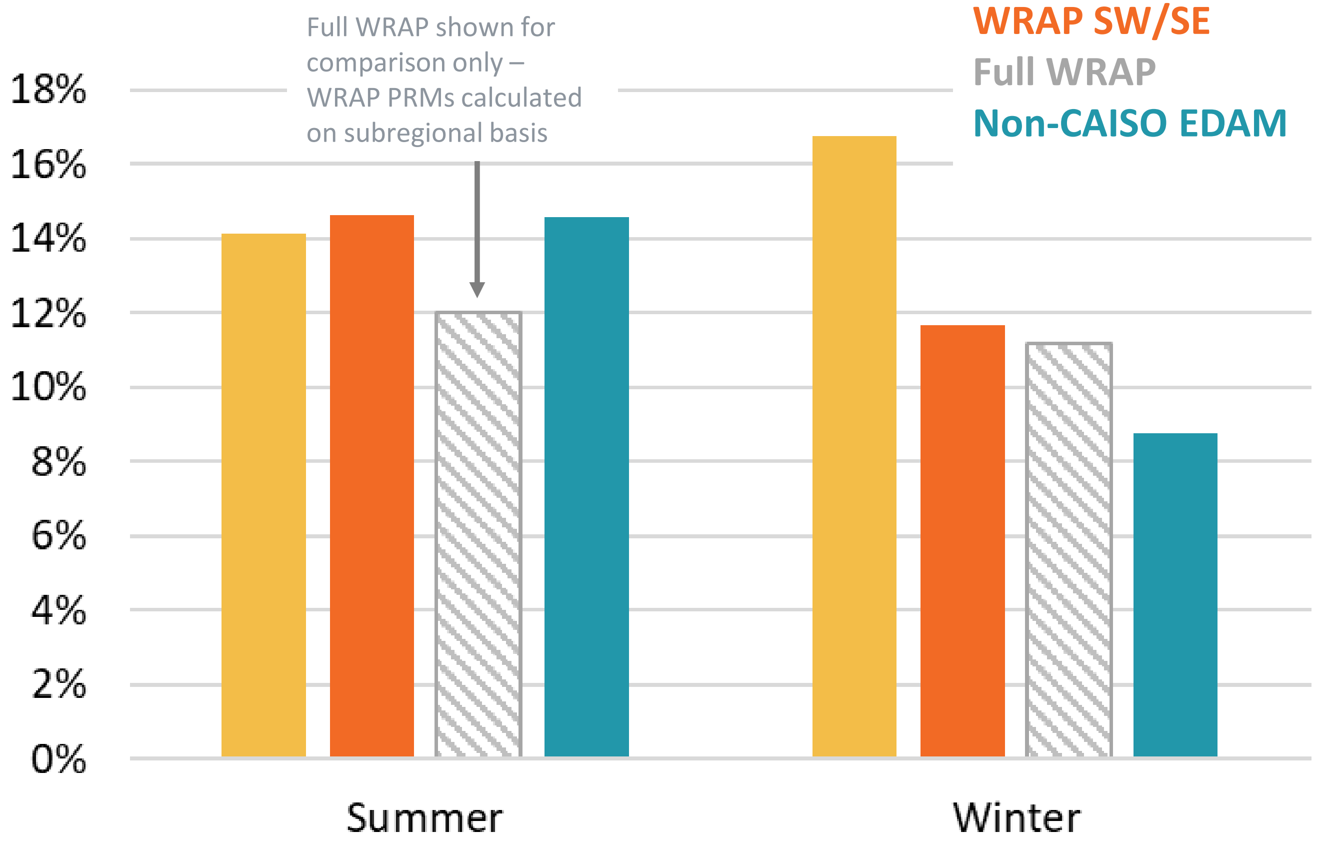
Seasonal PRM Results

Our analysis of regional PRMs, including detailed analysis of wind, solar, and battery storage ELCCs yields:

- **Summer**
  - Similar PRMs for WRAP and non-CAISO EDAM footprints, reflecting similar summer RA risk profiles
  - Summer loss of load risk largely constrained to evening hours and driven by availability of storage during high net load events and opportunities to charge storage in advance of those events
- **Winter**:
  - Lowest PRMs for the Non-CAISO EDAM among the footprints studied, reflecting fewer periods of risk
  - Winter loss of load risk also present into the evening and in the morning for WRAP NW and SW/SE, adding to the demands on storage resources and the frequency of high net load events in those footprints

Simulated Seasonal PRM by Footprint

% of footprint p50 peak



Note: Seasonal PRMs shown are the weighted average of season monthly PRMs, weighted by monthly QCC & peak.

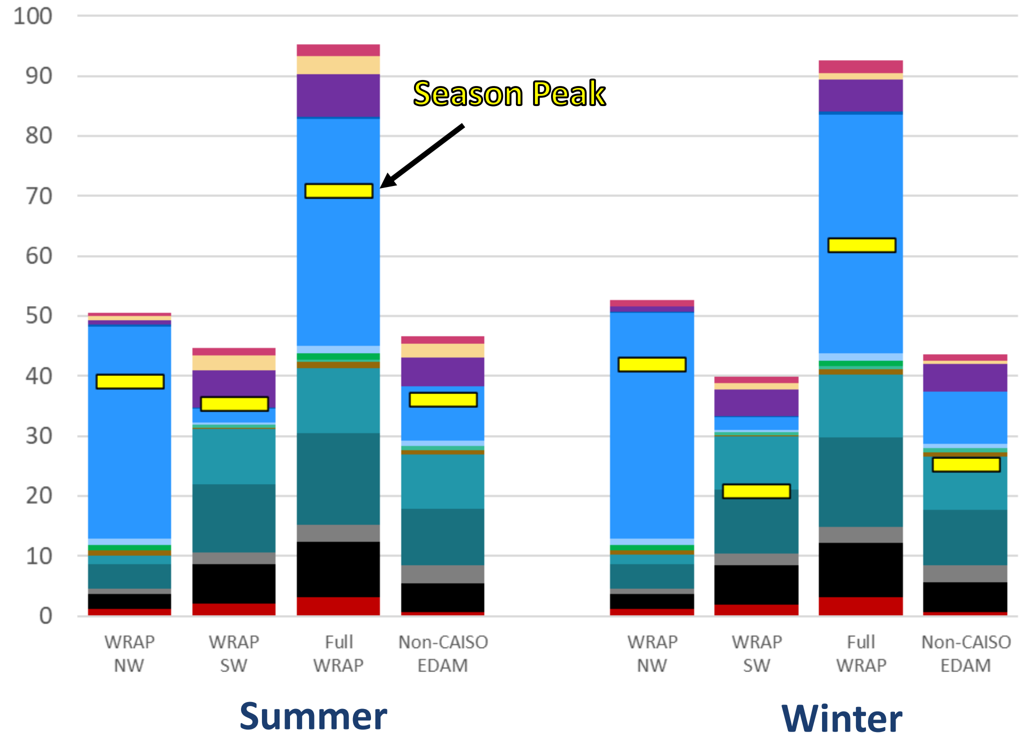
Regional Load and Resource Balance

Relative balance of footprint peak and QCC, and the types of QCC, influences the nature of the risk in each region

- A higher proportion of thermal resources can amplify outage risks vs a higher proportion of storage which can amplify net load and storage endurance/charge availability risks and shift the timing of risks

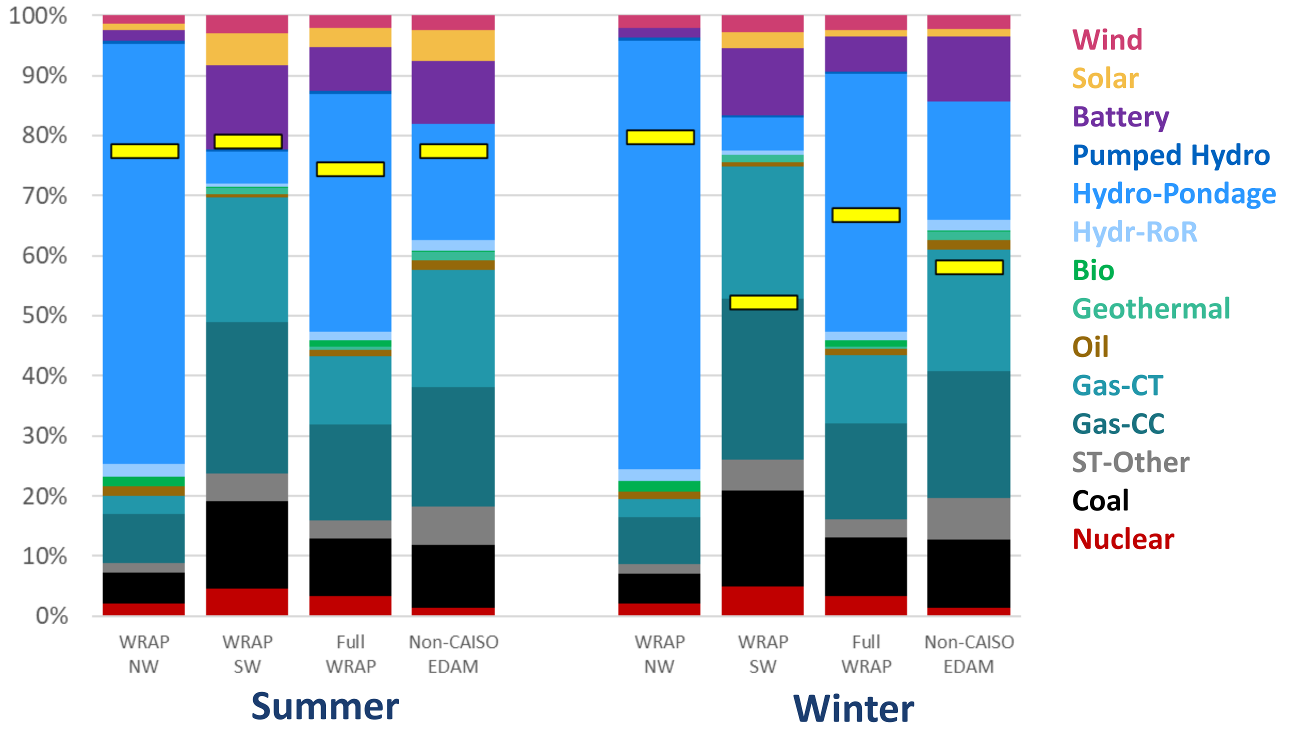
QCC by Footprint and Resource Type

GW of total footprint QCC



QCC Composition by Footprint and Resource Type

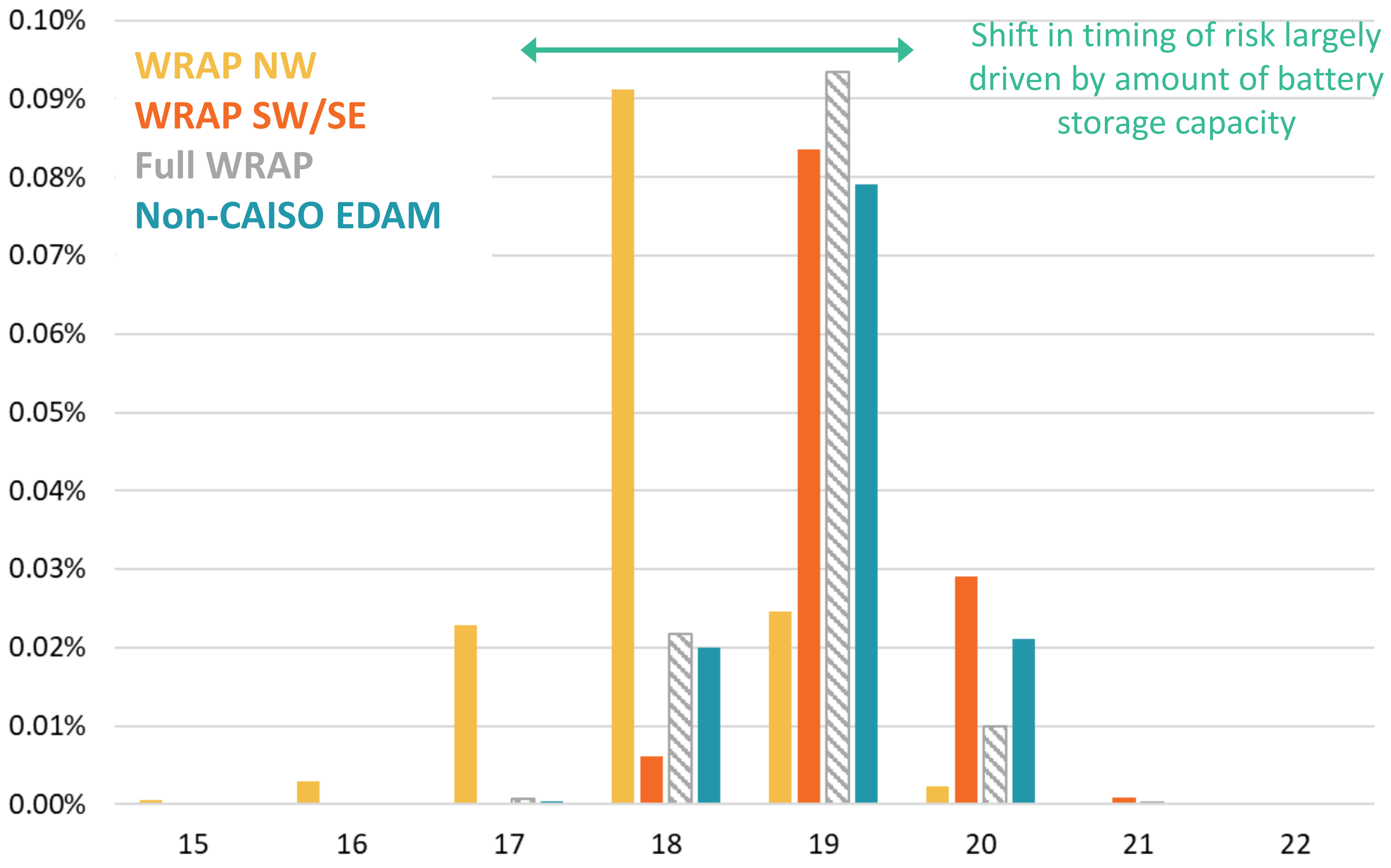
% of total footprint QCC



Note: Charts show average monthly seasonal QCC by type footprint, but maximum seasonal load.

Summer Loss of Load Risk Hours

Simulated Summer LOLP by Footprint
Probability of shortfall by hour of day



Note: For clarity, excluding hours of day with no LOLP; Full WRAP shown for comparison only – WRAP PRMs calculated on subregional basis.

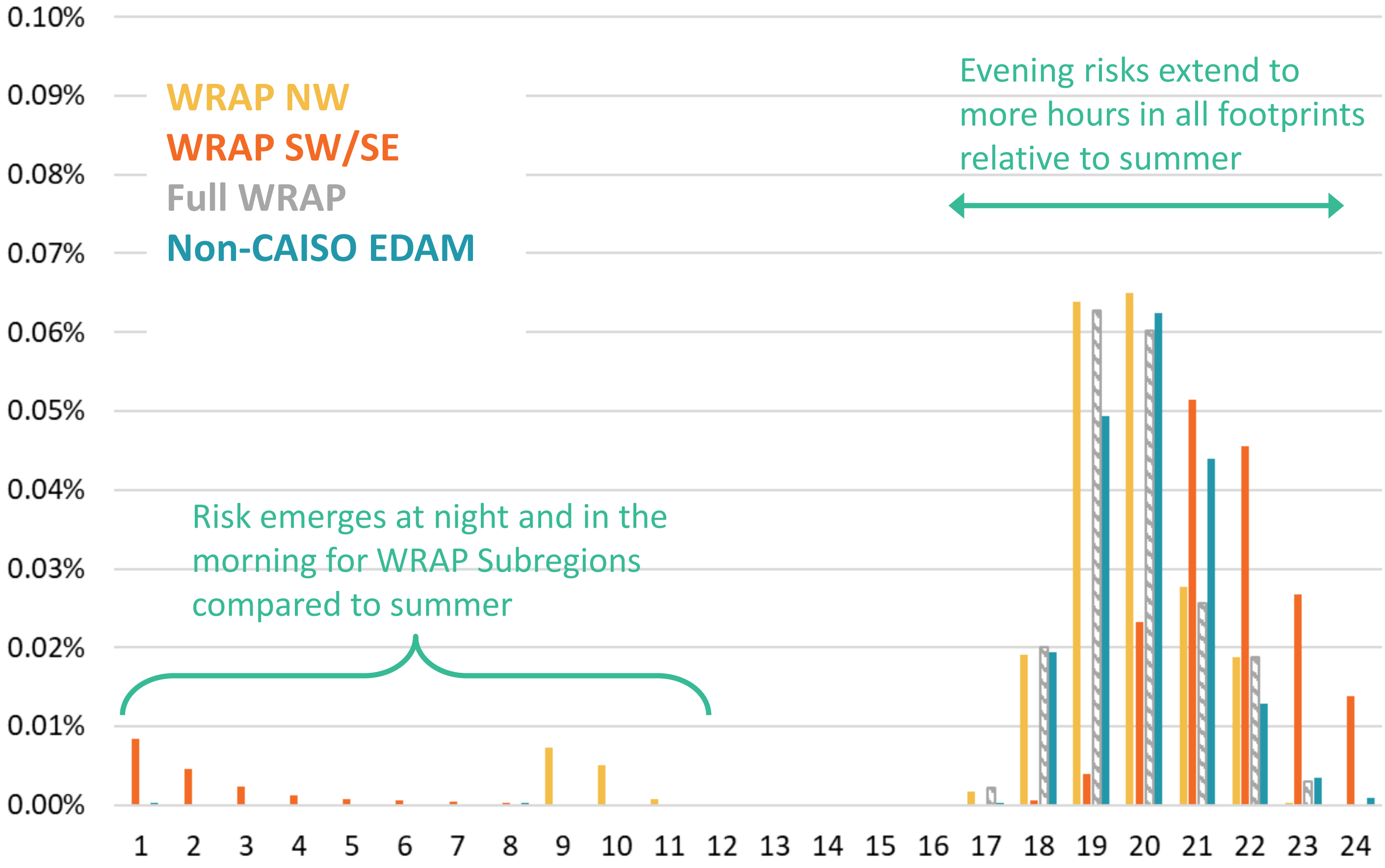
Summer loss of load risks are concentrated in the evening across footprints, when load remains high but solar output has declined

- We find this dynamic occurs consistently across footprints, though is time shifted in the NW relative to other footprints due to differences in timing of the net load peak and amount of battery storage in each footprint
- WRAP NW risks also driven by wind availability—wind tends to be lower in the early evening driving higher net loads as solar resource output declines and load remains high

Winter Loss of Load Risk Hours

Simulated Winter LOLP by Footprint

Probability of shortfall by hour of day



Note: Full WRAP shown for comparison only – WRAP PRMs calculated on subregional basis.

