

# Comparative Impacts on Planning Reserve Margin (PRM) of Alternative Regional Resource Adequacy Program Footprints

A SUMMARY OF STUDY FINDINGS FOR THE NEVADA REGIONAL COORDINATION TASK FORCE

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## STUDY CONDUCTED FOR



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# Study Overview

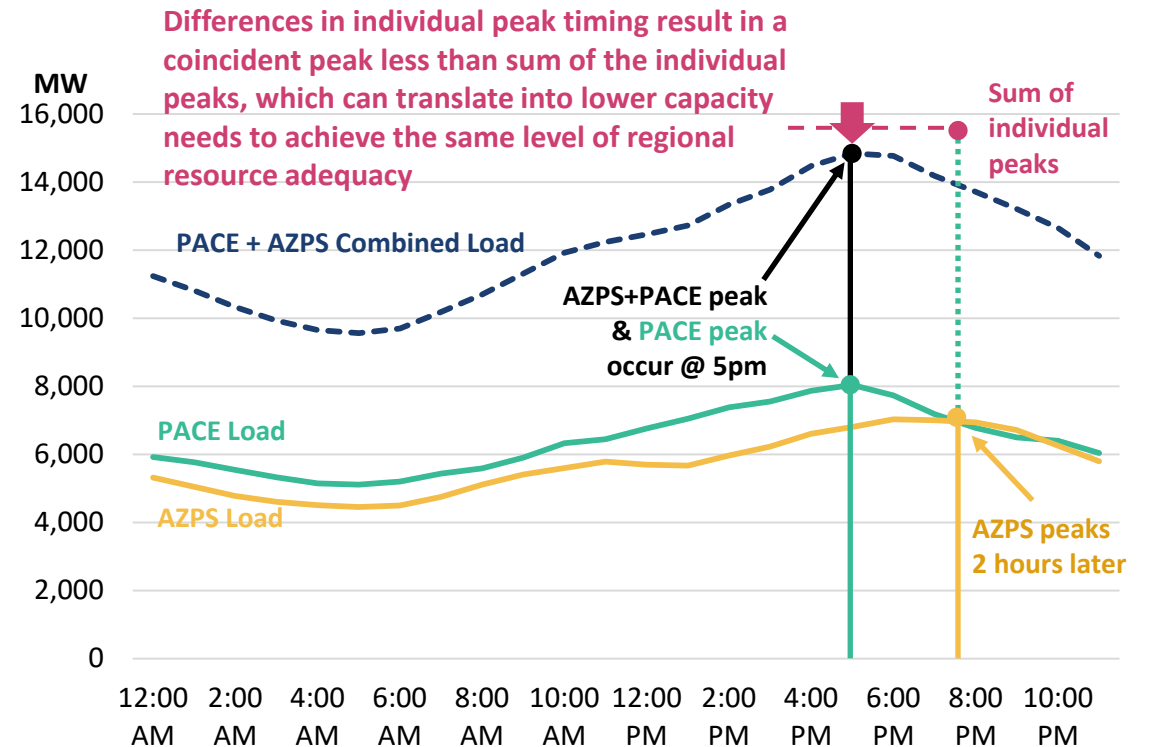


# Regional RA Programs Create Value by Unlocking Regional Diversity

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 10<sup>th</sup>, 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.

# 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

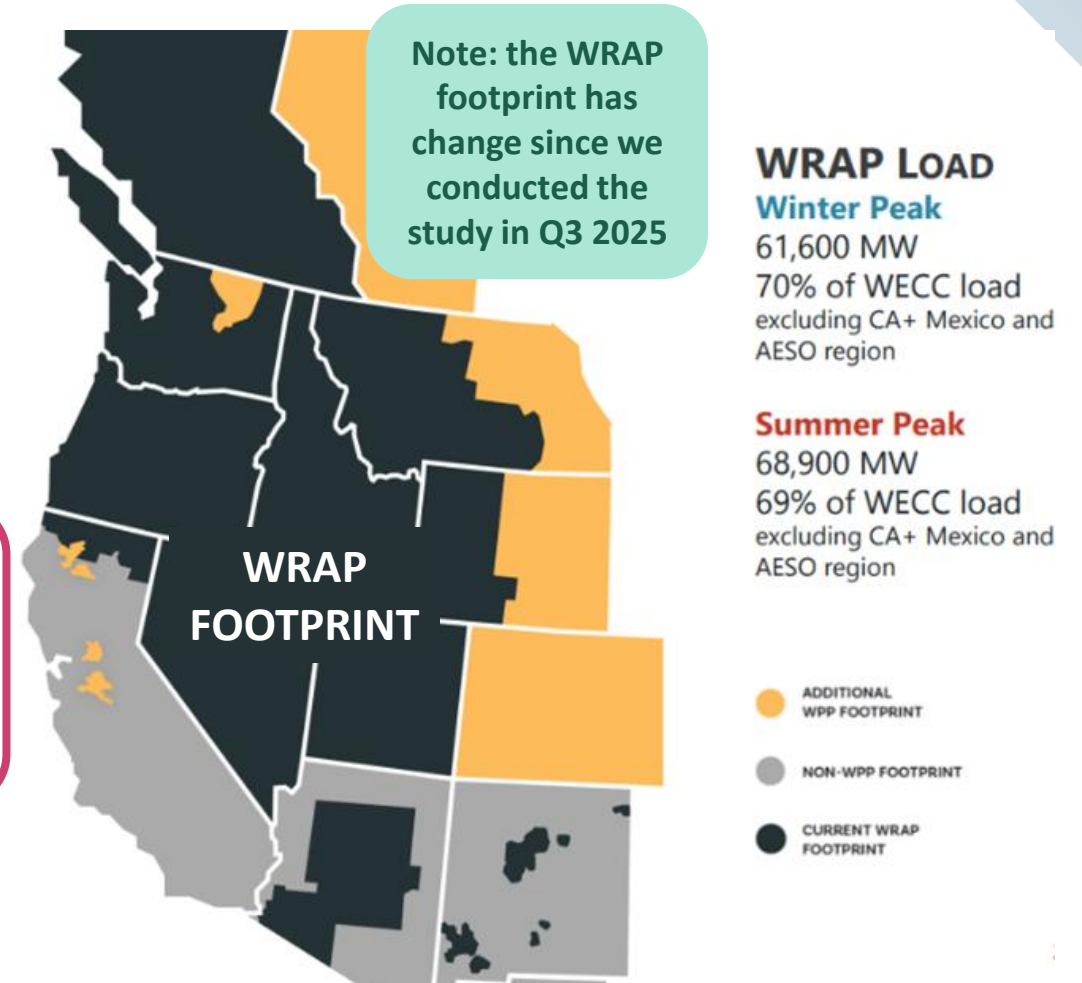
## WRAP has two components:

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
<b>Studies complete</b>	<b>October 31, 2028</b>	<b>March 31, 2029</b>
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
<b>Binding Season</b>	<b>June 1 – September 15, 2030</b>	<b>November 1 – March 15, 2030-2031</b>
Advisory Binding Season	June 1 – September 15, 2033	November 1 – March 15, 2033-2034

# Summary

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**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)?

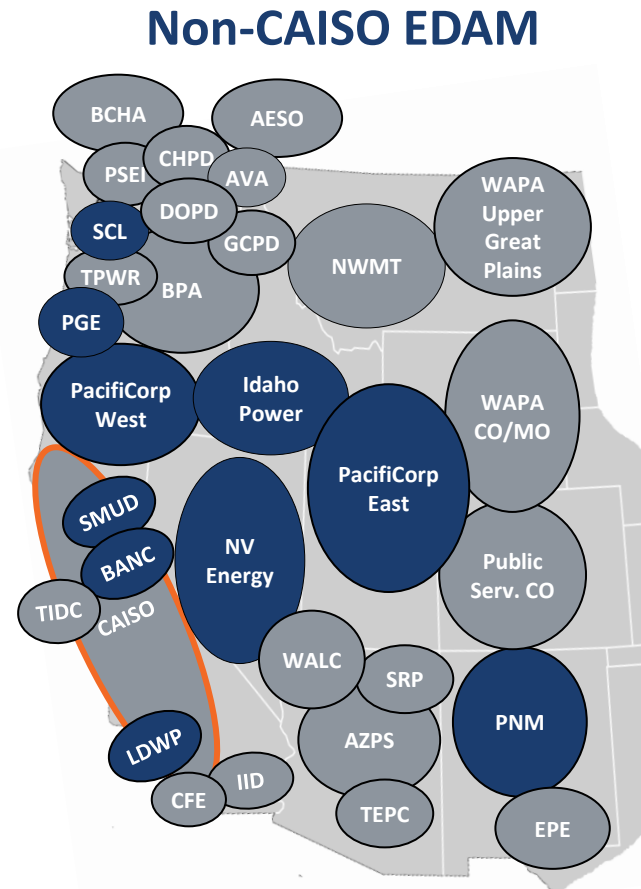
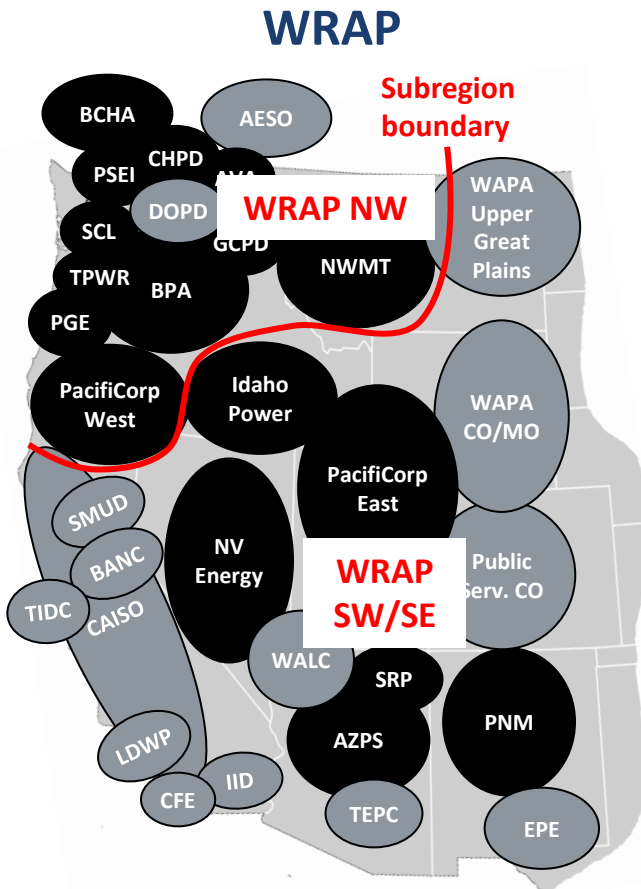
**To do so, we conducted a detailed PRM Analysis for four regional RA footprints:**

- Undertook RA modeling and analysis of historical data to **replicate the WRAP approach** to assessing Qualified Capacity Contribution (QCC) and PRM
  - Under WRAP, PRM is the percentage of availability-adjusted capacity in excess of the regional 50-50 peak load needed to meet the resource adequacy criterion (e.g., 1 event-day in 10 years per season)
- 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 Members**  
*(at time of study)*

**Study Participants**

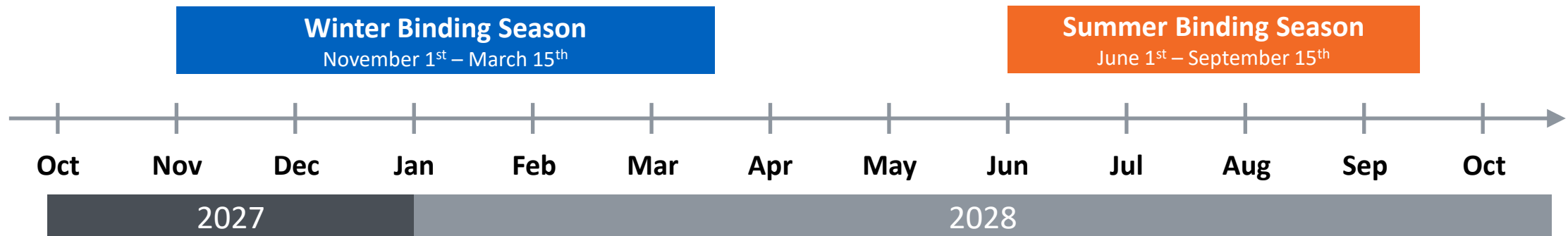
**Other BAAs**

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

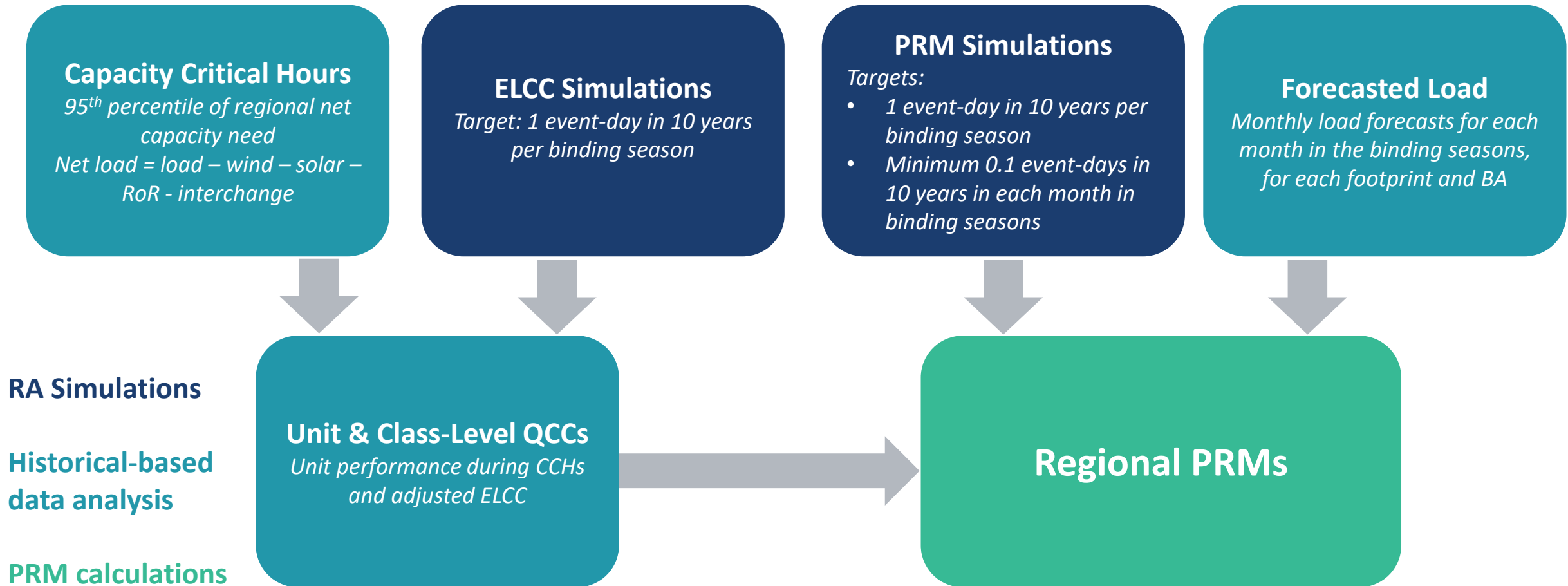
- We conducted all analysis on an hourly basis, with metrics calculated monthly or seasonally (as appropriate) to align with WRAP-defined methodologies\*
  - We conducted hourly PRM and ELCC simulations for each of the WRAP-defined summer and winter binding seasons to establish perfect capacity needs 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 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 to calculate PRMs using WRAP's approach