As in the summer, winter loss of load risks are concentrated in the evening, but extend over more hours

- These longer periods of risk account for the lower ELCC of storage during winter months for most footprints

We also see loss of load risks emerge in at night and in the morning in all but the Non-CAISO EDAM footprint, due to the dual morning/evening peak of winter load profiles

- The lack of morning risk in Non-CAISO EDAM vs WRAP SWSE is one driver of the lower winter PRMs in Non-CAISO EDAM

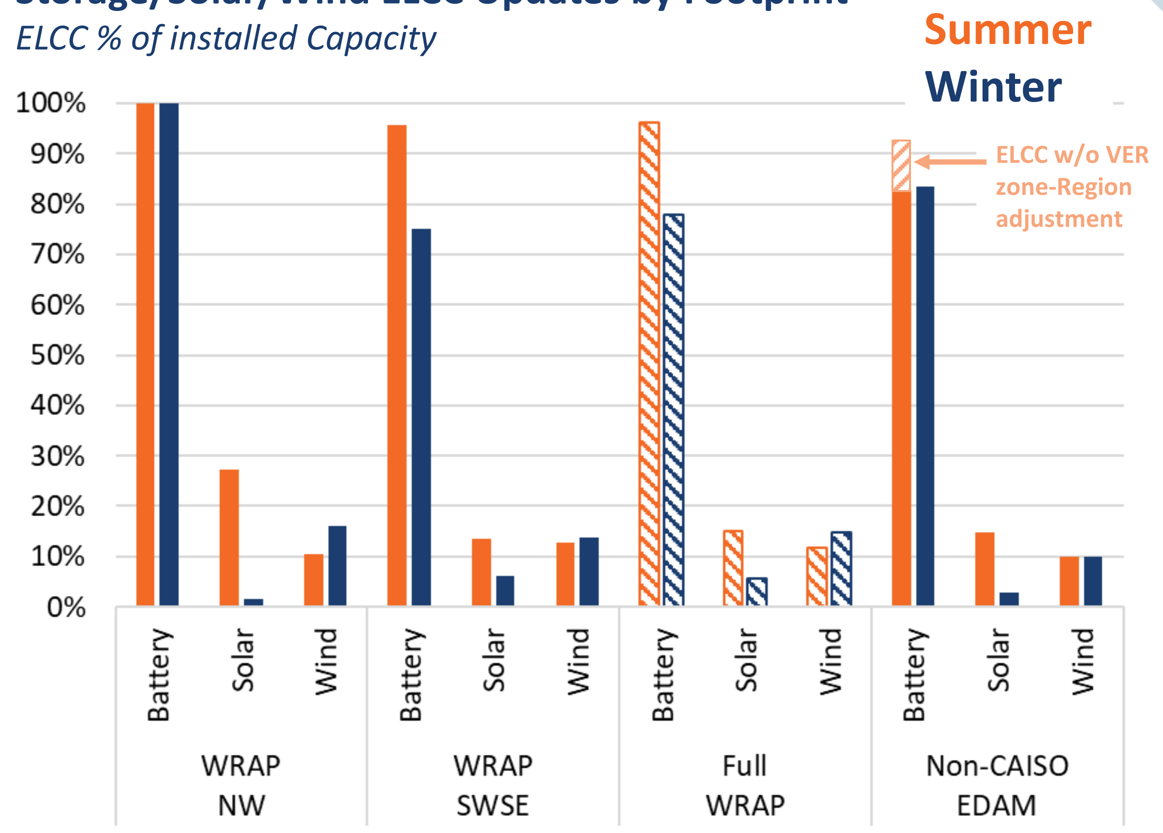
Regional ELCC Summary

ELCC results for battery storage, solar, and wind illustrate typical seasonal RA dynamics for these resource types:

- The additional challenges of meeting longer periods of high net load in the winter are revealed through lower winter storage ELCCs
  - VER-zone level ELCC results show a similar gap between summer and winter for Non-CAISO EDAM as the WRAP footprints, but the summer ELCC shown in the figure is additionally scaled down under WRAP methodology to align footprint-wide and VER zone ELCCs
- Solar ELCCs are significantly lower in the winter than summer in all regions, consistent with the timing of load peaks & availability of solar in summer vs winter
- Wind ELCC tend to be higher in the winter, consistent with the generally higher availability of wind in winter months across WECC

Storage/Solar/Wind ELCC Updates by Footprint

ELCC % of installed Capacity



Note: Seasonal ELCCs shown are the weighted average of resource-level season monthly ELCCs by footprint and resource type. Full WRAP ELCCs shown for comparison only – WRAP ELCCs/PRMs calculated on subregional basis.

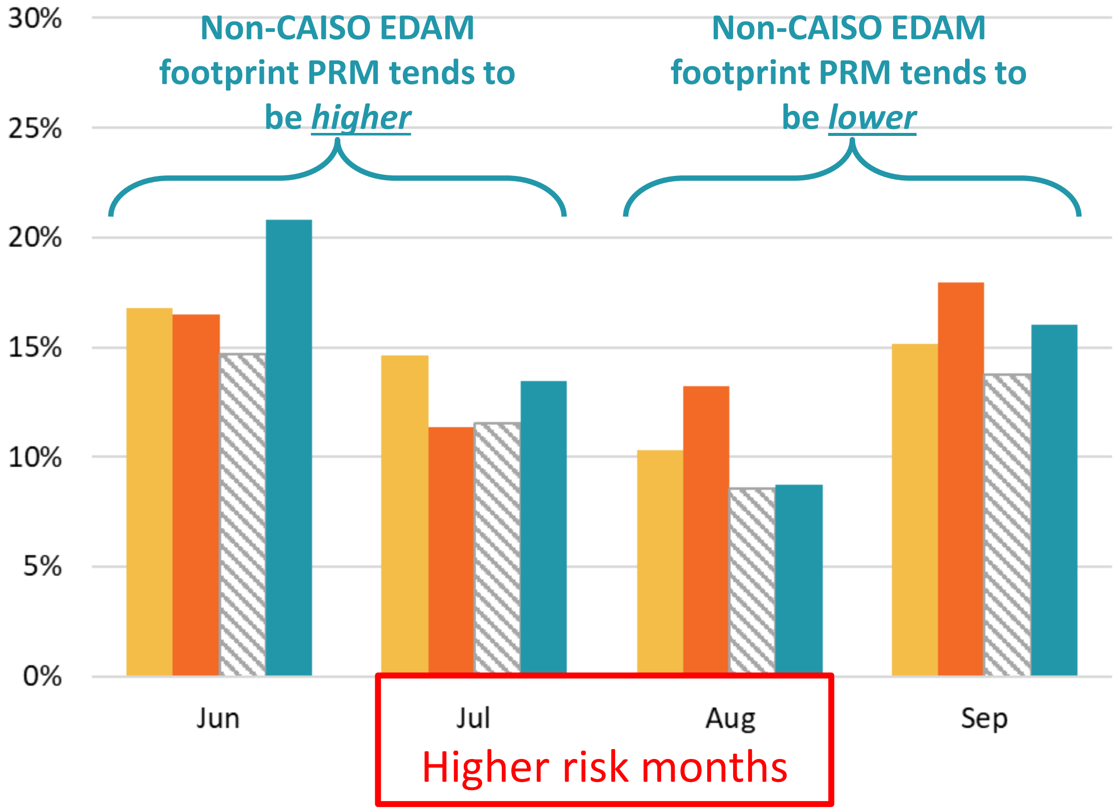
Monthly PRMs: Summer

Summer PRMs tend to be higher in Non-CAISO EDAM for the first half of summer, and lower in the second half

- PRM are similar or lower for the WRAP footprints in the higher-risk month of July, but lower for the EDAM footprint in August

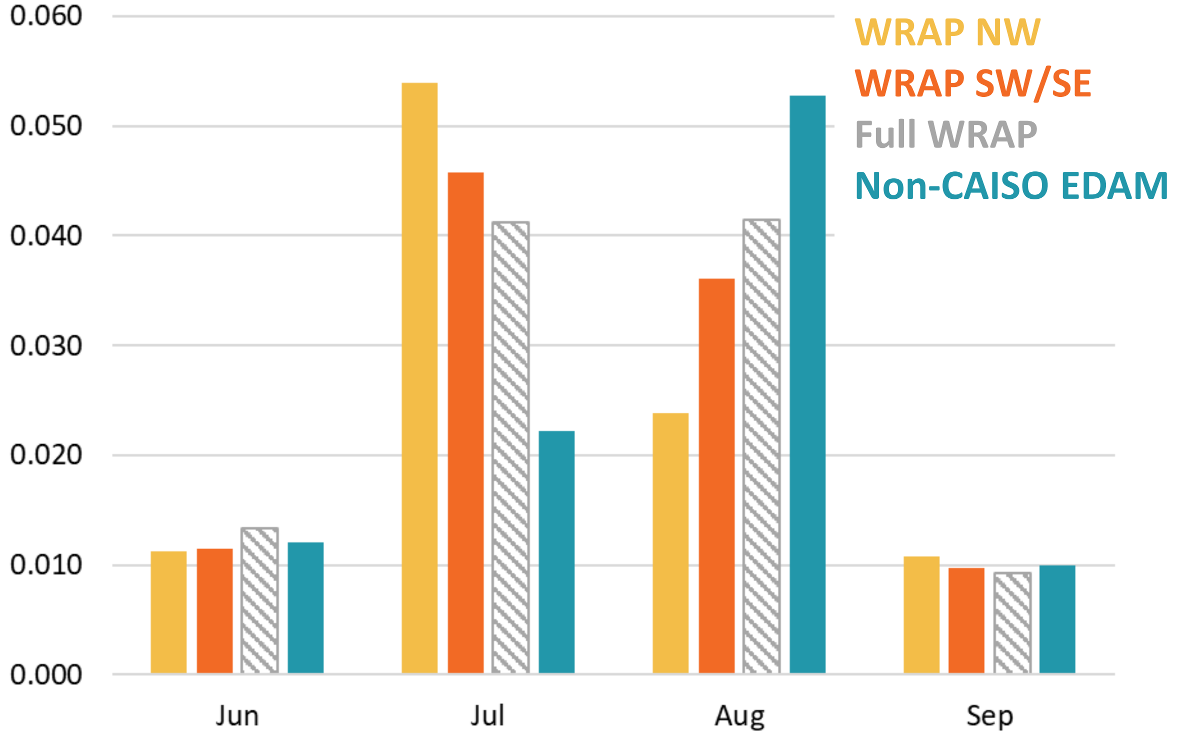
Simulated Monthly PRM by Footprint

% of footprint p50 peak



Simulated Monthly LOLE by Footprint

Days/year, expected loss of load



Note: Full WRAP shown for comparison only – WRAP PRMs calculated on subregional basis.

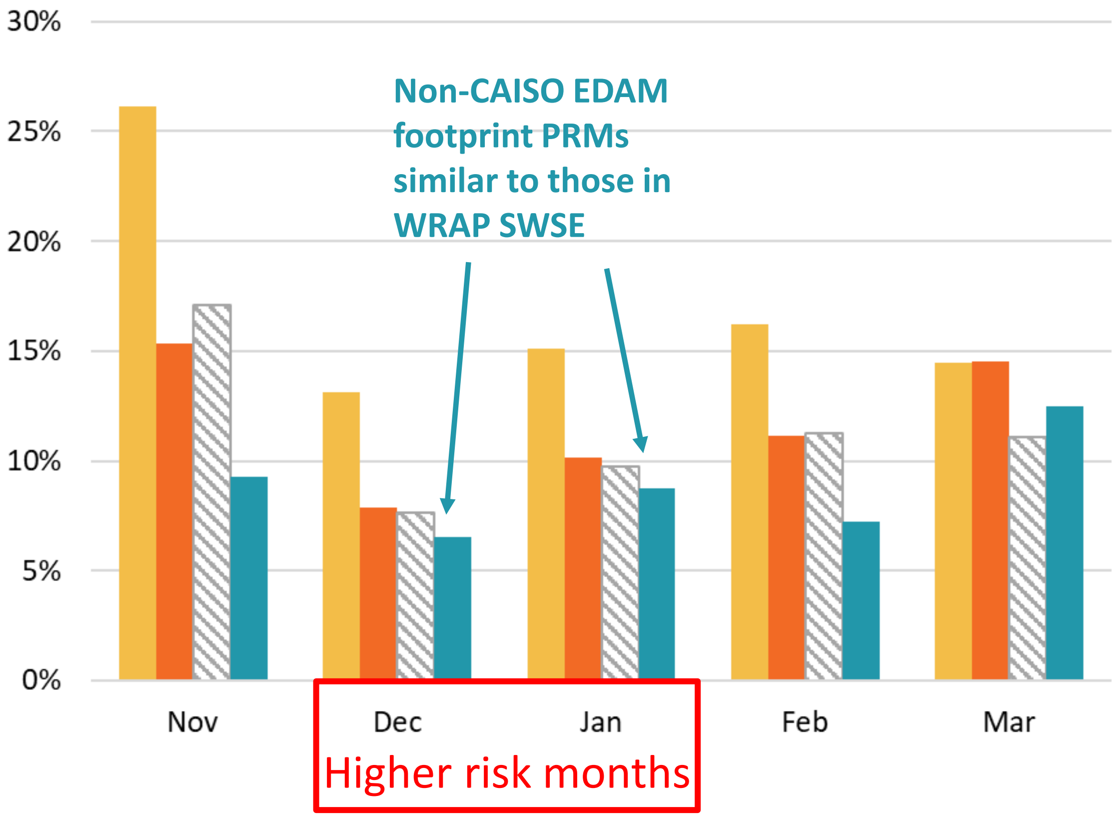
Monthly PRMs: Winter

Winter PRMs are lowest in Non-CAISO EDAM among the footprints studied

- PRMs similar between non-CASIO EDAM and WRAP SW/SE in higher-risk months, but lower for Non-CAISO EDAM in other months

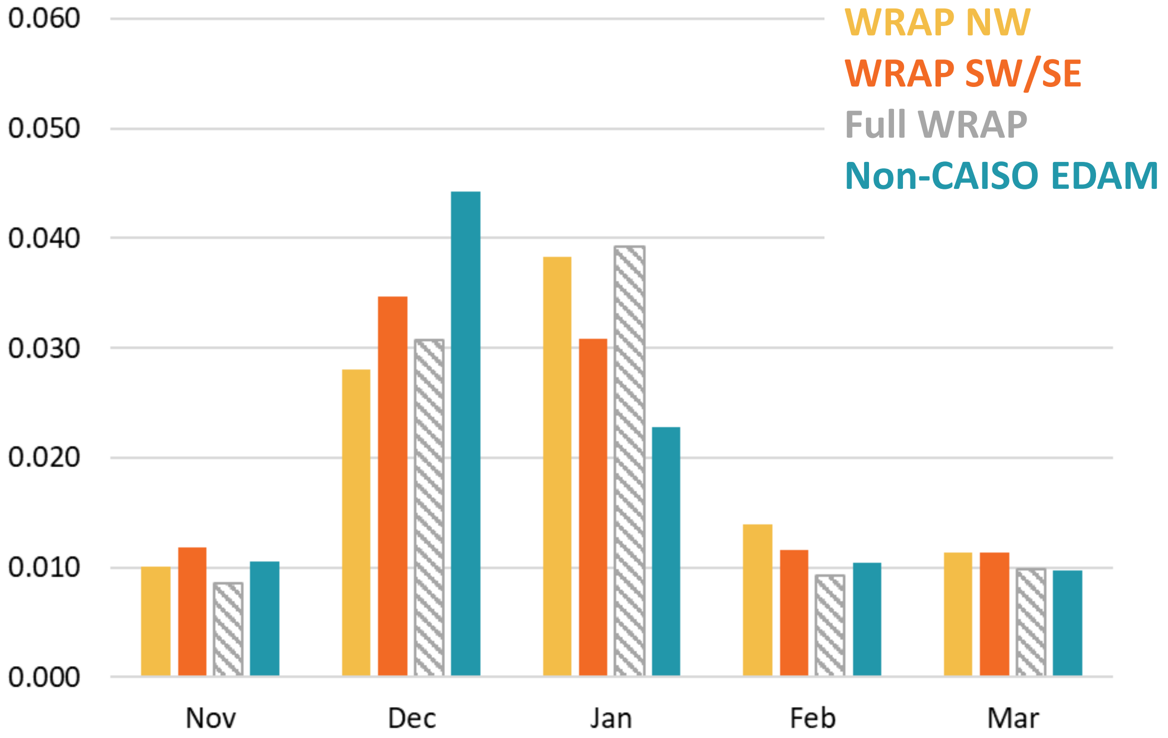
Simulated Monthly PRM by Footprint

% of footprint p50 peak



Simulated Monthly LOLE by Footprint

Days/year, expected loss of load

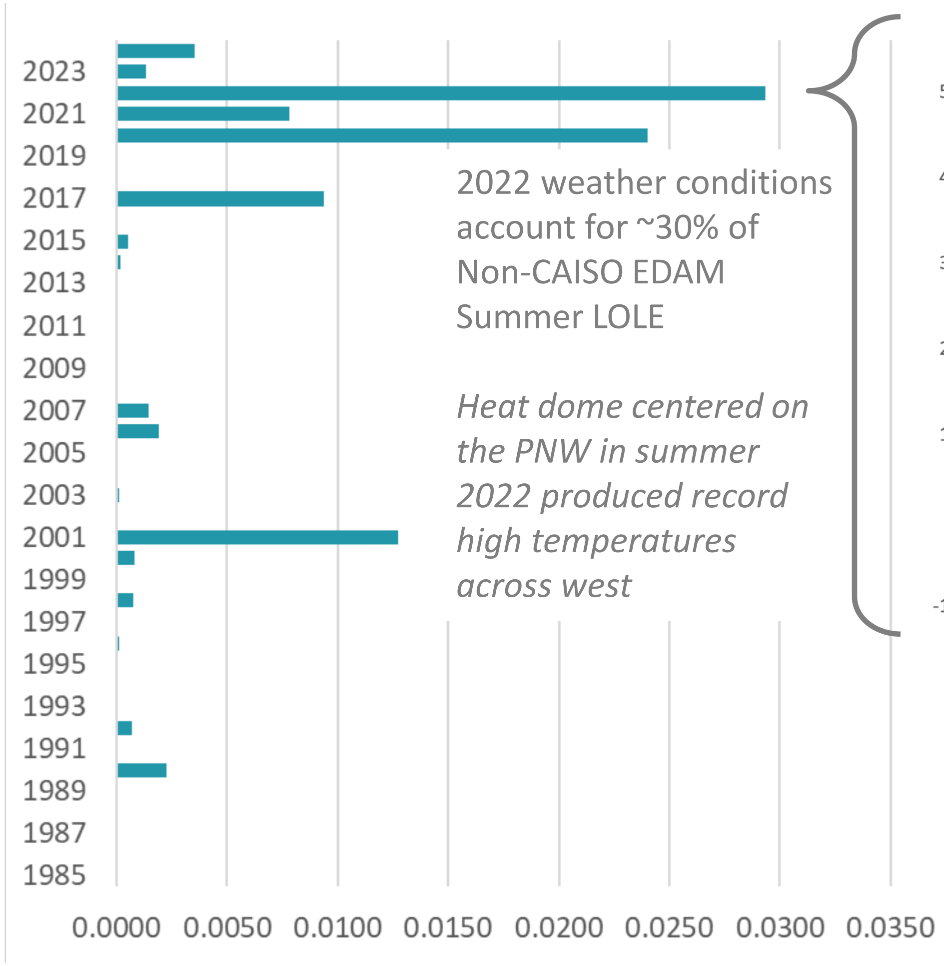


Note: Full WRAP shown for comparison only – WRAP PRMs calculated on subregional basis.

Example: Non-CAISO EDAM Summer

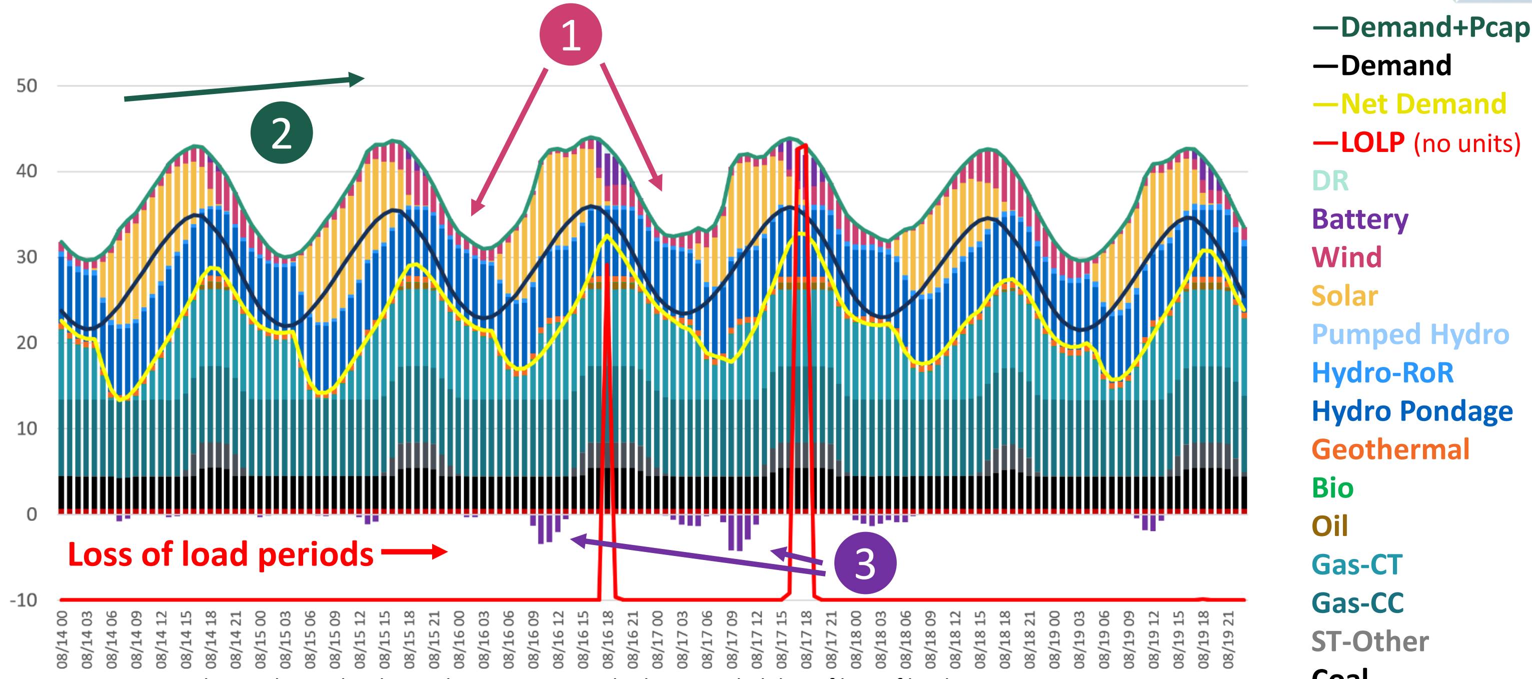
LOLE by Weather Scenario

Days/year



Simulated Dispatch For Aug. 14-19 2028 High Risk Period (2022 weather)

GW, hourly by unit type (average over outage draws)



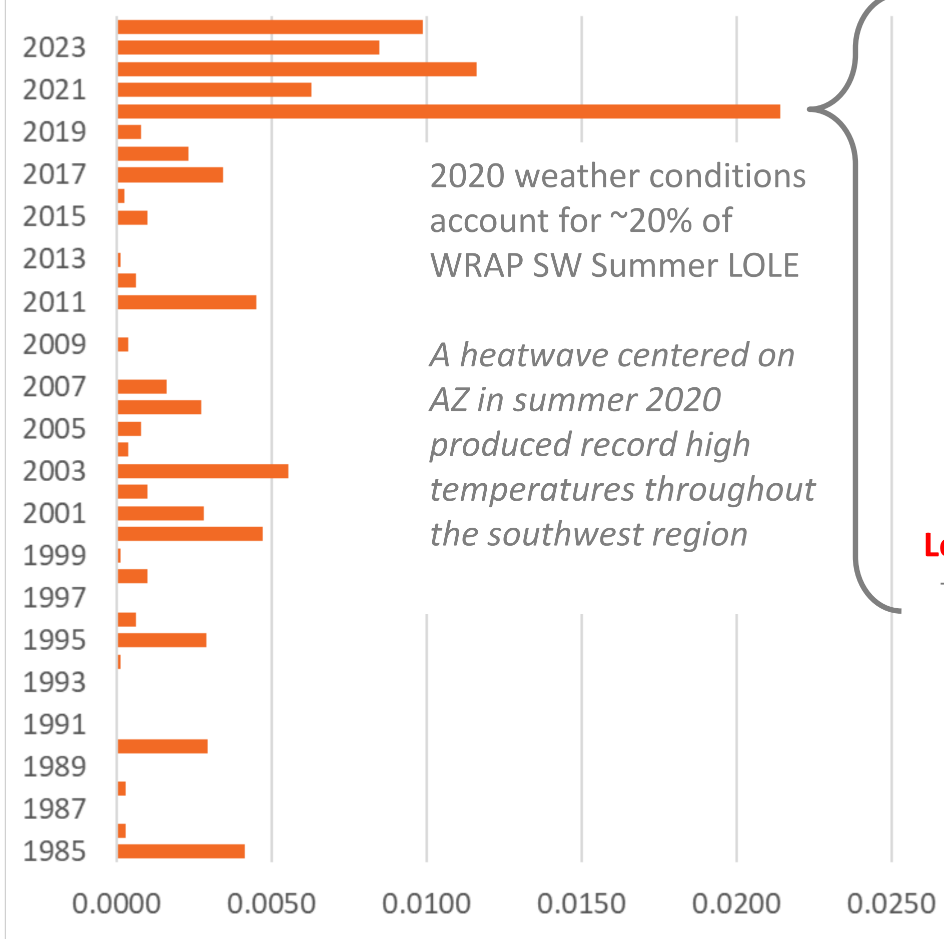
Note: LOLP scale not shown, but line indicates timing and relative probability of loss of load events.

1. Low wind output during the nights of Aug. 16th & 17th
2. Increasing evening peaks over the week due to heat wave conditions
3. Batteries unable charge enough to meet needs through duration of net load peaks, including making up for unanticipated outages (not shown)

Example: WRAP SW/SE Summer

LOLE by Weather Scenario and Footprint

Days/year

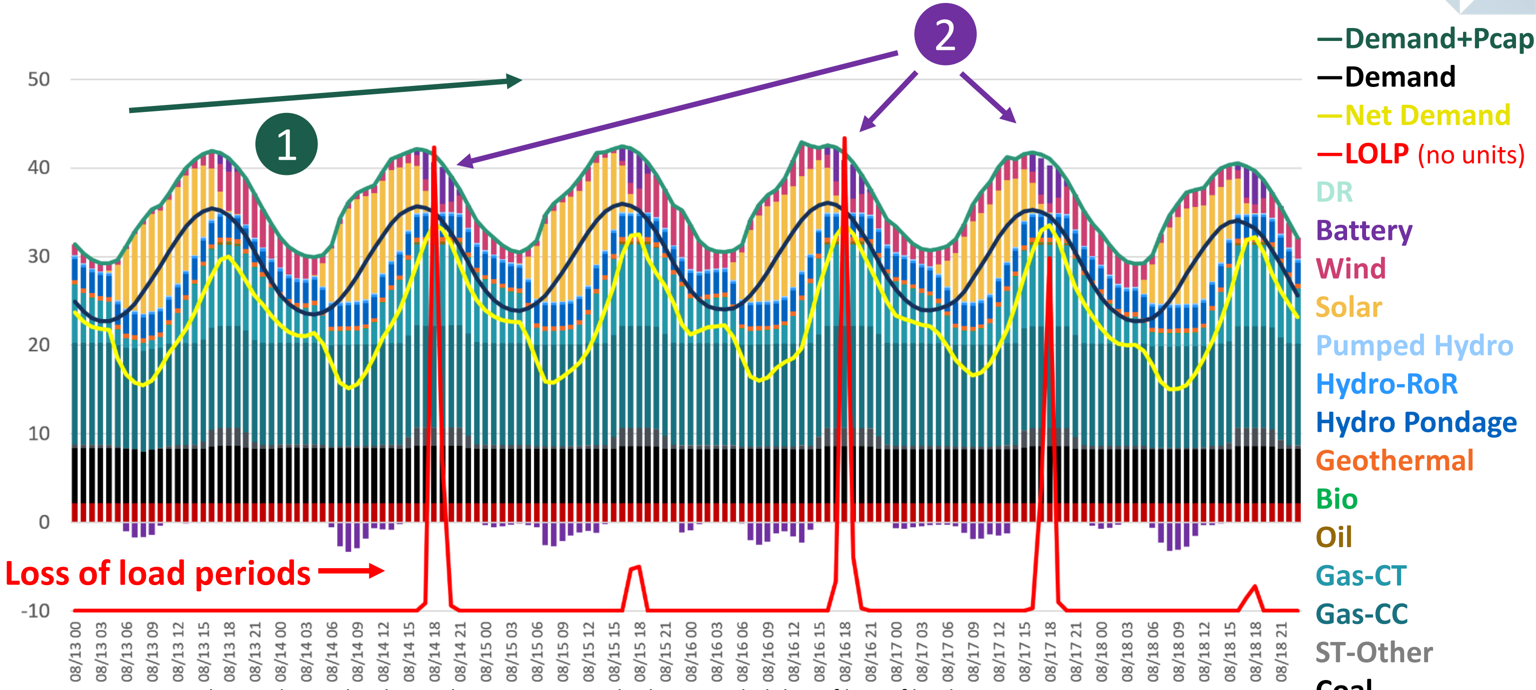


2020 weather conditions account for ~20% of WRAP SW Summer LOLE

A heatwave centered on AZ in summer 2020 produced record high temperatures throughout the southwest region

Simulated Dispatch For Aug. 13-18 2028 High Risk Period (2020 weather)

GW, hourly by unit type (average over outage draws)



Note: LOLP scale not shown, but line indicates timing and relative probability of loss of load events

1. Persistently high net load, especially at night
2. Full utilization of thermal fleet and extended evening needs (beyond storage duration) exhaust available resources

Conclusions

We find that Summer 2028 PRMs are similar between WRAP Subregions and Non-CAISO EDAM footprint; Winter 2027/2028 PRMs are lower for Non-CAISO EDAM

- Winter loss of load risk spans more periods of the day in the WRAP subregions compared to the Non-CAISO EDAM footprint
- Summer loss of load risks are concentrated in the evening across all footprints
- Batteries are an important driver of risk timing, shifting loss of load risk to later in the evening

We find that monthly PRMs within the seasons are uniformly lower for Non-CAISO EDAM in winter, and mixed for summer (with WRAP subregions lower in June/July and Non-CAISO EDAM lower in August/September)

- Variation in regional net load and the ELCC of wind, solar, and storage for each month drive these differences

Incorporating enhancements to the WRAP methodology (as used in this analysis), such as transmission limits within the footprints and temperature-dependent thermal outage rates, would likely reveal additional risks and yield a more complete assessment of regional RA needs

Additional PRM Analysis Details

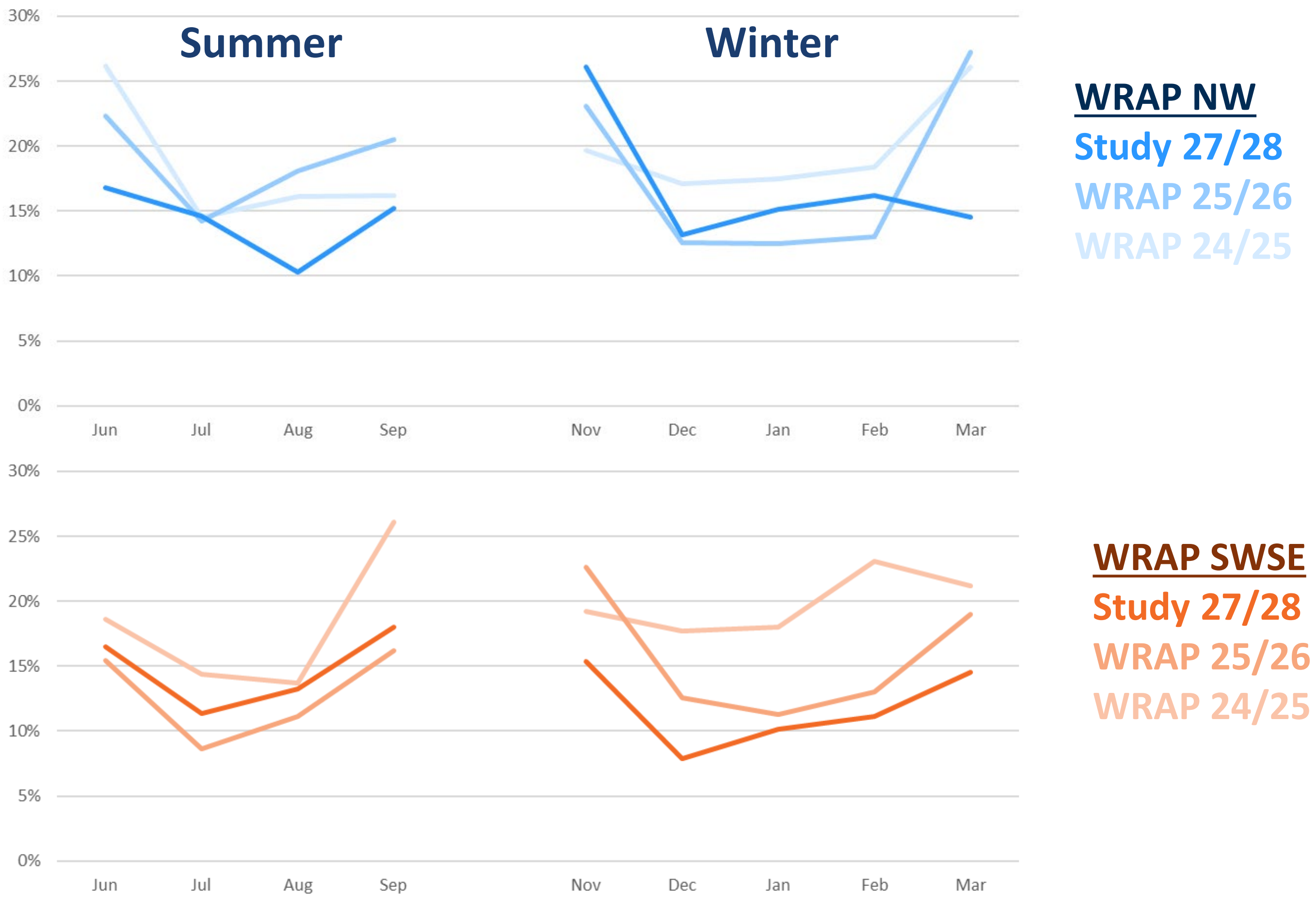
Simulated vs WRAP-reported Monthly PRMs

Our simulated PRMs for the WRAP SWSE and WRAP NW footprints fall in the range of what WRAP has found in their latest two Forward Showing Assessments

- We find lower PRMs in the SWSE for winter, largely due to lower ELCCs for that region than those reported by WRAP
- We expect our PRMs to differ from WRAP's due to data differences and the binding seasons under study:
  - We use publicly available data for WRAP members that are not participants in this study (e.g., BPA)
  - We studied the 2027/2028 binding seasons, for which the resource mix will have changed compared to the mix used in prior WRAP-reported forward showing studies. Higher renewables in 2027/2028 compared to prior assessments would tend to reduce ELCCs.

Simulated vs WRAP-reported Monthly PRM by Footprint

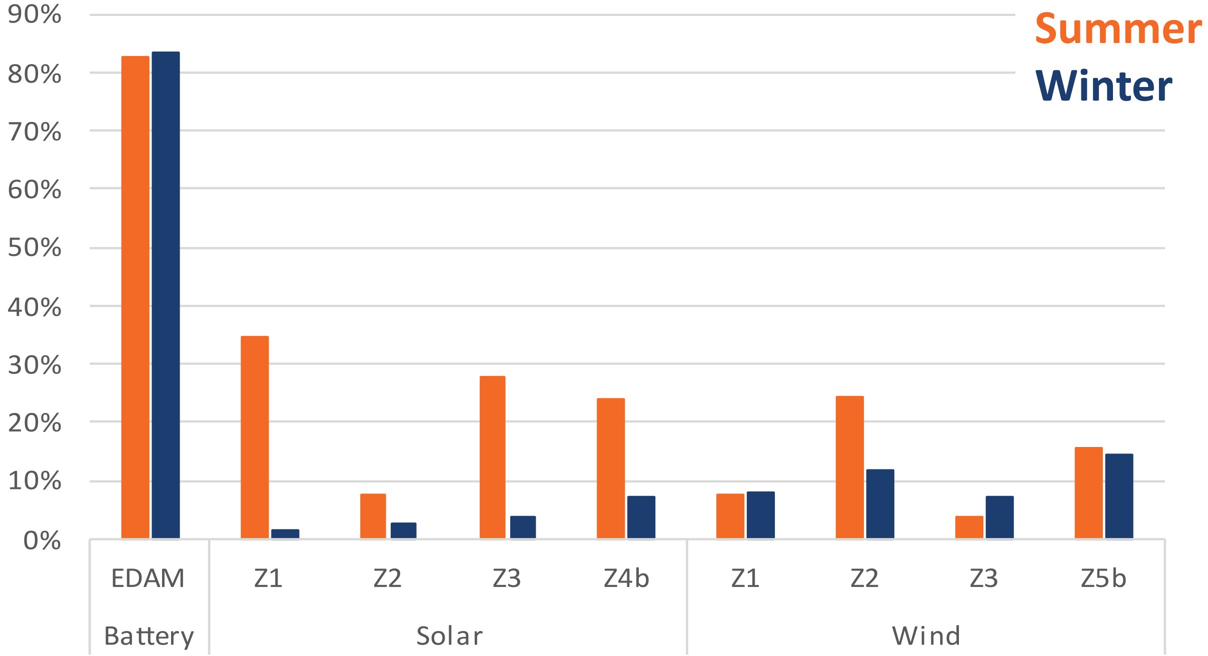
% of footprint p50 peak



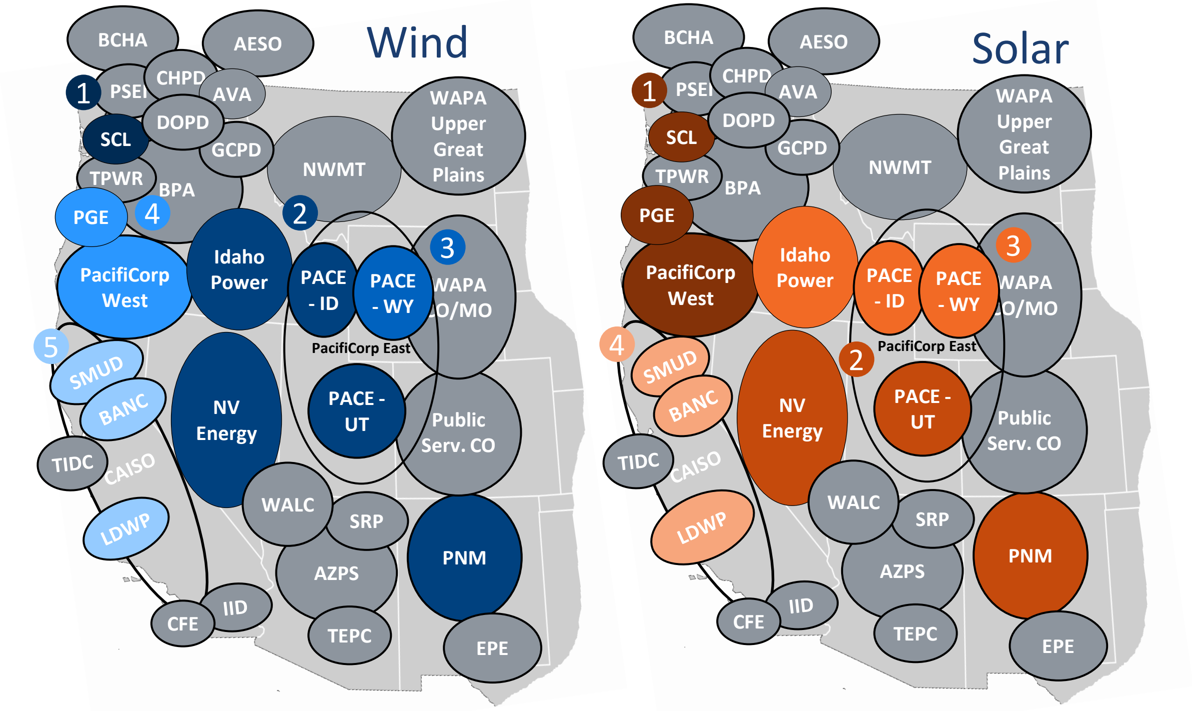
Non-CAISO EDAM Seasonal ELCC by VER Zone

Storage/Solar/Wind ELCC% by VER Zones

ELCC % of installed Capacity



Non-CAISO EDAM VER Zones



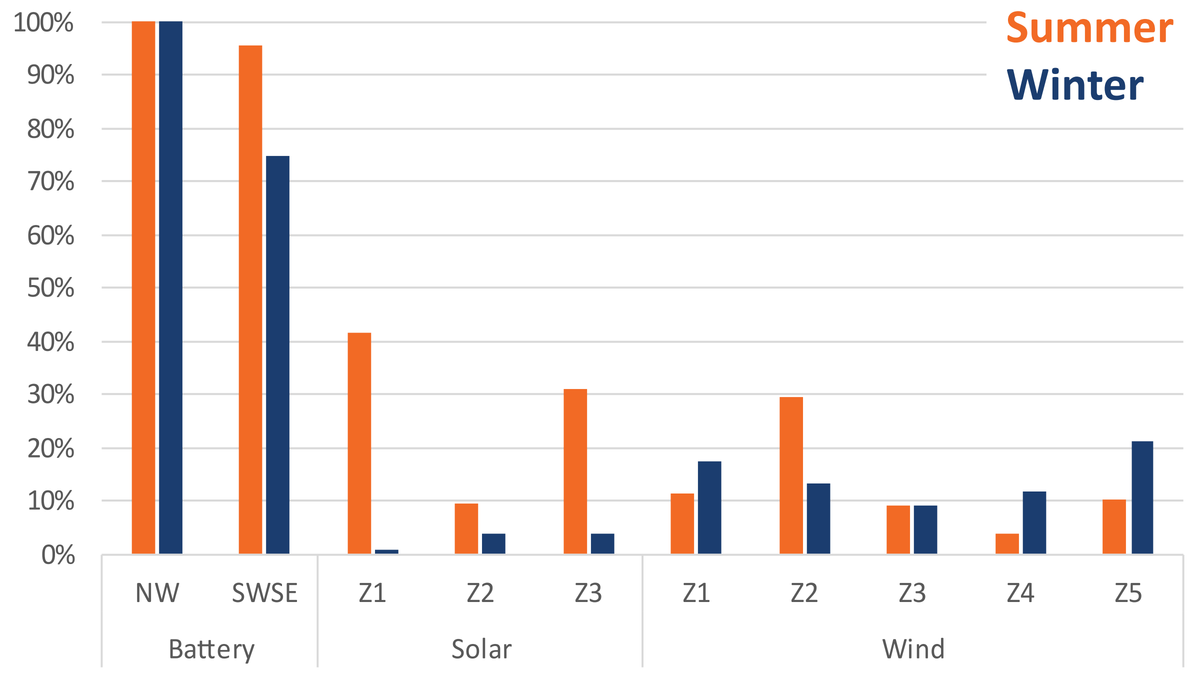
Note:

- We assess storage ELCC on a region-wide basis for the non-CAISO EDAM footprint.
- Wind VER zone 4 contained no wind resources and was thus not simulated.