# Summary of Findings



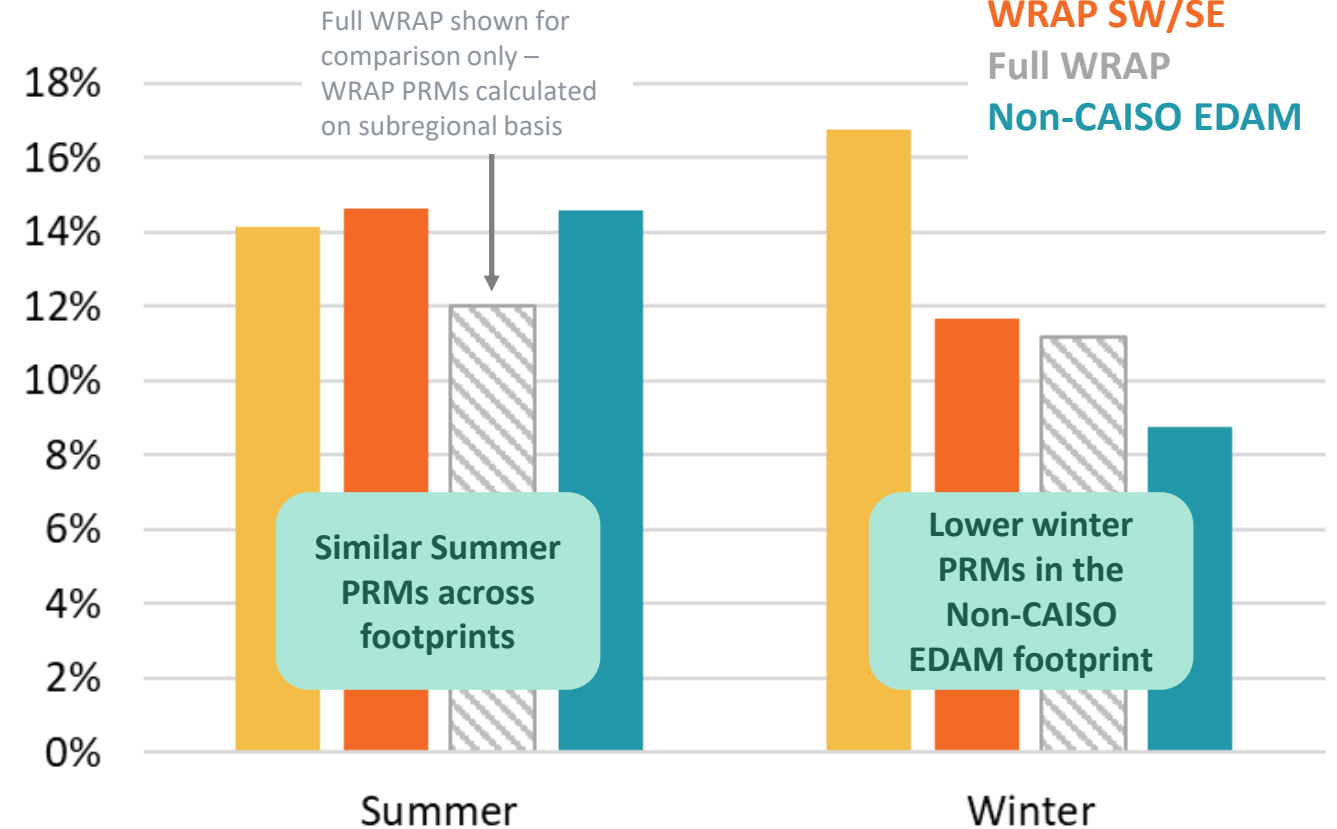
# Seasonal PRM Results

**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.

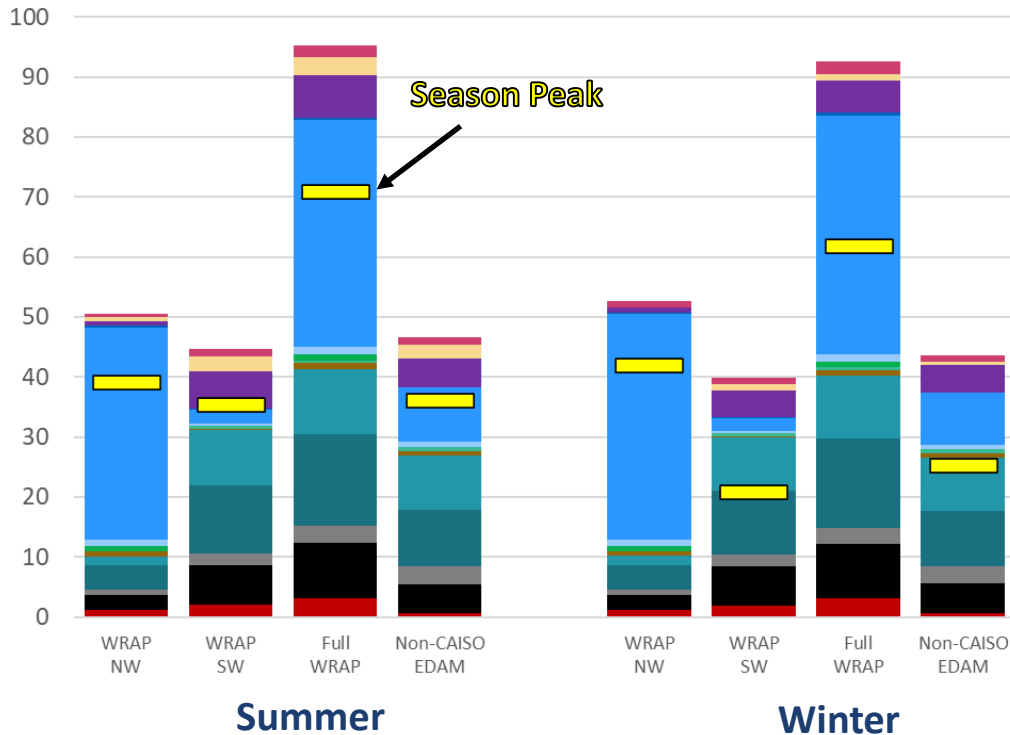
# Regional Load and Resource Balance

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

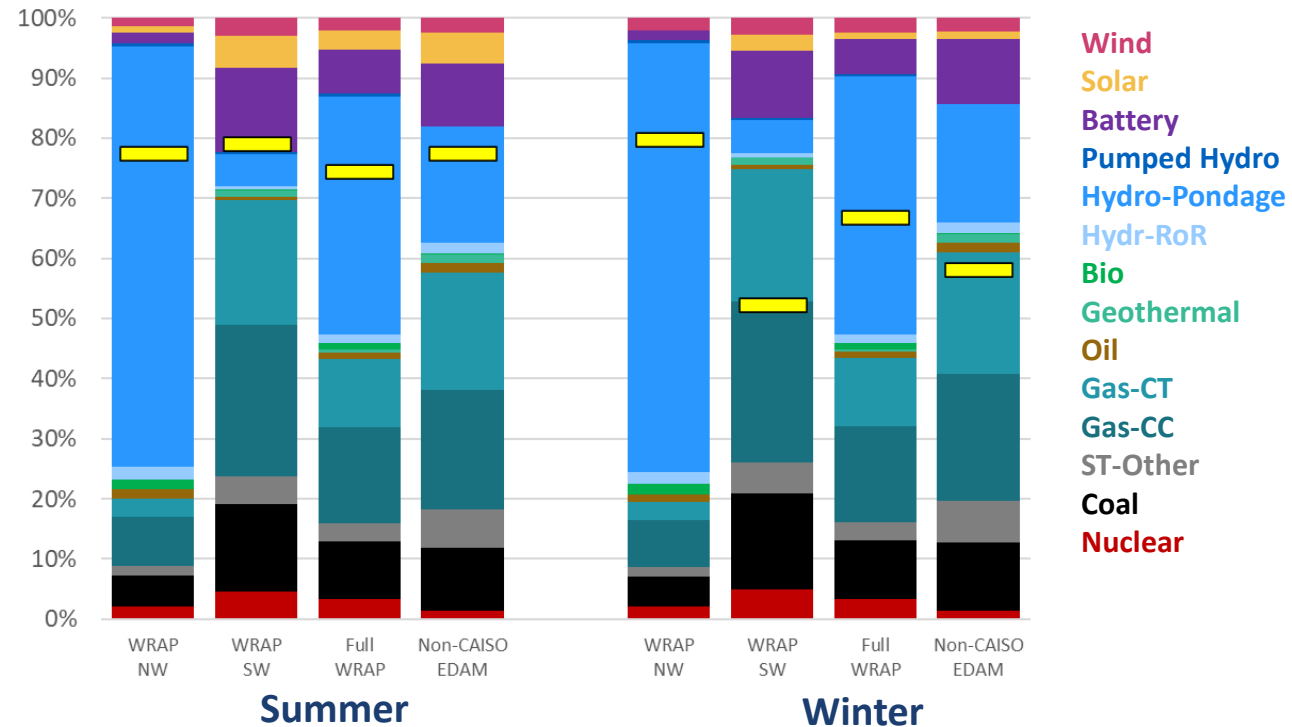
## QCC by Footprint and Resource Type

GW of total footprint QCC



## QCC Composition by Footprint and Resource Type

% of total footprint QCC

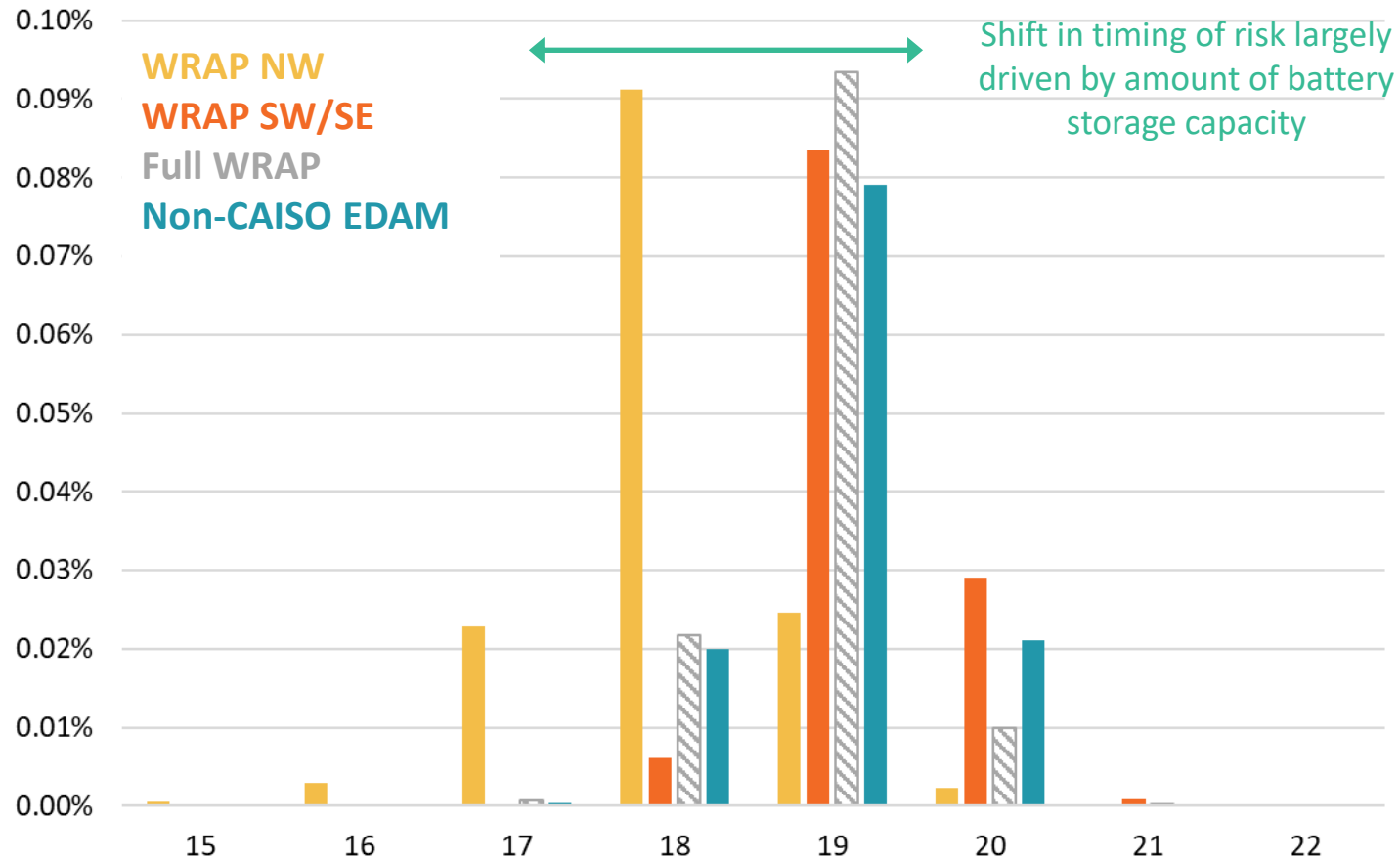


Note: Charts show average monthly seasonal QCC by type footprint, but maximum seasonal load.