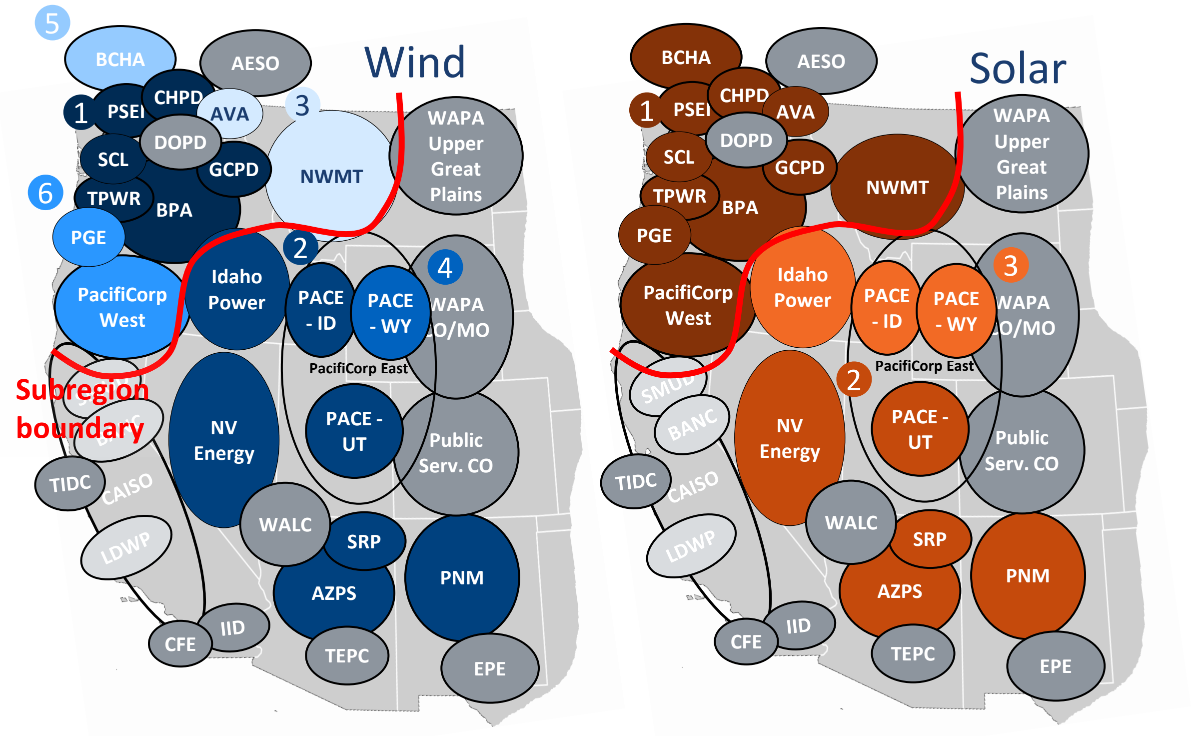
WRAP Seasonal ELCC by VER Zones and Sub-regions

Storage/Solar/Wind ELCC% by VER Zones and Subregions

ELCC % of installed Capacity



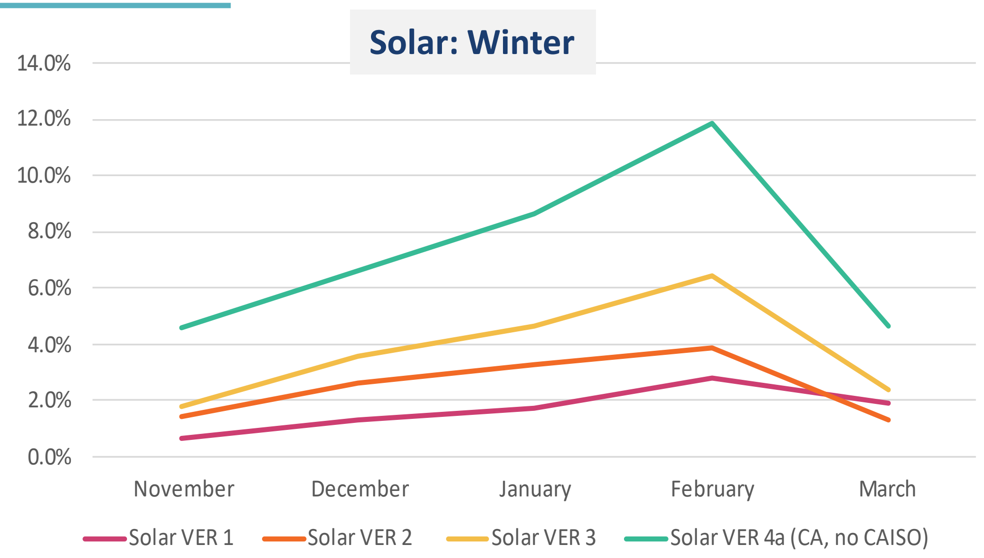
WRAP VER Zones

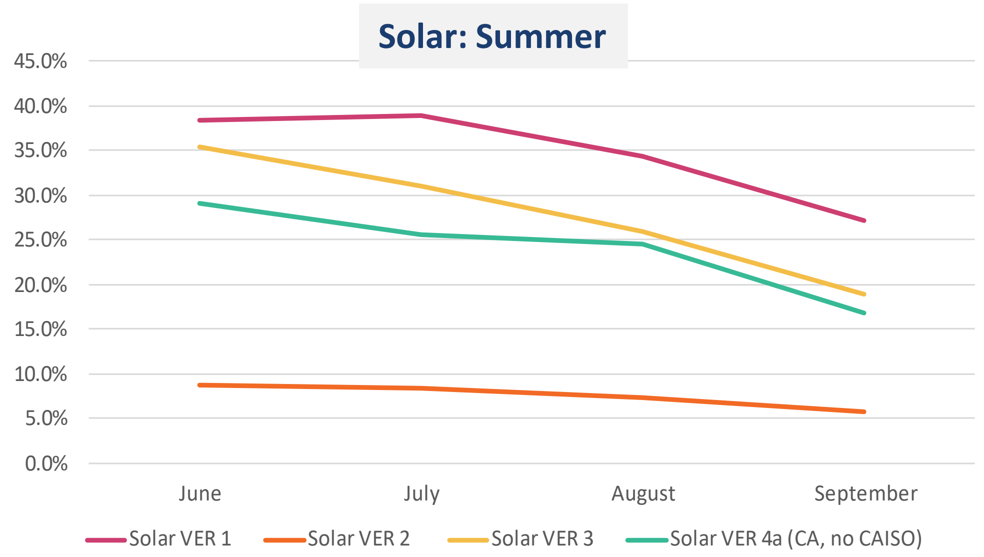


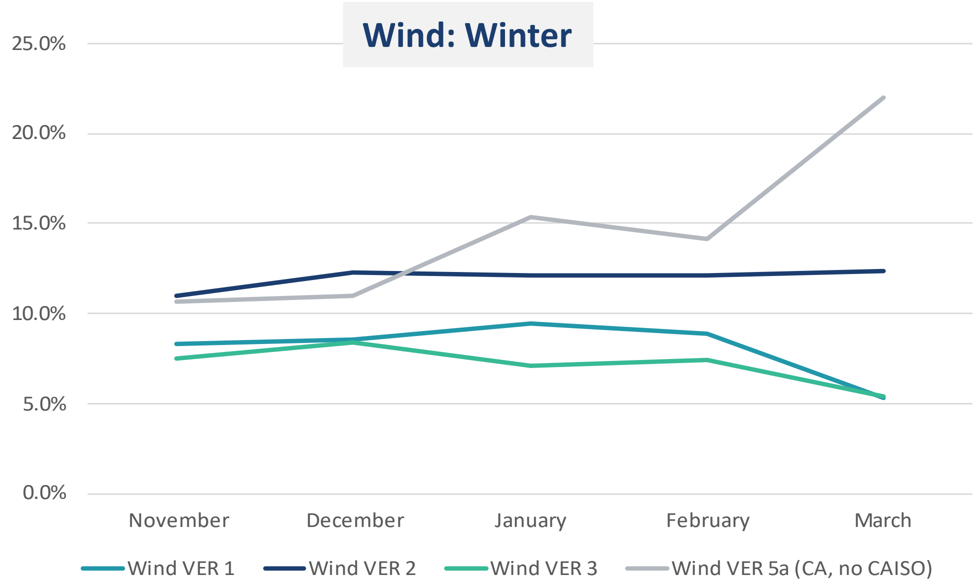
Note:

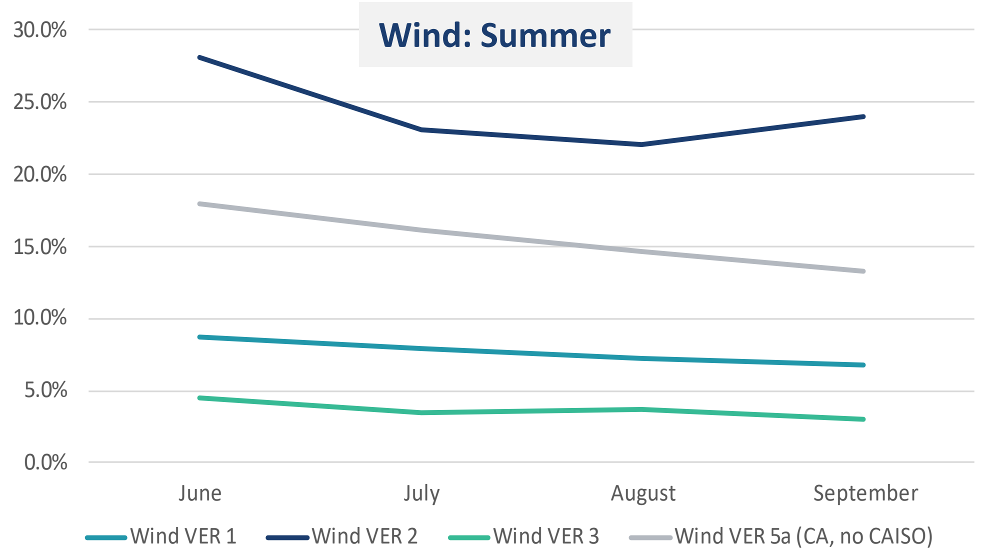
- We assess Energy Storage Resources (ESR) ELCC for the WRAP NW and WRAP SW/SE sub-regions.
- Wind VER zone 6 contained no wind resources and was thus not simulated.

Non-CAISO EDAM – Monthly ELCCs for VERs

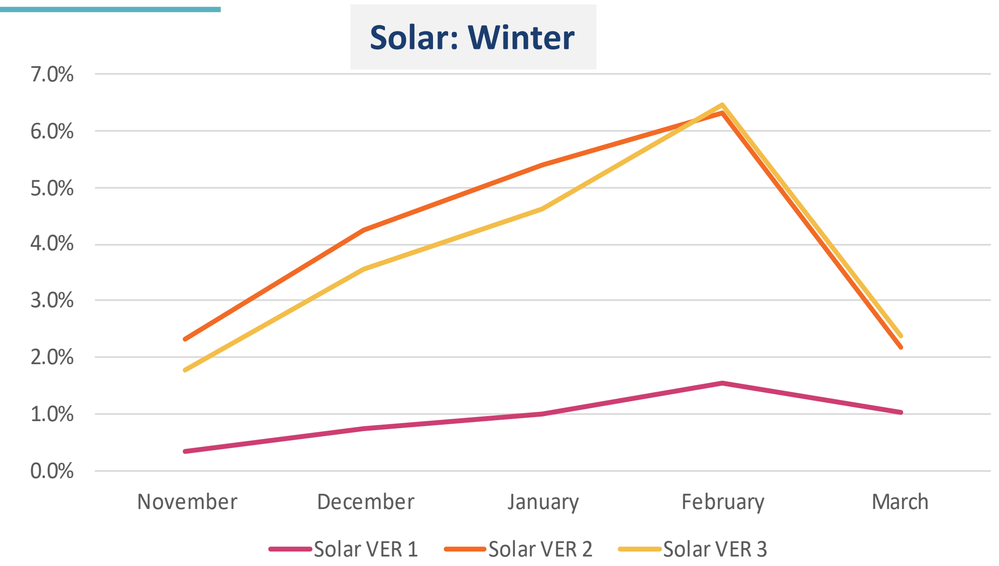


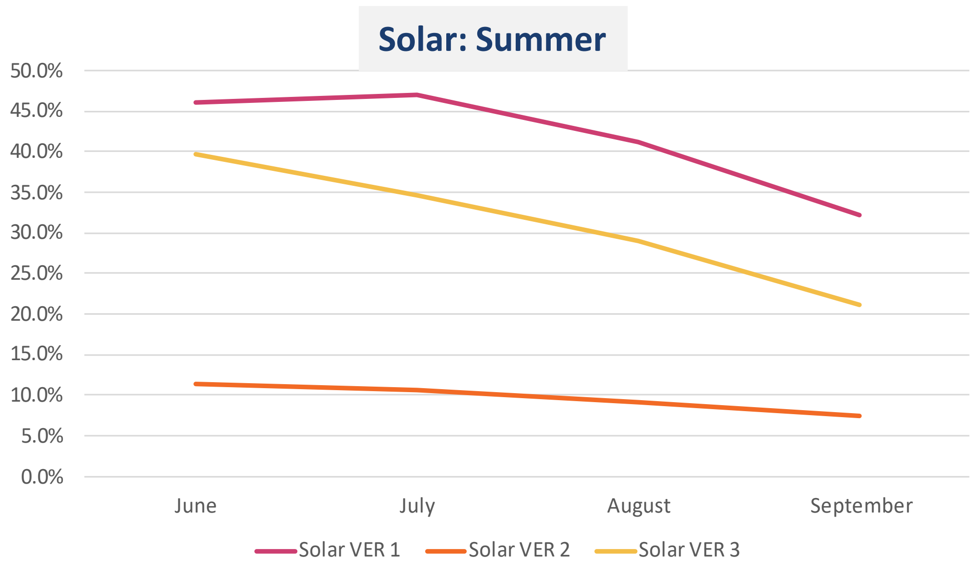


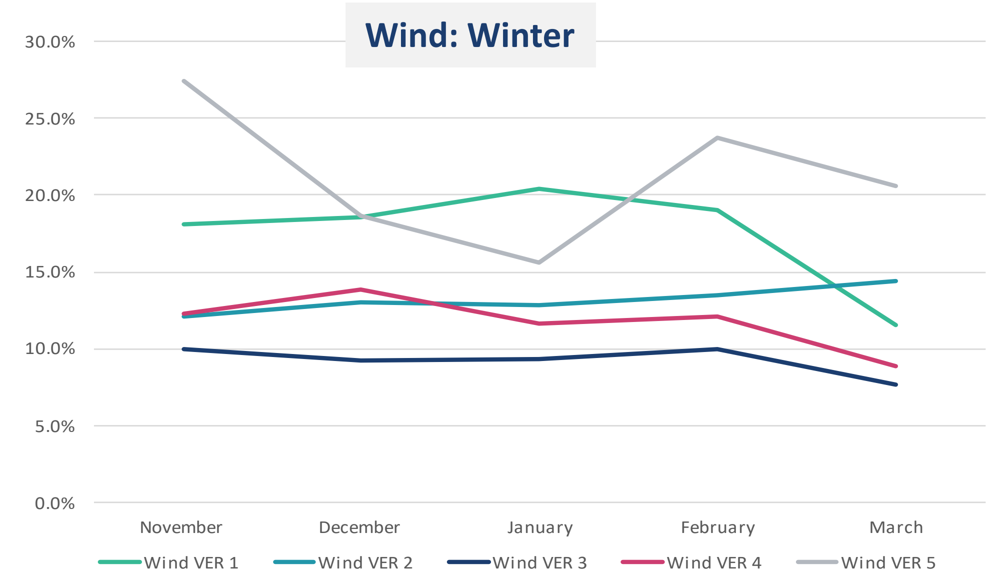


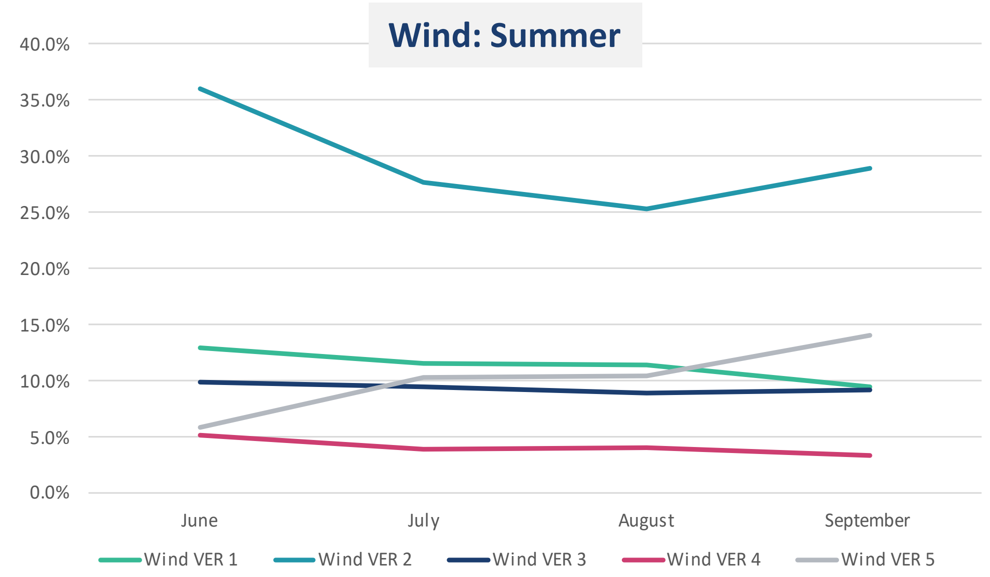


WRAP – Monthly ELCCs for VERs (Solar and Wind)