# Summer Loss of Load Risk Hours

## Simulated Summer LOLP by Footprint

Probability of shortfall by hour of day



Shift in timing of risk largely driven by amount of battery storage capacity

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

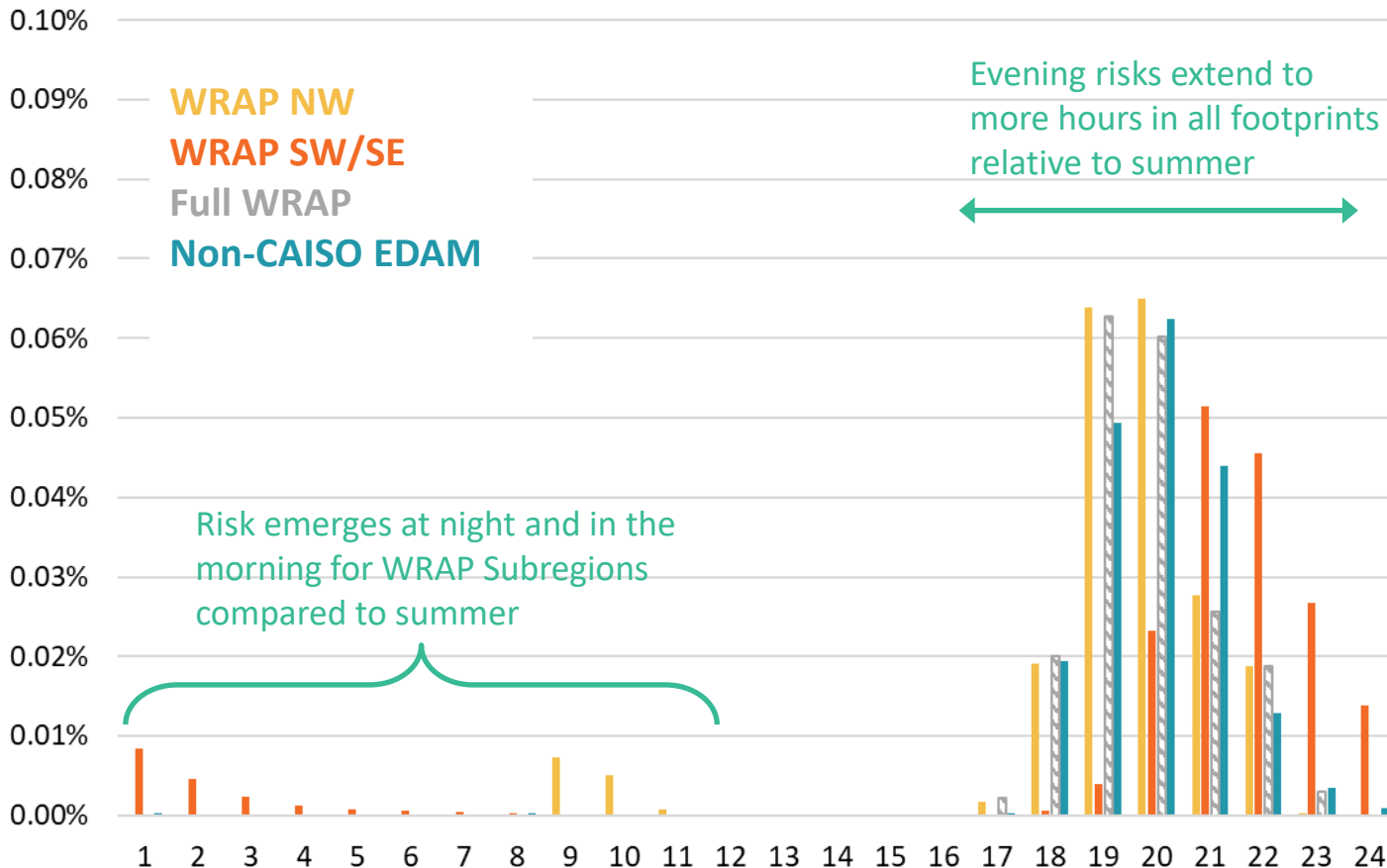
- We find this dynamic occurs consistently across footprints, though is time shifted in the NW relative to other footprints due to differences in timing of the net load peak and amount of battery storage in each footprint
- WRAP NW risks also driven by wind availability—wind tends to be lower in the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

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

# 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

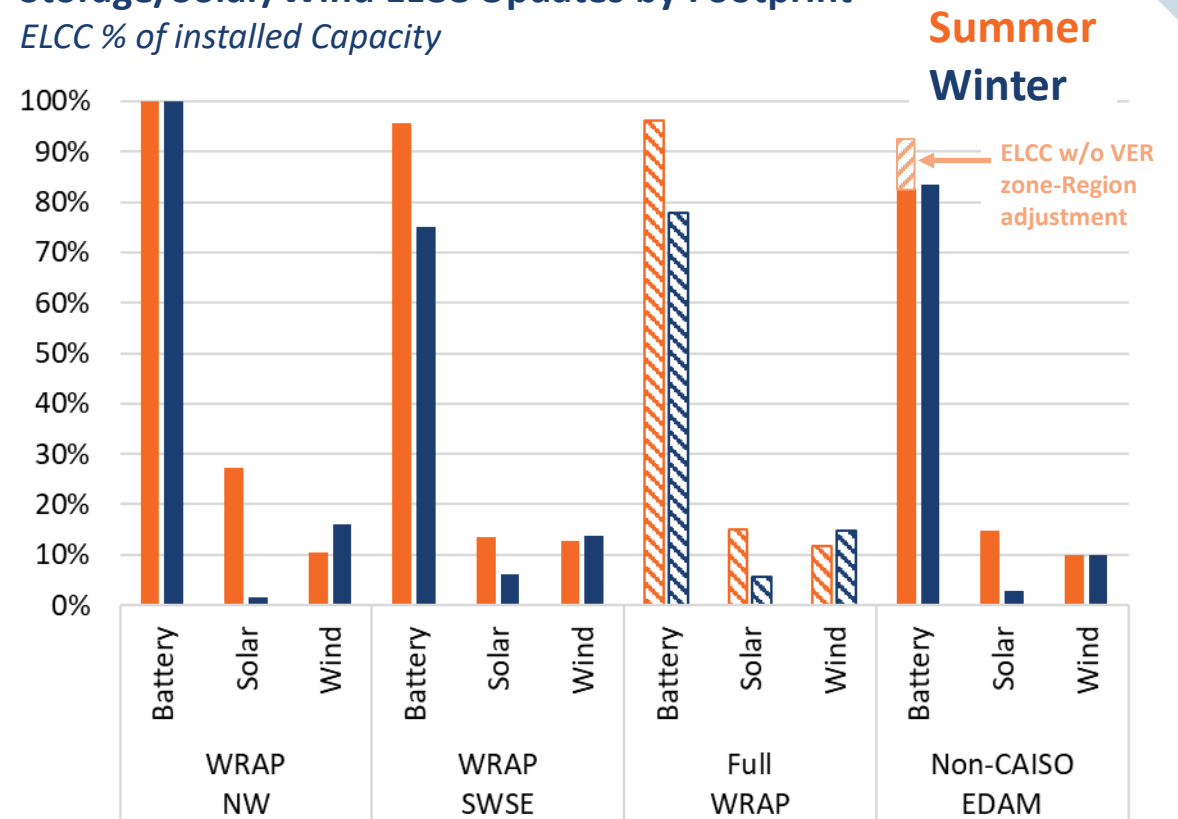
- The lack of morning risk in Non-CAISO EDAM vs WRAP SWSE is one driver of the lower winter PRMs in Non-CAISO EDAM

# Regional ELCC Summary

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

- 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
- 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