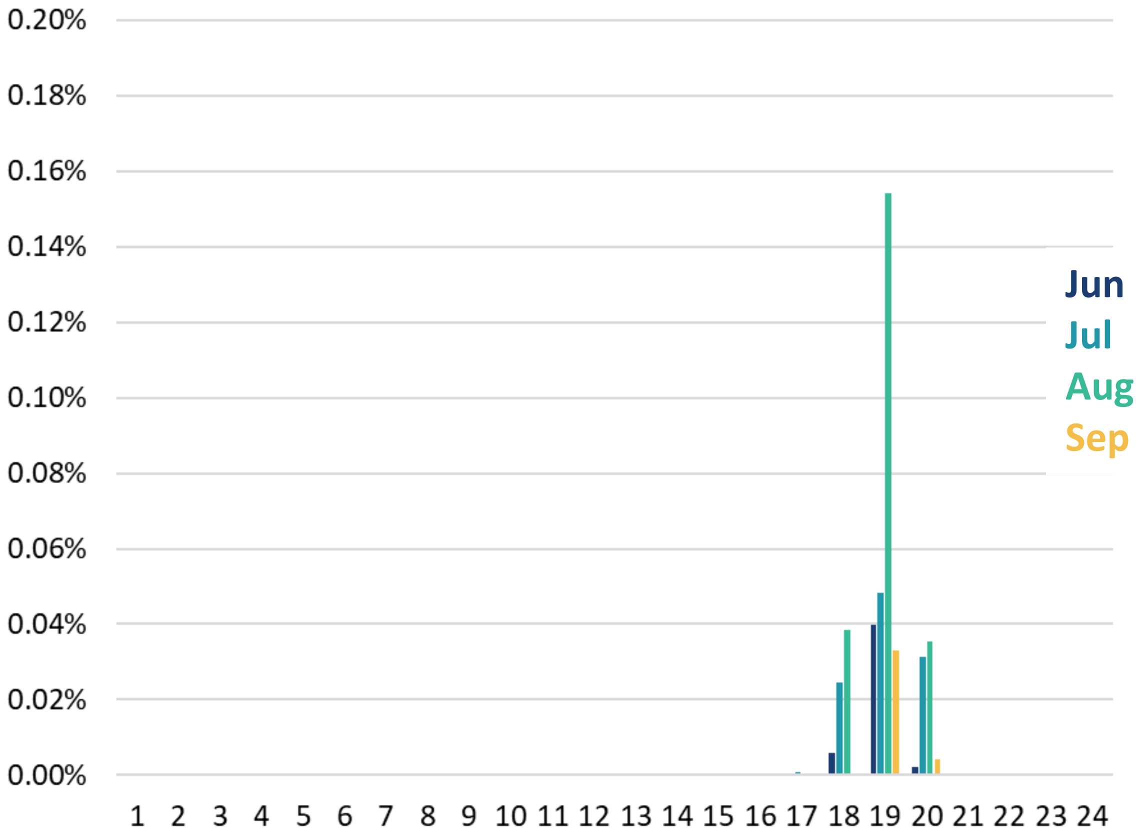




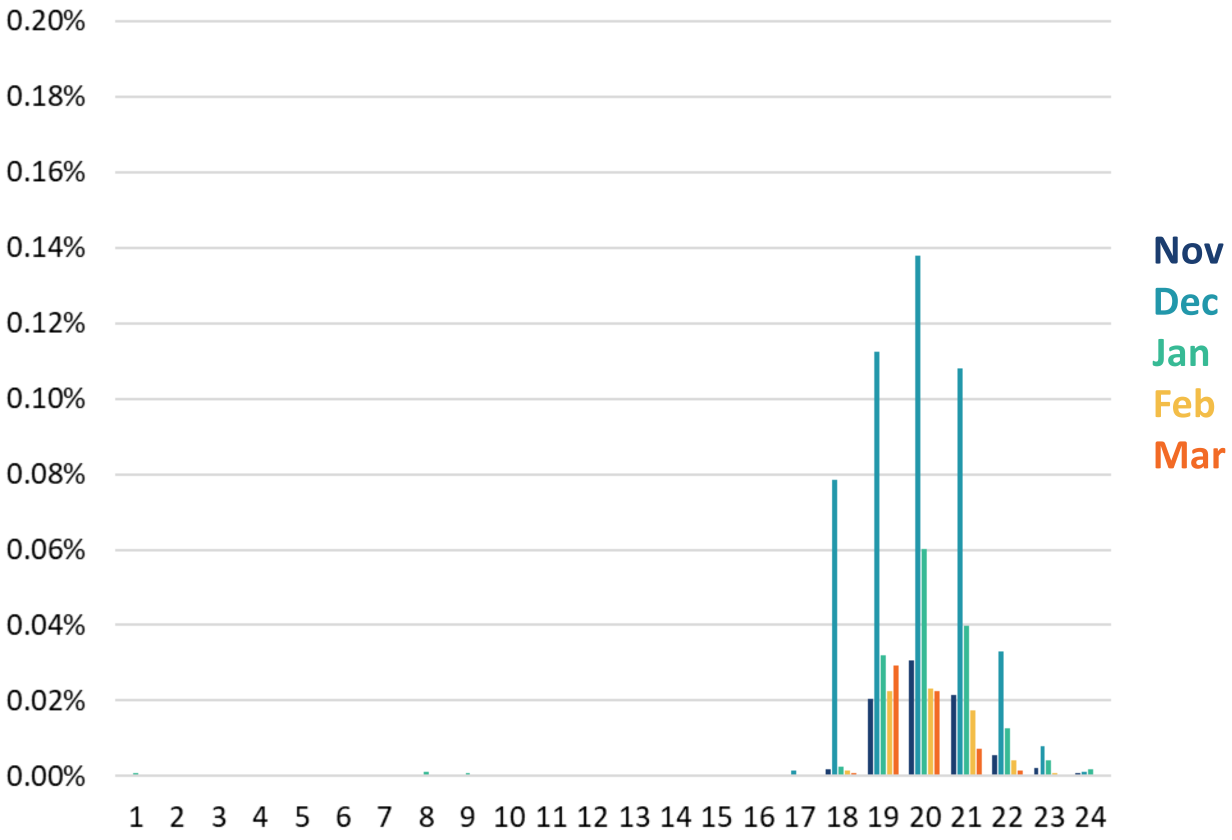


Risk by Month – Non-CAISO EDAM

Simulated Summer LOLP by Hour of Day
Probability of shortfall by hour of day

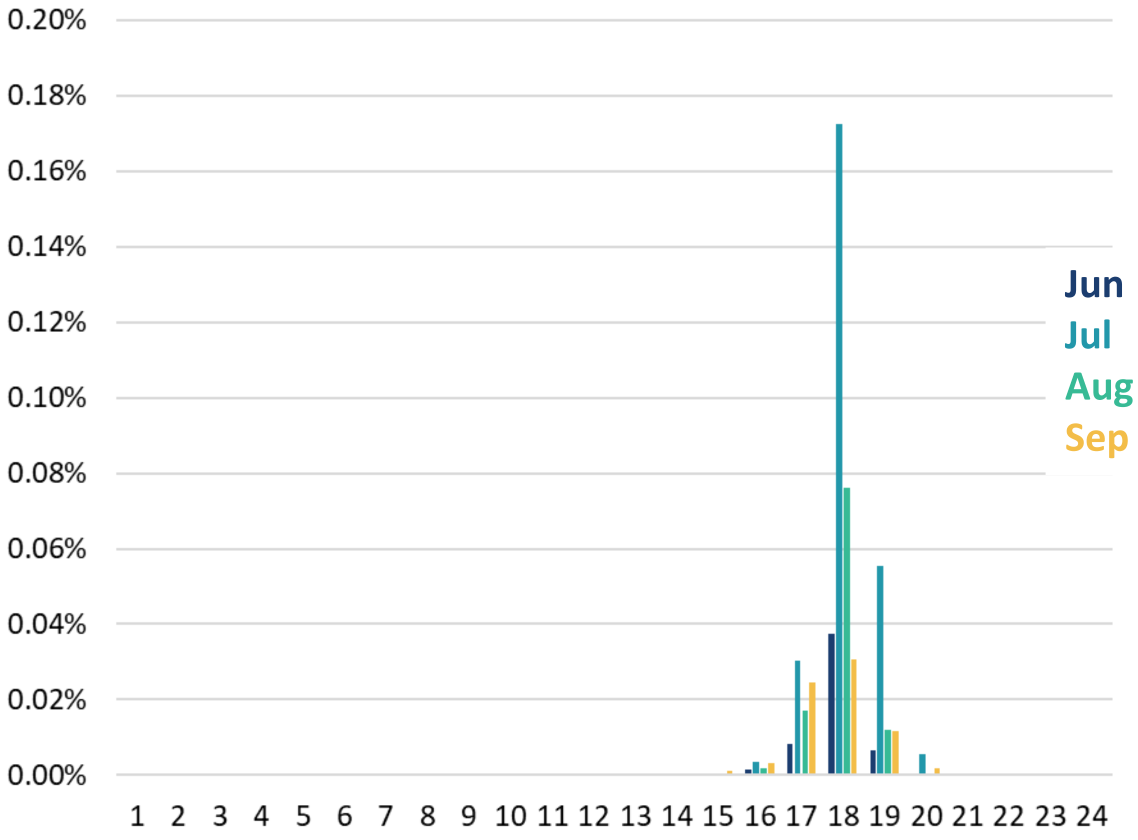


Simulated Winter LOLP by Hour of Day
Probability of shortfall by hour of day

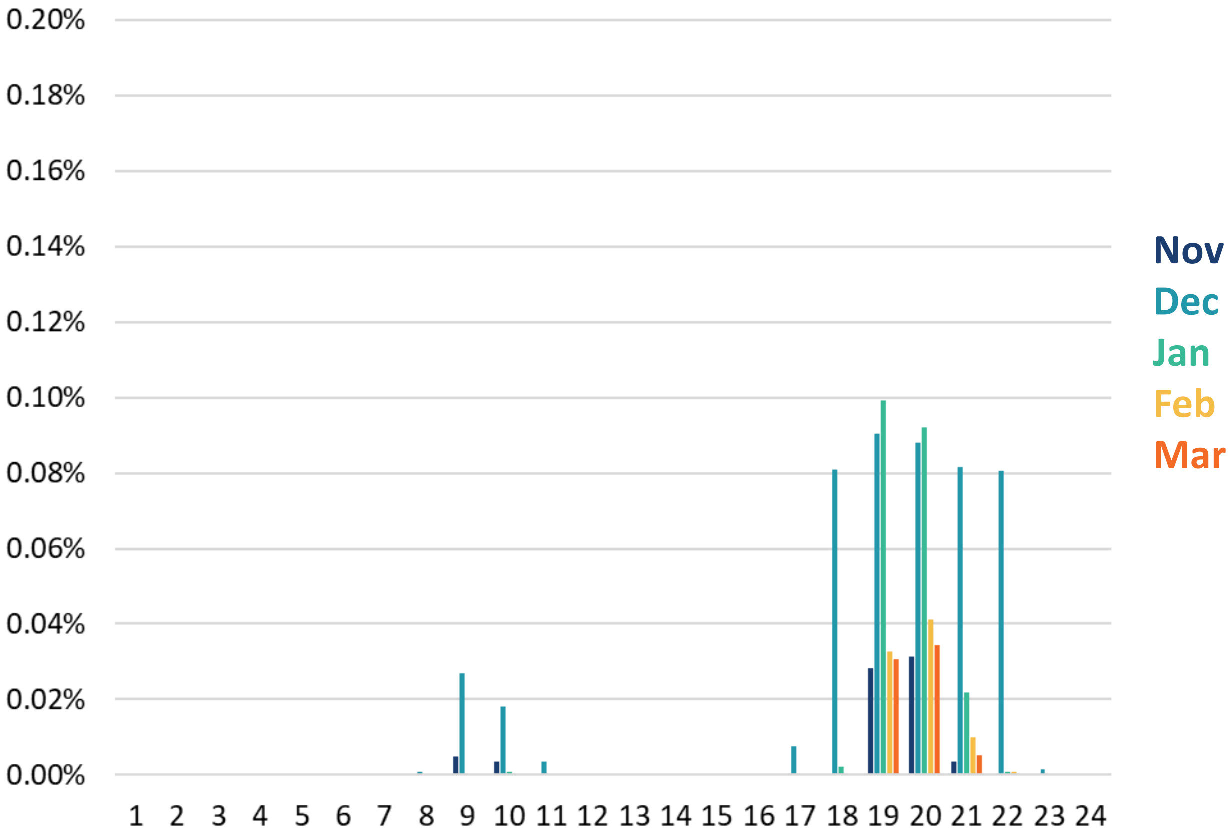


Risk by Month – WRAP NW

Simulated Summer LOLP by Hour of Day
Probability of shortfall by hour of day

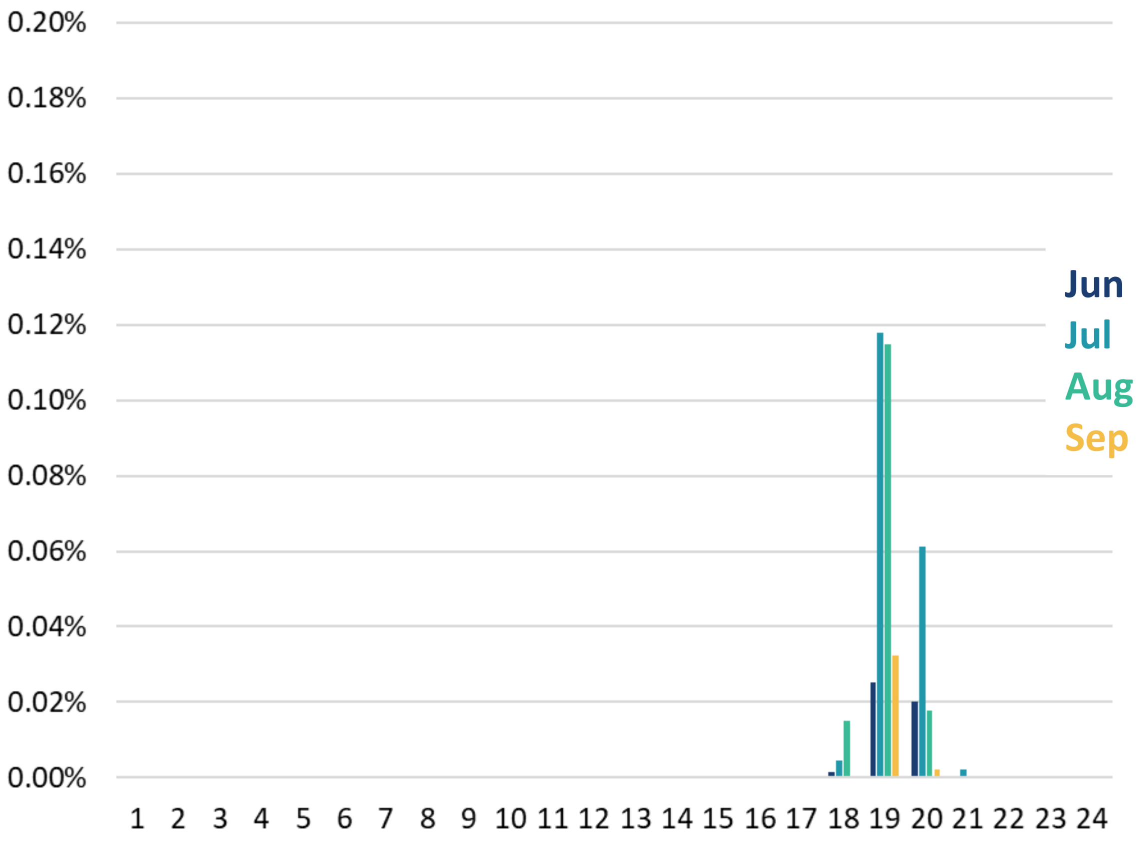


Simulated Winter LOLP by Hour of Day
Probability of shortfall by hour of day

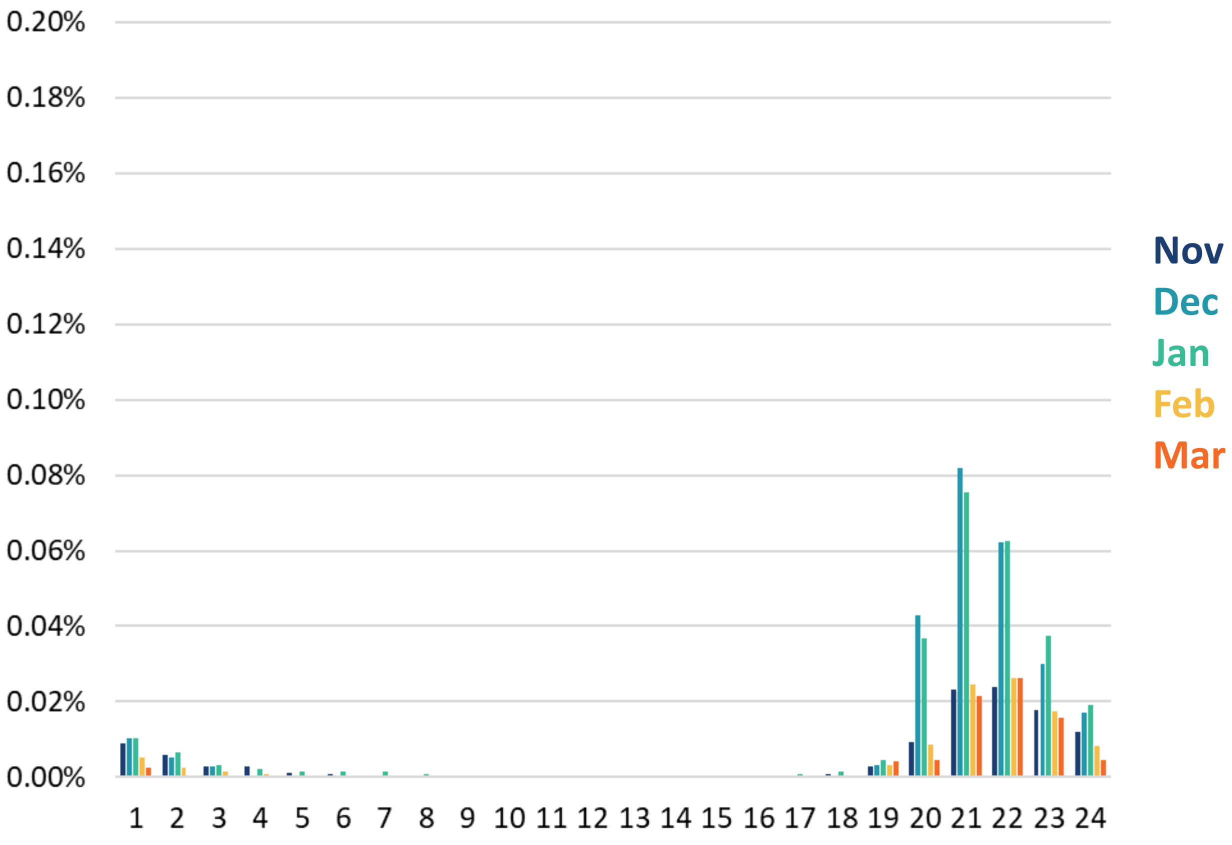


Risk by Month – WRAP SWSE

Simulated Summer LOLP by Hour of Day
Probability of shortfall by hour of day



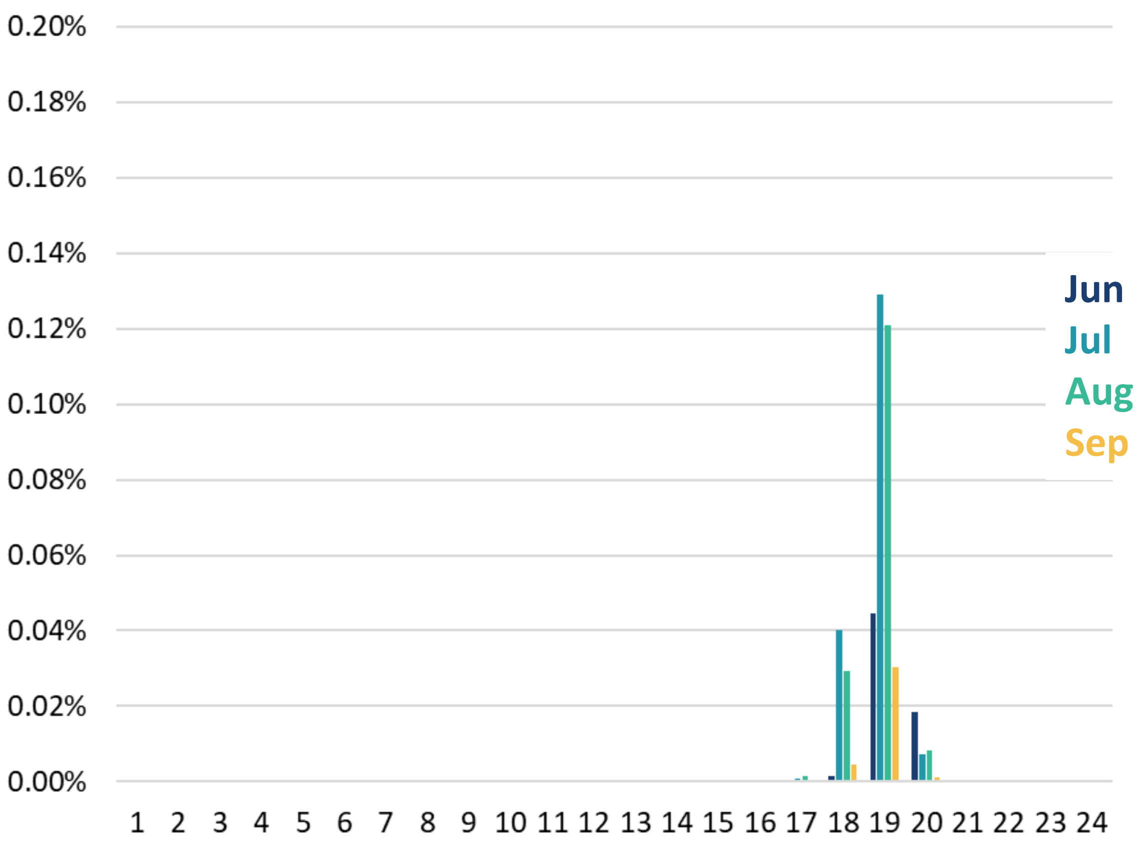
Simulated Winter LOLP by Hour of Day
Probability of shortfall by hour of day



Risk by Month – Full WRAP

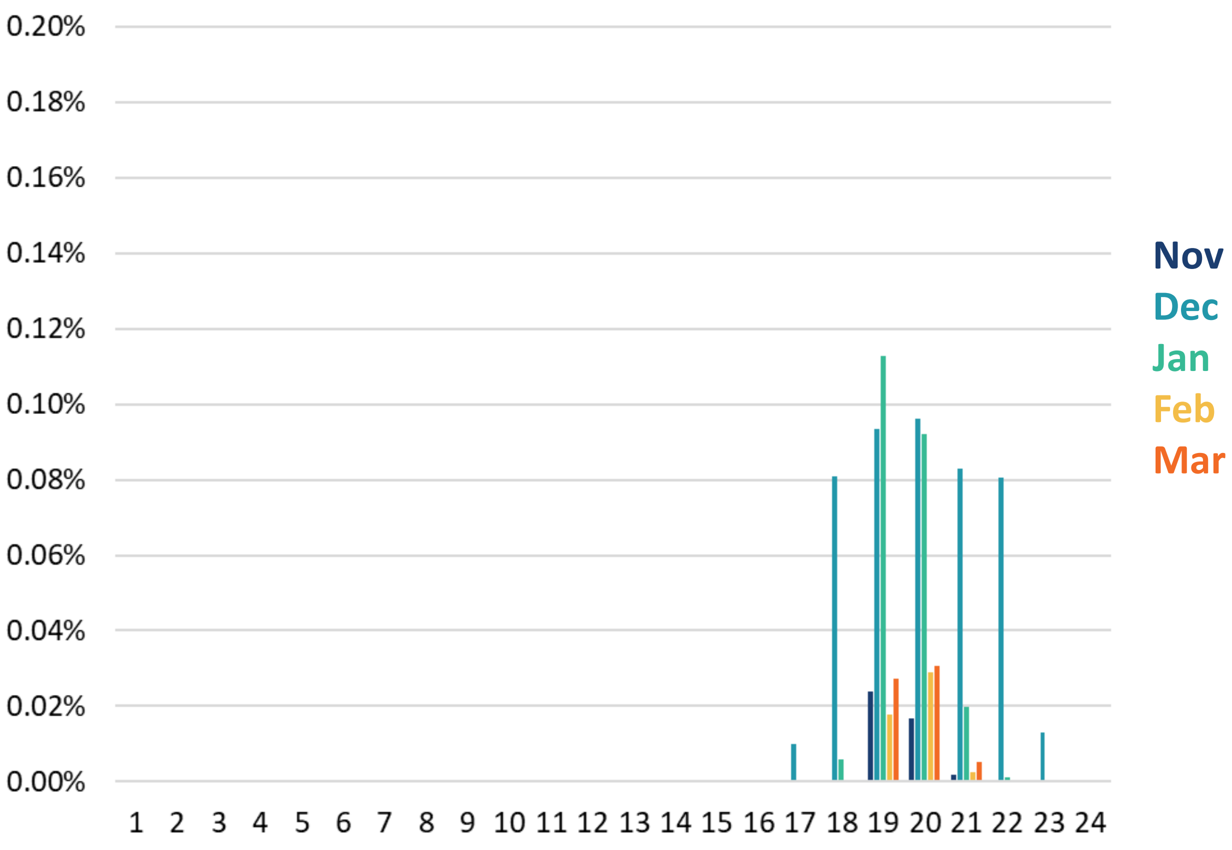
Simulated Summer LOLP by Hour of Day

Probability of shortfall by hour of day



Simulated Winter LOLP by Hour of Day

Probability of shortfall by hour of day



Appendix

Intro to WRAP & the Forward Showing Program

What is the Western Resource Adequacy Program (WRAP)?

WRAP is a regional resource adequacy program

- The program creates a framework for coordination between participating entities to meet resource adequacy planning criteria (i.e., maintain sufficient planning reserve margins) and manage capacity emergencies

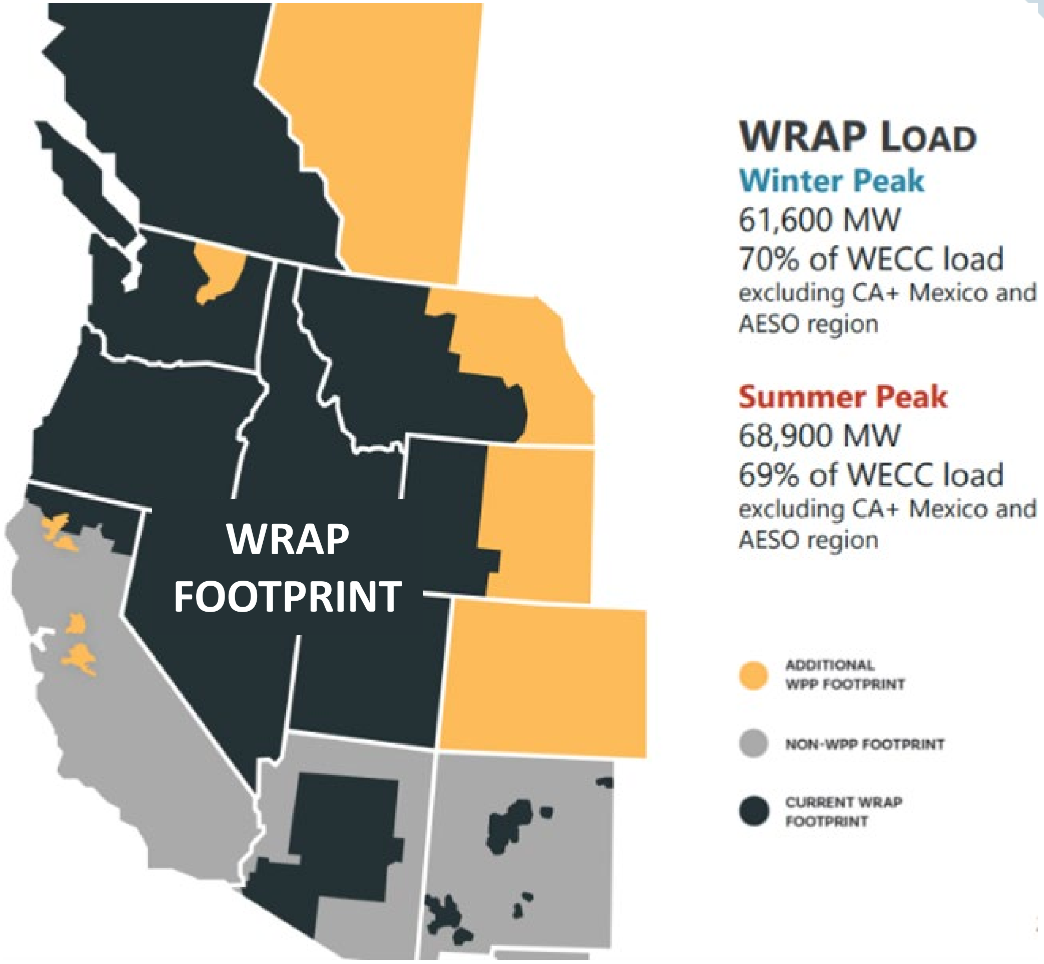
WRAP has two components:

Focus of this study

- Forward Showing Program
  - Facilitates regional diversity sharing and savings for participants when determining capacity needs
  - Participants will have lower capacity procurement obligations compared to meeting capacity planning standards individually
- Operational Program
  - Facilitates coordination between members to meet capacity needs during periods of system stress

Resource: video overview of WRAP programs.

WRAP Program Footprint



Source: Western Power Pool

WRAP's Forward Showing Program

- Establishes Region-wide and sub-regional Planning Reserve Margins (PRM) needed to meet RA planning criterion
  - RA simulations used to assess capacity required to meet "1 in 10" criterion
- Sets binding requirements participating utility capacity based on regional or sub-regional PRMs
  - Requirements established for winter & summer "binding seasons"
  - Studies conducted ~2 years ahead of binding season, and 1 year ahead of forward showing deadline
- Participants must demonstrate they have sufficient capacity to meet their requirement 7 months in advance of each binding season

Table 2. Example Advance Assessment and Data Submittal Timeline

Activity/Milestone	Summer	Winter
Program Operator sends out updated Advance Assessment Data Request	January 15, 2028	
Participant provides data to Program Operator for Advance Assessment	March 1, 2028	
Participant Review of input data	April 1 – April 15, 2028	October 1 – October 15, 2028
Program Operator provides Participants with draft modeling outputs	September 15, 2028	February 15, 2029
Any discrepancies reviewed and resolved	September 15 – October 1, 2028	February 15 – March 1, 2029
Studies complete	October 31, 2028	March 31, 2029
Deadline for Board of Directors review and approval of Binding FSPRM	January 31,2029	June 30, 2029
FS Deadline for Binding Season	October 31, 2029	March 31, 2030
Binding Season	June 1 – September 15, 2030	November 1 – March 15, 2030-2031
Advisory Binding Season	June 1 – September 15, 2033	November 1 – March 15, 2033-2034

Source: WRAP BPM 101 – Advanced Assessment

Summary of Modeling Methodology & Key Assumptions

Resource Adequacy (RA) Simulations

RA simulations are a tool for assessing if the system can meet load under a range of uncertainties

Input Data:
- Weather Scenarios
- Outage parameters
- Load forecast uncertainty
- Capacity contract data
- Historical interchange
- Resource mix
- Topology

Uncertainty draws across multiple sources produce unique year scenarios (i.e., "replicants")

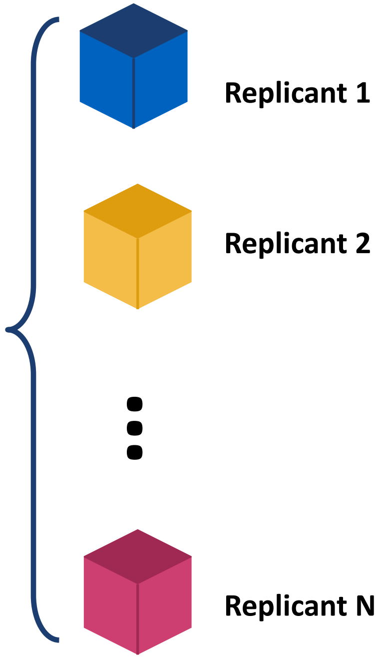
Outages

Weather Scenarios

Peak Load Forecast Uncertainty (LFU)

[may be captured by weather scenarios]

Simulated dispatch for each replicant tests for shortages



N = # outage draws
x # weather scenarios
x # LFU draws
(on the order of hundreds or thousands)

Output Data:
(Aggregate RA metrics calculated across all simulated replicants):
- EUE
- LOLE
- LOLP

Including timing of RA risk within seasons

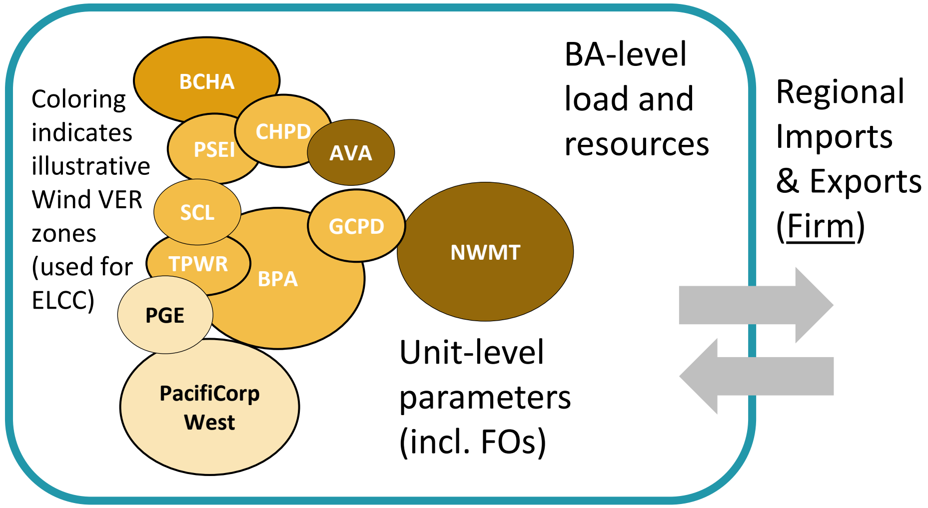
Output data used to calculate PRMs

Other results:
- Hourly dispatch & cost

Detailed RA simulation is a Key Input to PRM for the RRA Footprints

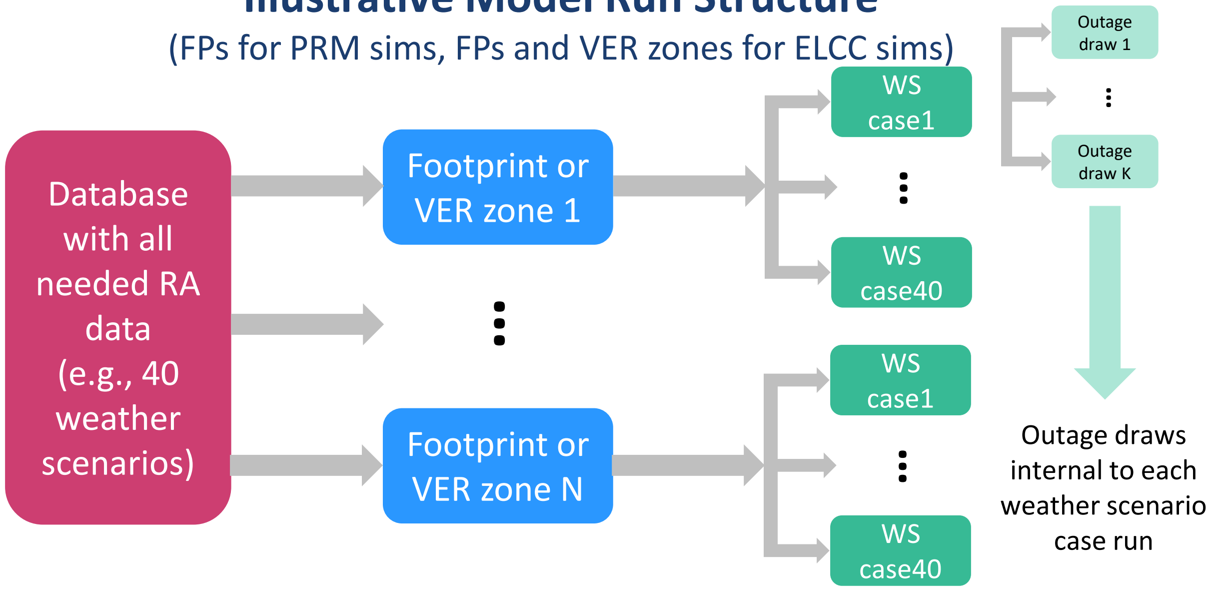
- We developed a WECC-wide RA model with renewable and loads under 40-years of weather year conditions and thermal outages. The WECC-wide RA model can be configured to reflect each focus footprint and VER zone.
- We ran RA simulations to evaluate the LOLE in each footprint/VER Zone considering the 40 weather scenarios and hundreds/thousands of thermal outage draws in each scenario
- By adding or removing perfect capacity to achieve reliability standards, we identified the RA value (QCCs) of solar, wind, and storage in each footprint and calculated PRMs of each footprint

Example Model Topology (WRAP NW)



Illustrative Model Run Structure

(FPs for PRM sims, FPs and VER zones for ELCC sims)



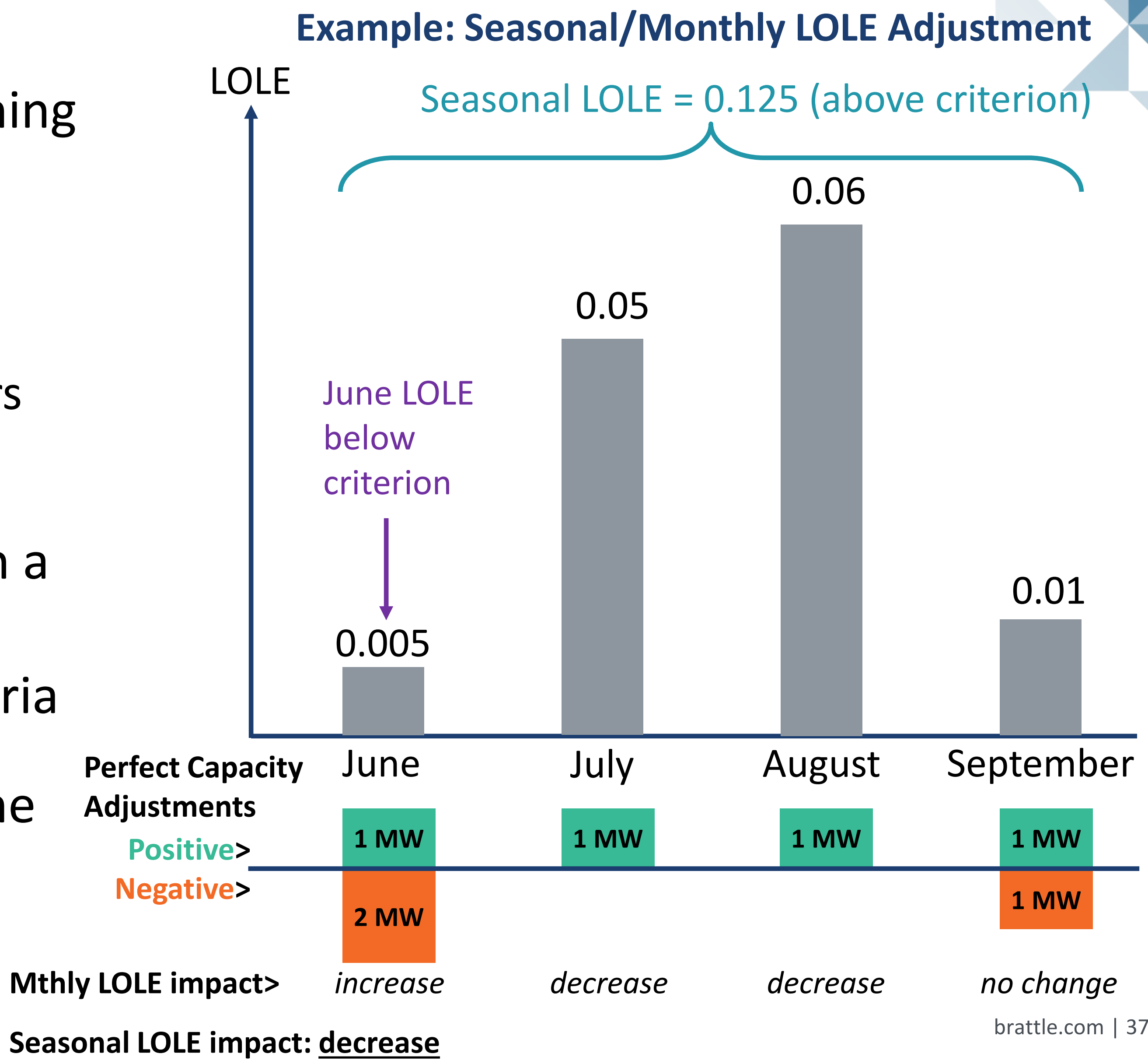
WRAP Resource Adequacy Criteria

WRAP has two RA criteria for establishing the seasonal and monthly PRMs:

- A target of 1 event-day in 10 years per **binding season**
- A *minimum* of 0.1 event-days in 10 years **per month** within a binding season

Level of perfect capacity is adjusted on a seasonal and monthly basis in RA simulations until regional LOLE at criteria