**Storage/Solar/Wind ELCC Updates by Footprint**  
 ELCC % of installed Capacity

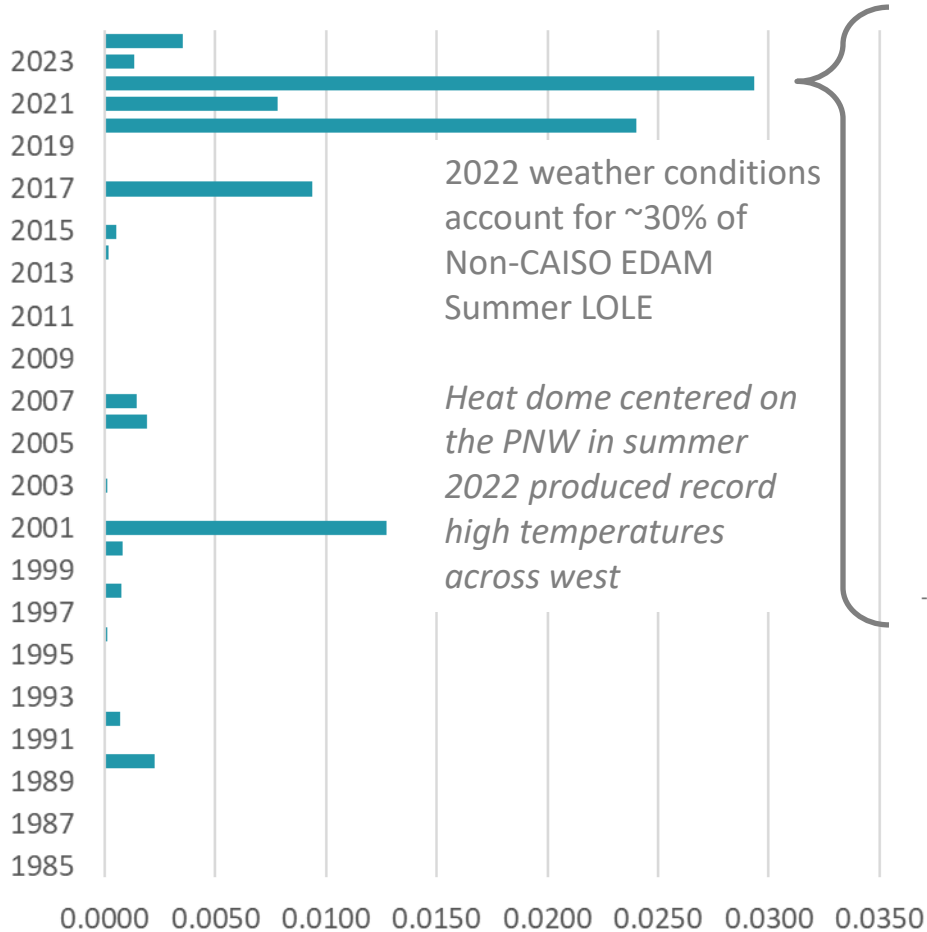


Note: Seasonal ELCCs shown are the weighted average of resource-level season monthly ELCCs by footprint and resource type. Full WRAP ELCCs shown for comparison only – WRAP ELCCs/PRMs calculated on subregional basis.