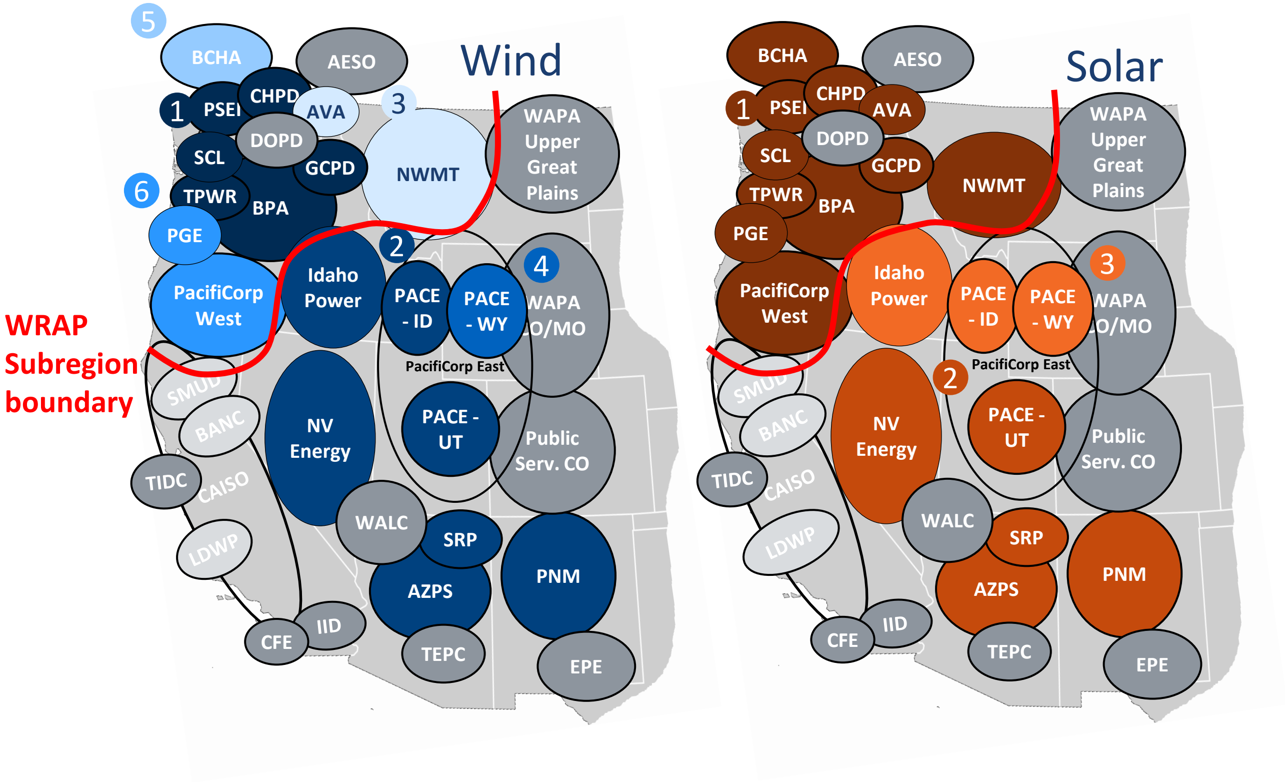
ELCC simulations are subject only to the seasonal PRM criterion



In addition to PRM footprints, We Analyzed Twenty VER Zones

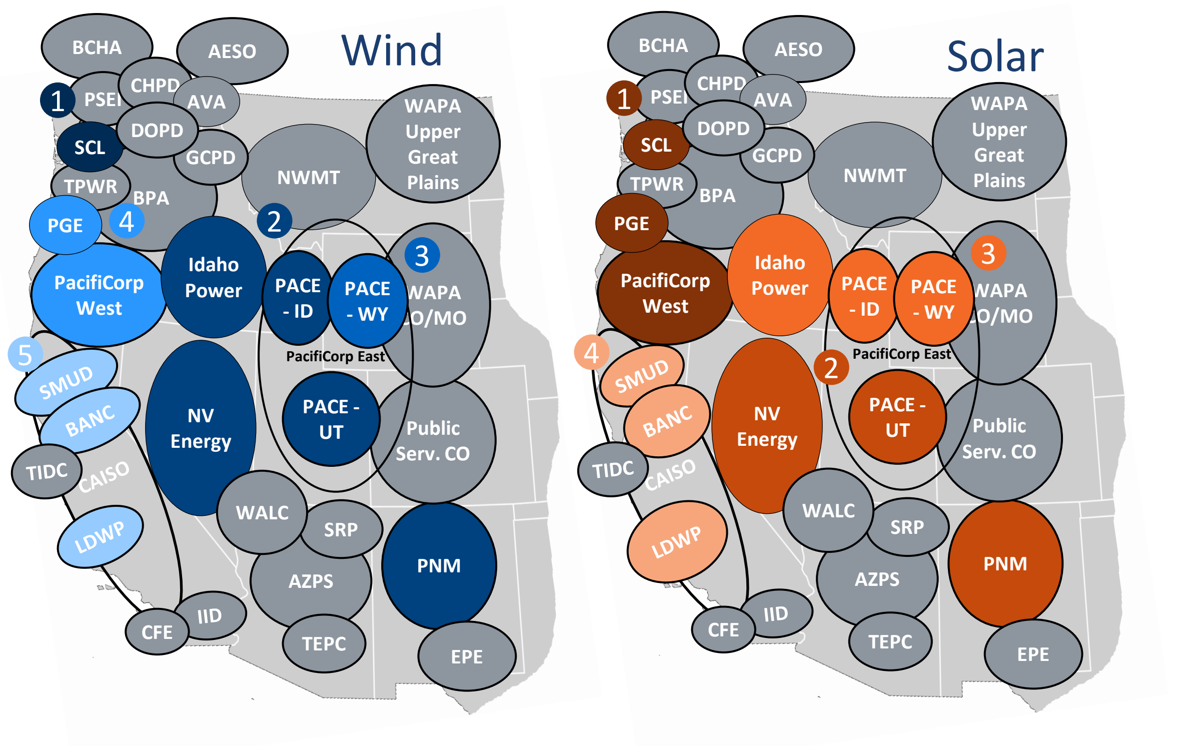
We used VER zones to assess wind and solar ELCC as an input into the PRM calculation

WRAP VER Zones



Note: We assess storage ELCC for the WRAP NW and WRAP SW/SE sub-regions.

EDAM Footprint VER Zones



Note: We assess storage ELCC on a region-wide basis for the EDAM footprint.

We Conducted Analysis to Calculate FSPRM For Each Footprint

$$FSPRM\ (\%) = \frac{UCAP_{1-in-10} - Regional\ P50\ Load\ Forecast}{Regional\ P50\ Load\ Forecast} * 100$$

→ *See WRAP BPM 102 for more details*

FSPRM components:

- $UCAP_{1\text{-}in\text{-}10}$: total availability-adjusted capacity in the footprint
  - Calculating UCAP requires calculating the ELCC or QCC of all resources
  - Conducting ELCC and QCC analyses requires resource mix, historical hourly unit outages (6+ years), historical hourly load, renewables, and hydro (20-40 years), pondage hydro storage (20-40 years), unit outage parameters
- Regional P50 Load Forecast:
  - Requires historical load, load escalation factors & monthly peak adjustment factors
- WRAP Participant PRMs are based on the FSPRM

See WRAP BPM 103 for more details ←

$$\begin{aligned} FS\ Capacity\ Requirement &= FS\ Capacity\ Requirement\ Unadjusted \\ &\quad + Contingency\ Reserve\ Adjustment \end{aligned}$$

where

$$FS\ Capacity\ Requirement\ Unadjusted = (P50\ Peak\ Load\ Forecast) * (1 + FSPRM)$$

and

$$\begin{aligned} Contingency\ Reserve\ Adjustment &= Contingency\ Reserve\ Adjustment\_Generation \\ &\quad + Contigency\ Reserve\ Adjustment\_Load \end{aligned}$$

WRAP UCAP Methodologies

Resource type	Conversion to UCAP Values
Thermal Generation	The Net Generating Capability will be replaced by QCC values calculated by the Program Operator using the thermal QCC methodology (see *BPM 105*)
Wind, Solar and ESR	Values for wind, solar, and ESR resources will be determined by using an ELCC analysis (see *BPM 105*). The capacity values attributed to wind and solar resources and ESRs will be consistent with the QCC values assigned to such resources in the QCC analysis (see *BPM 105*).
Storage Hydro	QCC values submitted by the Participants calculated using the Storage Hydro QCC methodology (see *BPM 105*).
Run-of-River Hydro	QCC values calculated by the Program Operator using the ROR QCC methodology (see *BPM 105*).
Demand Response	No conversion needed. Modeled maximum monthly capacity of all programs submitted by the Participants.
Pure Capacity adjustment to meet reliability metric	No conversion needed.

Source: WRAP BPM 105 – Forward Showing Qualifying Resources

→ *See WRAP BPM 105 for more details on QCC analyses*

Based on historical net load & outage data

Based on ELCC from RA simulations (with QCC adjustments)

Based on historical load, resource output, and storage levels

Based on historical load, resource output

Input from participants

Output from PRM RA simulations

Overview of Study Data & Data Sources

Study Group Member BAs

Member-Provided Data

New and existing generation
Hourly load profiles
Hourly generation profiles
Hourly GADS reporting
QCC for pondage hydro

Renewables Ninja

Hourly temperature
Hourly generation profiles

EIA 930

Hourly interchange

Non-Study Group Member BAs

Generation Mix

1. IRP, BA Filings
2. Energy Velocity
3. S&P Global CapIQ
4. WECC ADS

Renewables Ninja

Hourly temperature
Hourly generation profiles

WRAP BPMs

Class-level QCCs

EIA 930

Hourly load profiles
Hourly interchange

GADS

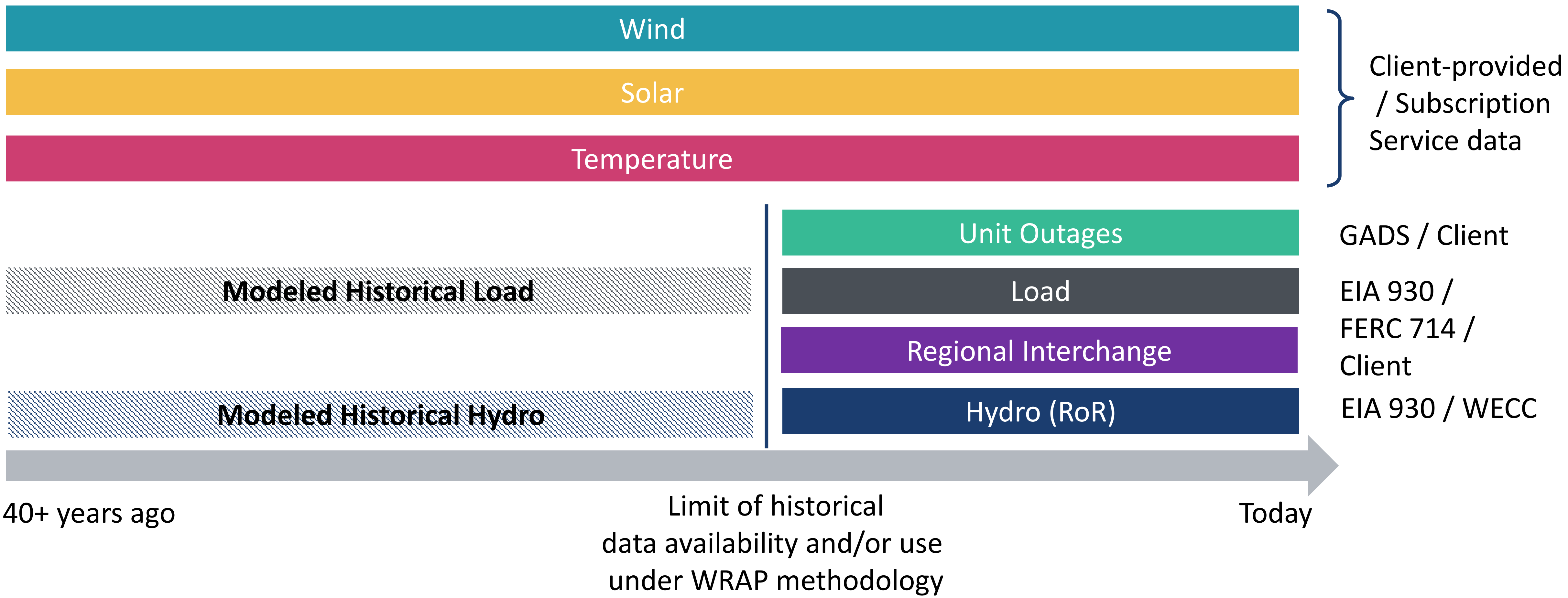
Class-level outage parameters

2025 CA Load and Resources Assessment

CA class level QCCs

We Used 40 Years of Historical Data Across Multiple Dimensions

Data Dimensions Required for Weather Year Scenarios (for each BA in study footprints, 8760 by year) Source(s):



We Also Use Forward-looking Data for the RA Simulations

We updated the resource mixes for study group members using on member-provided data

We updated the resource mixes for non-study group members using available public data. We reviewed the following sources, and considered them in the following order:

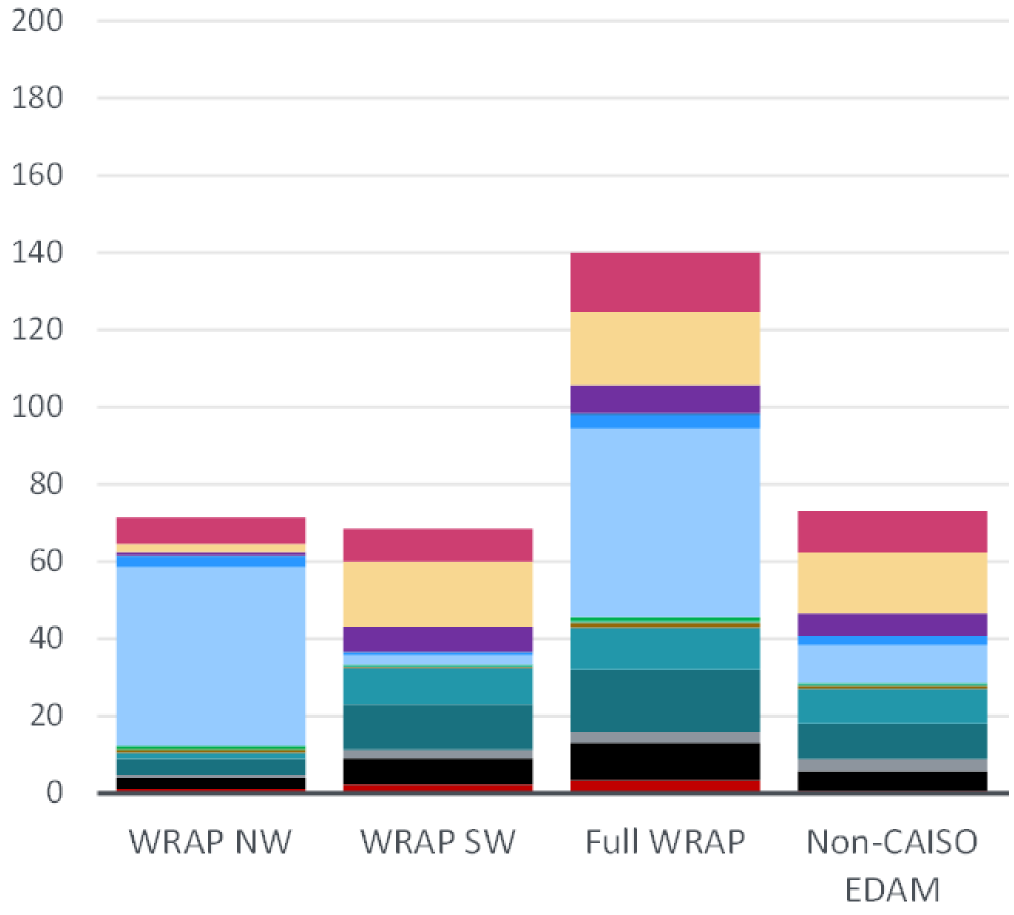
1. Resource Planning expectations published by utilities (IRPs, BPA White Book, etc.)
2. Generator-level capacity projections from Energy Velocity (EV)
3. Utility-level capacity projections from S&P Global CapIQ (SNL)
4. Publicly available data through WECC ADS

We forecasted monthly load for the winter 2027/2028 and summer 2028 binding seasons using WRAP-established methodology, which relies on historical monthly peak load data.