# Example: Non-CAISO EDAM Summer

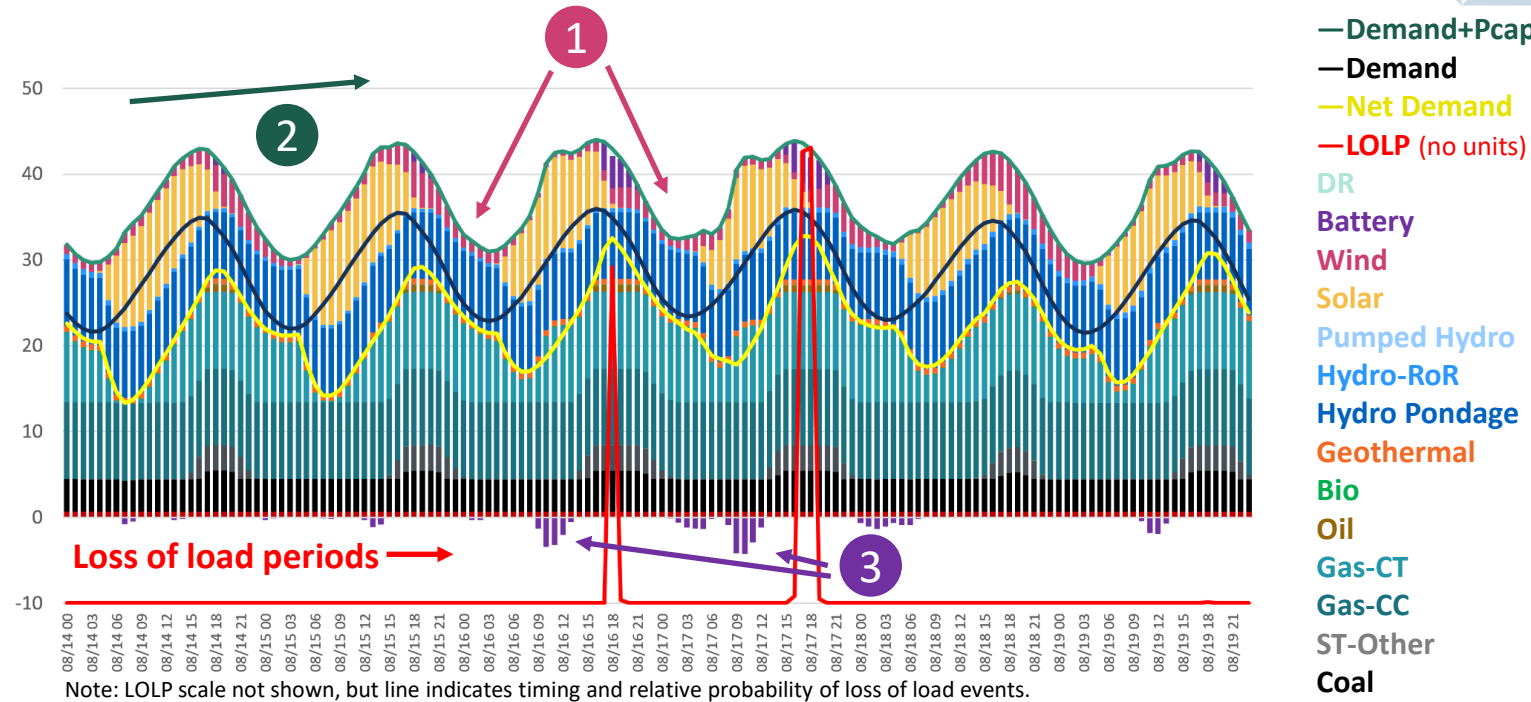
## LOLE by Weather Scenario

Days/year



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

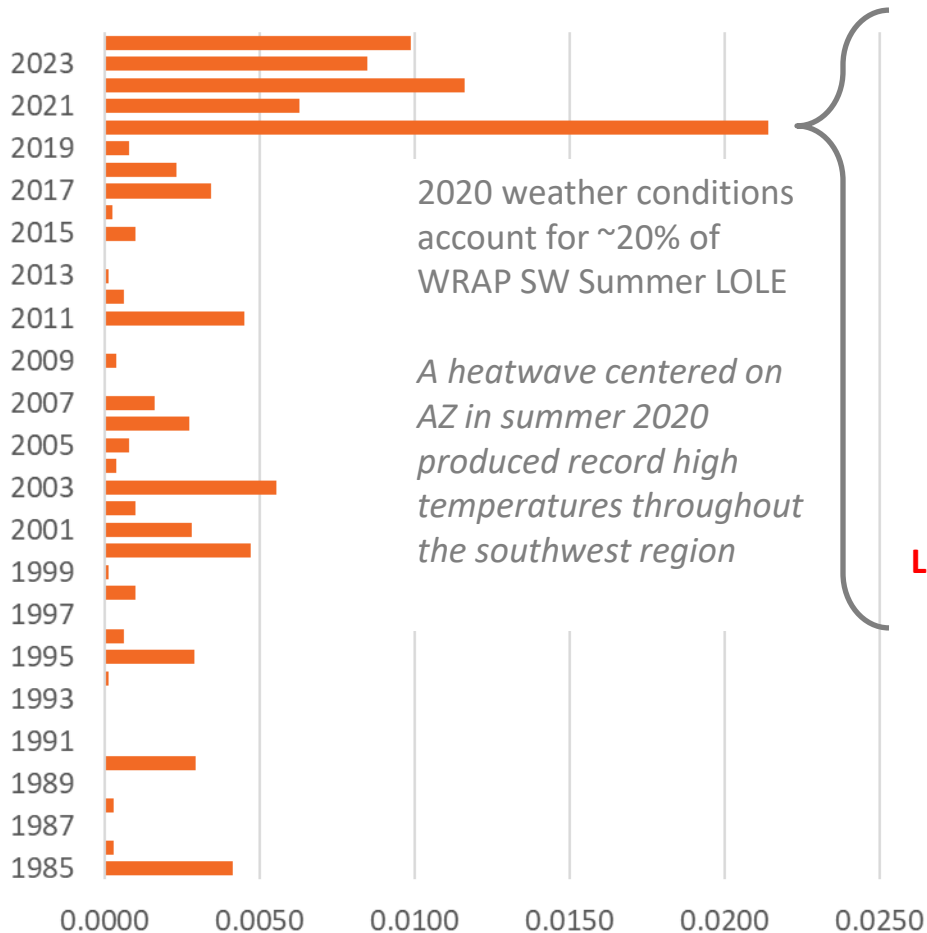
GW, hourly by unit type (average over outage draws)



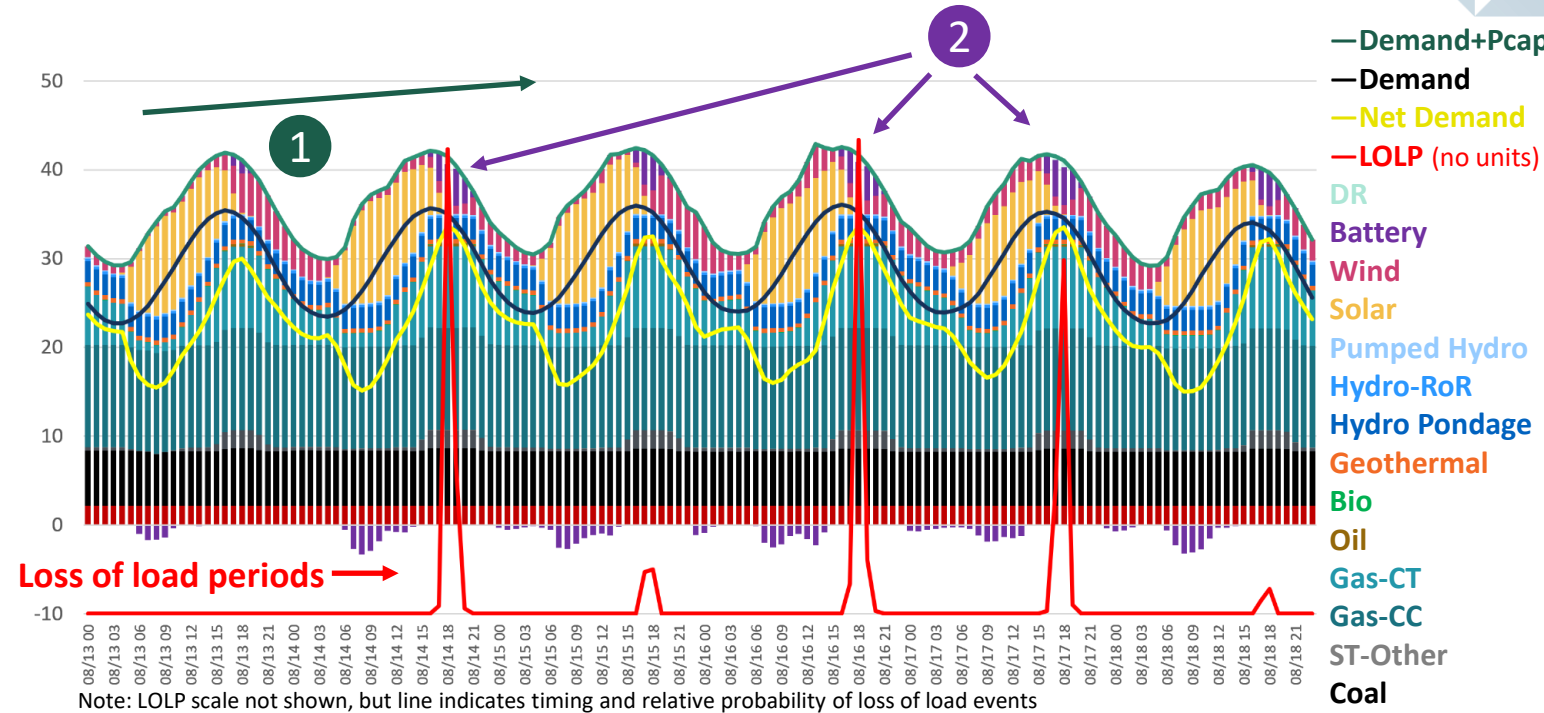
- 1 Low wind output during the nights of Aug. 16th & 17th
- 2 Increasing evening peaks over the week due to heat wave conditions
- 3 Batteries unable charge enough to meet needs through duration of net load peaks, including making up for unanticipated outages (not shown)

# Example: WRAP SW/SE Summer

**LOLE by Weather Scenario and Footprint**  
Days/year



**Simulated Dispatch For Aug. 13-18 2028 High Risk Period (2020 weather)**  
GW, hourly by unit type (average over outage draws)



- 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

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**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**

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

**Incorporating enhancements to the WRAP methodology (as used in this analysis), such as transmission limits within the footprints and temperature-dependent thermal outage rates may reveal additional resource adequacy needs and opportunities**