Resource Mix by Footprint

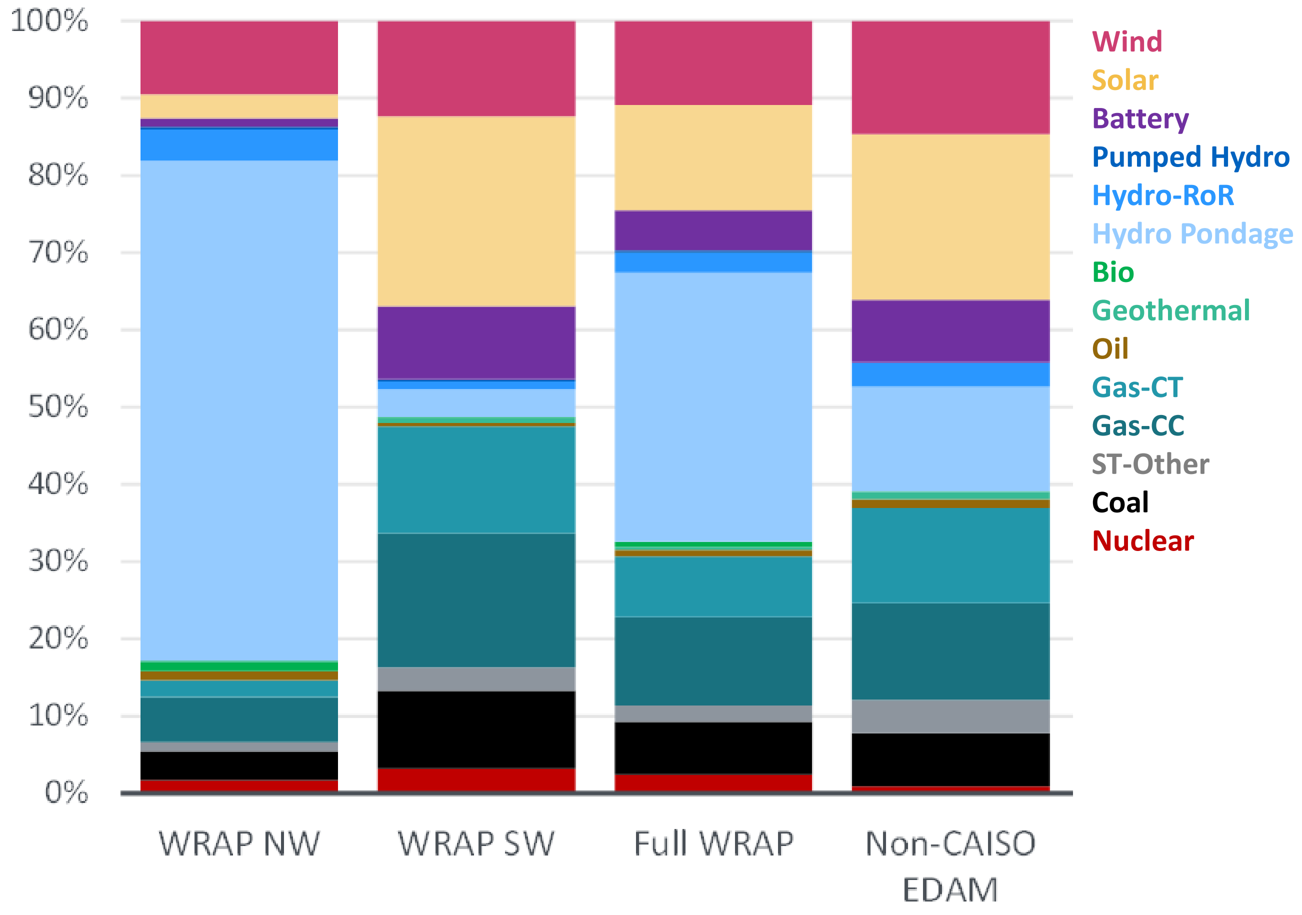
Capacity by Footprint and Resource Type

GW



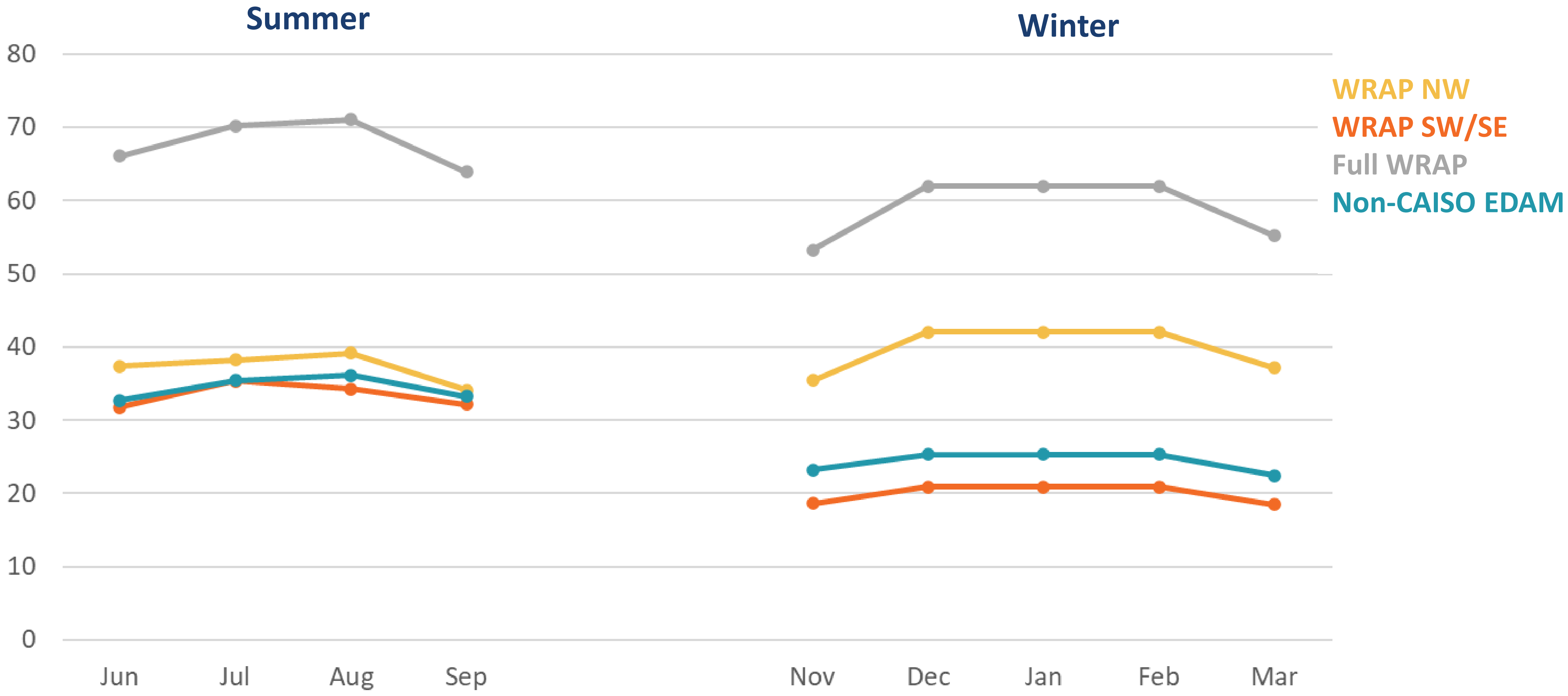
Capacity Composition by Footprint and Resource Type

% of total footprint capacity



Summary of Forecast Monthly 50/50 Peak Load by Footprint

Forecasted Monthly 50/50 Peak Load by Footprint (Summer 2028, Winter 2027/2028)
GW



Overview of RA Simulation Platform (Enelytix/PSO)

(used with permission of Enelytix/PSO)

ENELYTIX Approach to Resource Adequacy

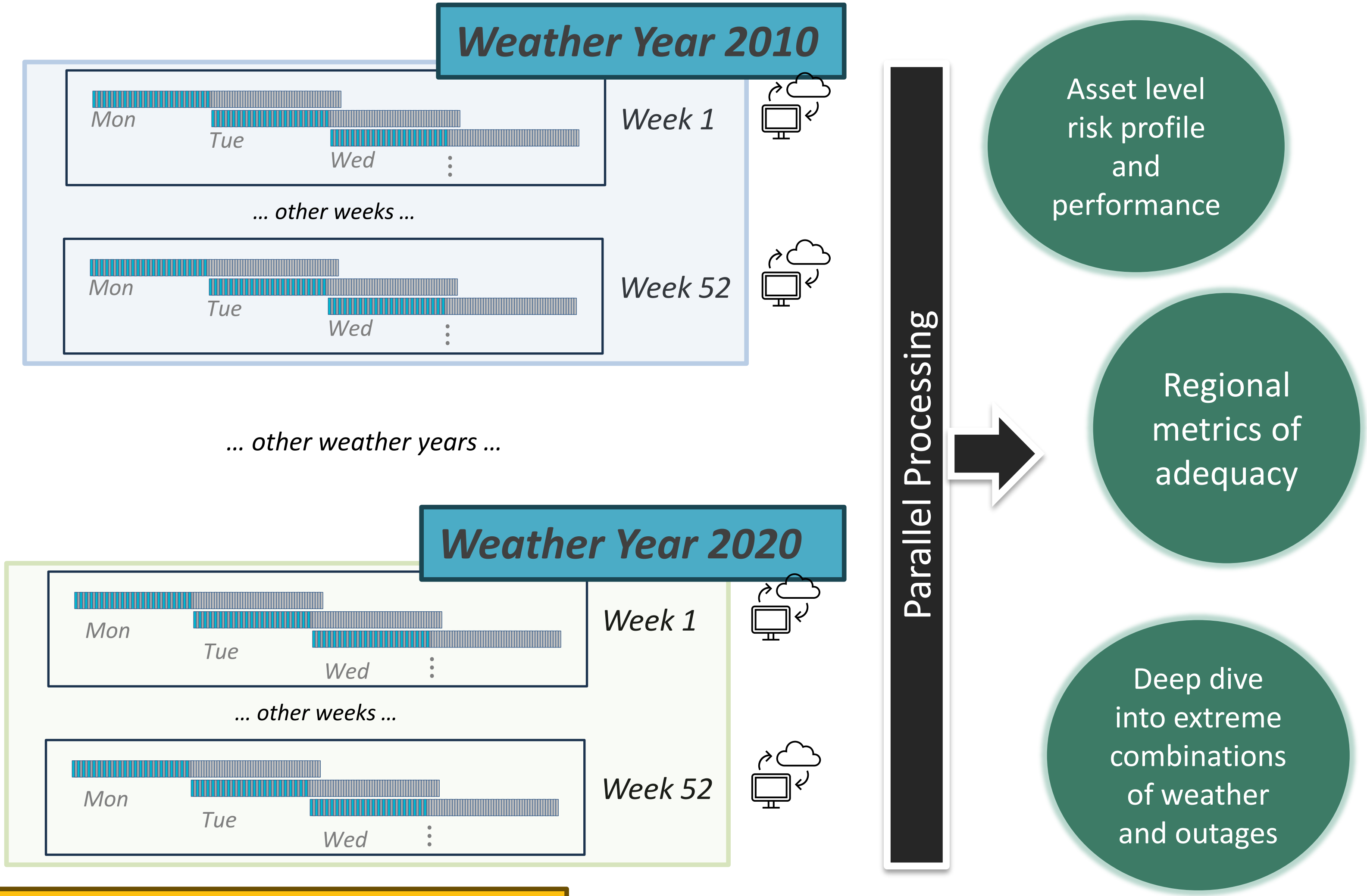
- Uses chronological Monte Carlo modeling with
  - Simulated outages of resources and weather correlated availability of variable resources
- Can be applied to many timeframes including short-term
- Can include physical and operational details of the system
- In addition to conventional reliability metrics, report locational economic signals provided to generation, transmission and demand that incorporate value of adequacy
- Can model the effects of extreme weather and common mode events

ENELYTIX®
powered by PSO

Planning Use Case

Assessment of adequacy for **system annual planning**

Is there sufficient capacity available for Day-Ahead commitment?



Use historical weather correlations for forward-looking planning studies:

What are the reliability impacts of decisions under multiple weather correlation scenarios?

ENELYTIX/PSO RA Computational Methodology

Stratified Sampling
Stratified sampling method to allocate compute resources in proportion to the estimated variance

Weather scenarios

Probabilistic forecasts or historical weather years

Integrated Scenario Reduction
Scenario reduction method based on the simplified optimization formulation

Resource Adequacy Computing

Time periods

Random outages

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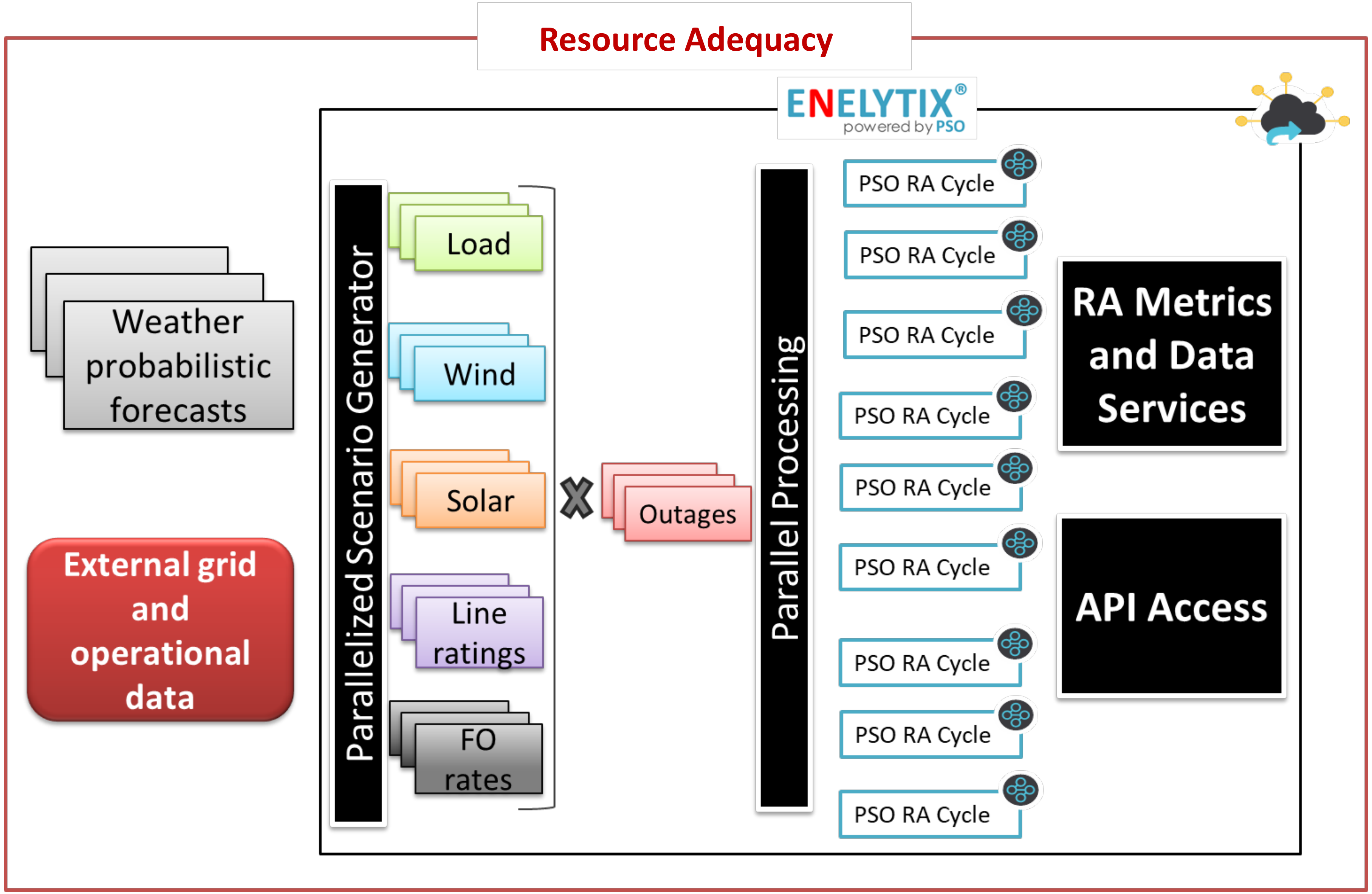
Probabilistic World of RA



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RA Stratified Sampling Process

User input
- Start date and duration
- Total number of VMs
- Number of outage draws
- Variance aggregation preferences

Filtering stage
- Run all weather scenarios
- Discard weather scenarios where no shortage is detected

Shortage

VM allocation
- Allocate VMs to weather scenarios with shortage in **proportion to** their **total variance**

Shortage scenario evaluation
- Re-run the scenarios with shortage

No shortage

End of process – no metrics reported

Improved precision and run-time

RA metrics

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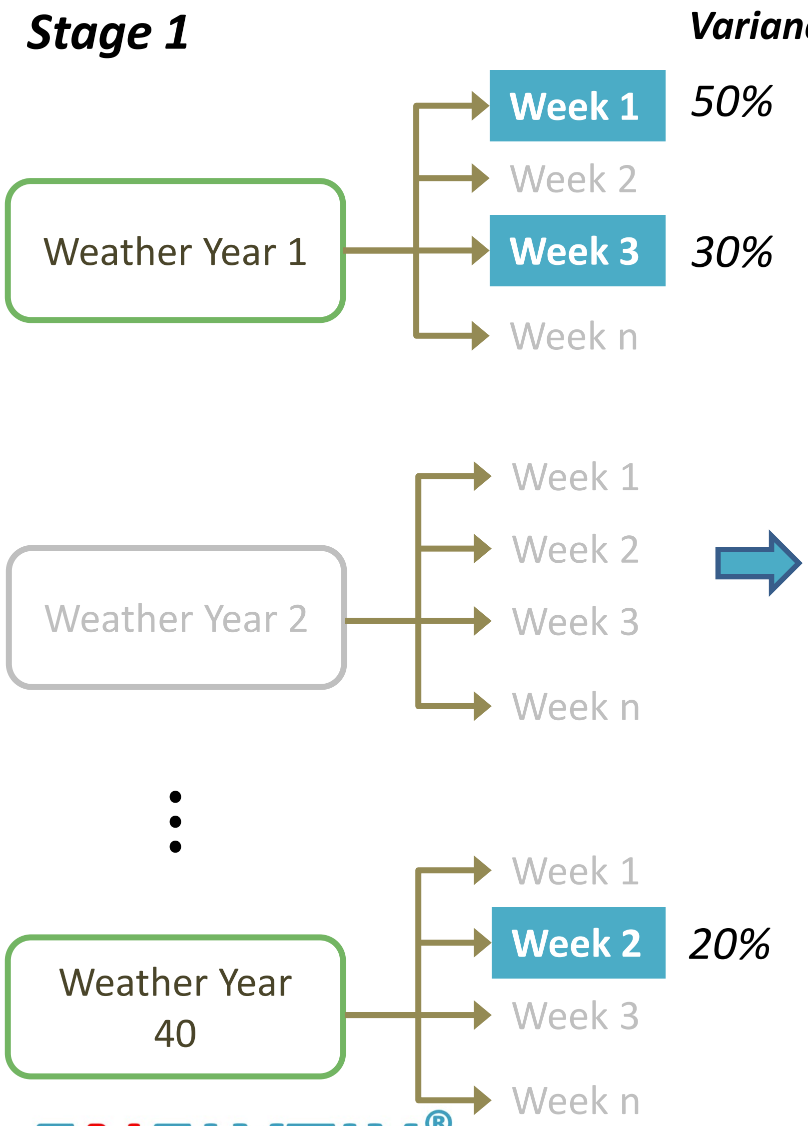
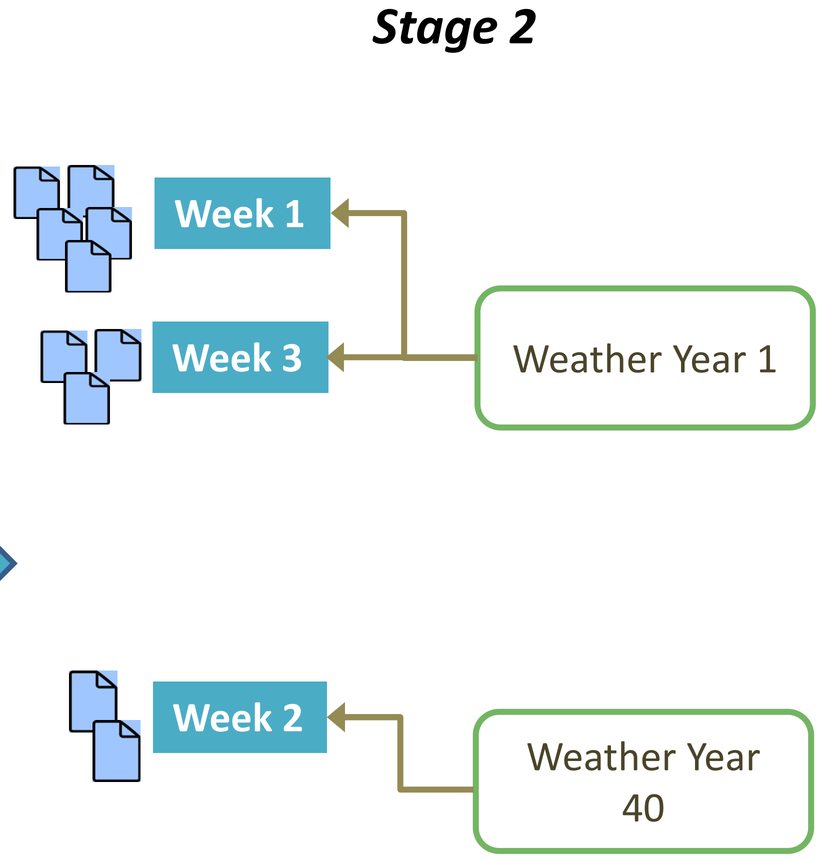
Stratified Sampling for Weather and Time Dimension



Filtering stage evaluation shows shortage in:

- Weeks 1 and 3 of Year 1
- Week 2 of Year 40

Further evaluate these weeks by allocating computational resources in proportion to **shortage variance**



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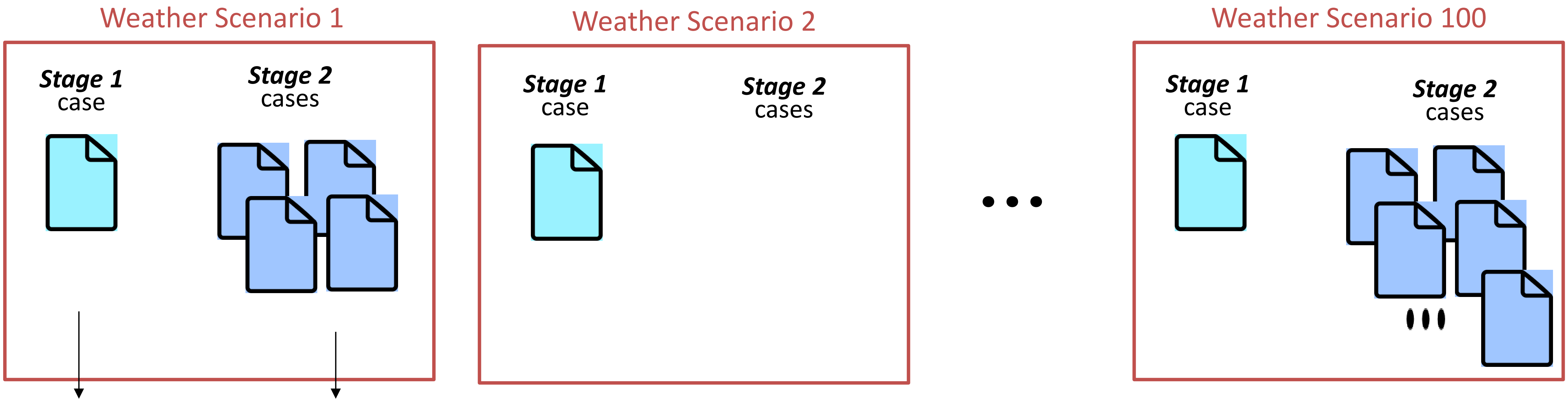
Final Metrics Calculation Methodology after Stratified Sampling

Calculation of results for each scenario,
Stage 1 and ***Stage 2*** cases are grouped



50 outage draws per case * 1 case + 20 outage draws per case * 4 cases = 130 total draws

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