# **Additional PRM Analysis Details**

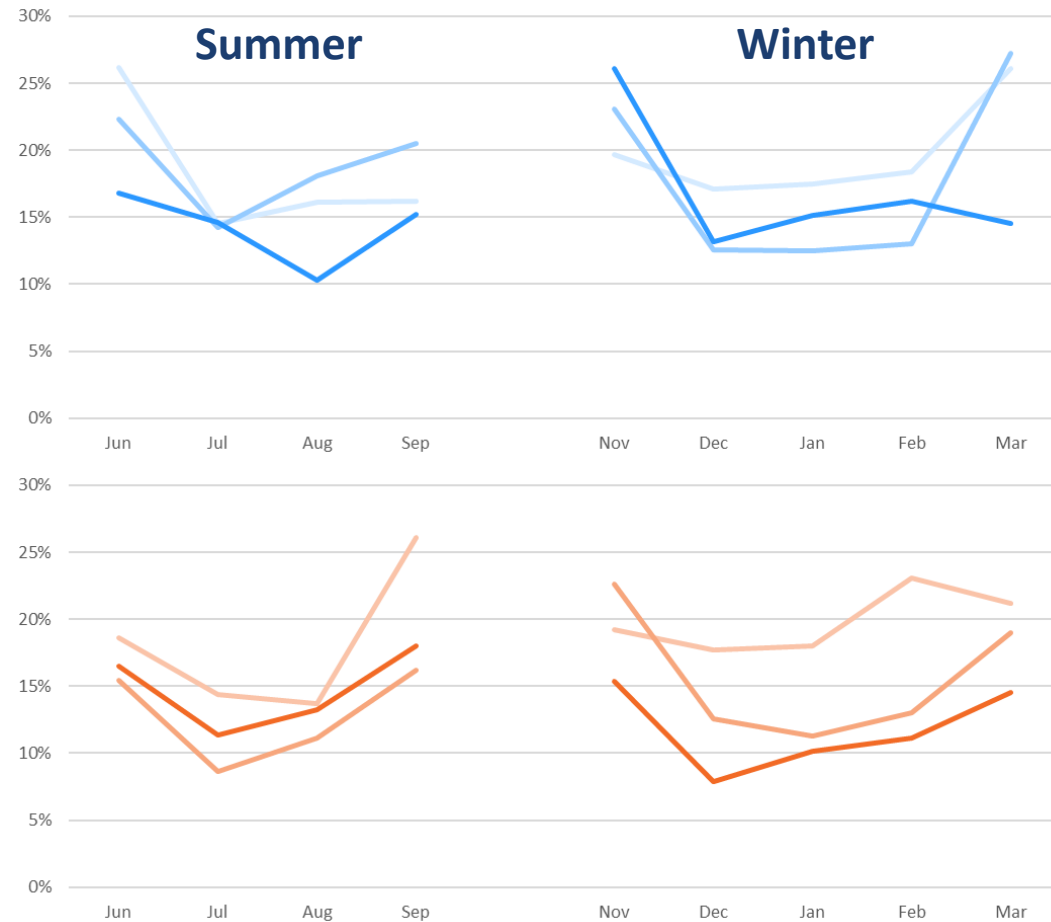


# Simulated vs WRAP-reported Monthly PRMs

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*



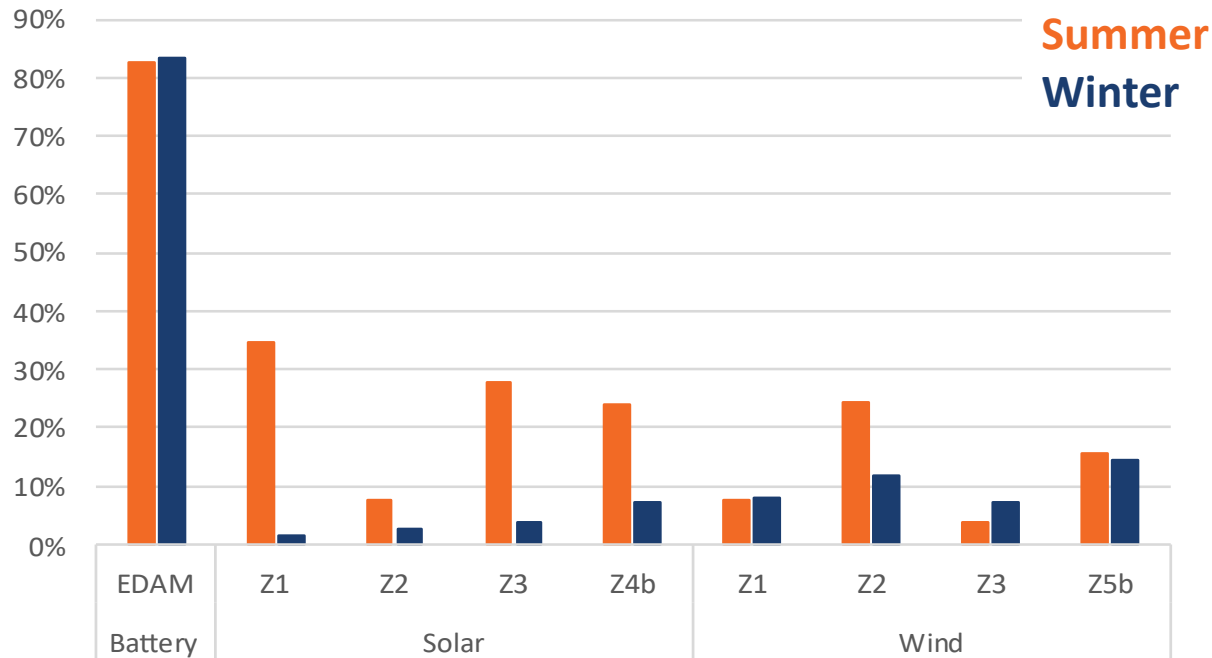
**WRAP NW**  
 Study 27/28  
 WRAP 25/26  
 WRAP 24/25

**WRAP SWSE**  
 Study 27/28  
 WRAP 25/26  
 WRAP 24/25

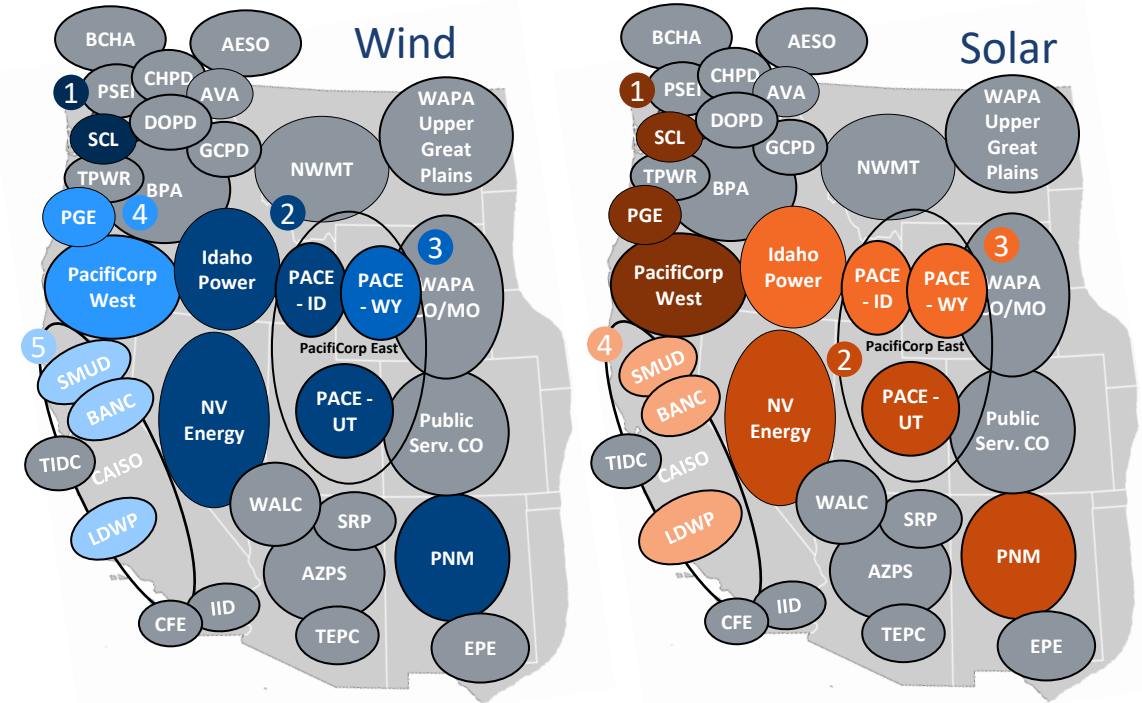
# Non-CAISO EDAM Seasonal ELCC by VER Zone

## Storage/Solar/Wind ELCC% by VER Zones

ELCC % of installed Capacity



## Non-CAISO EDAM VER Zones



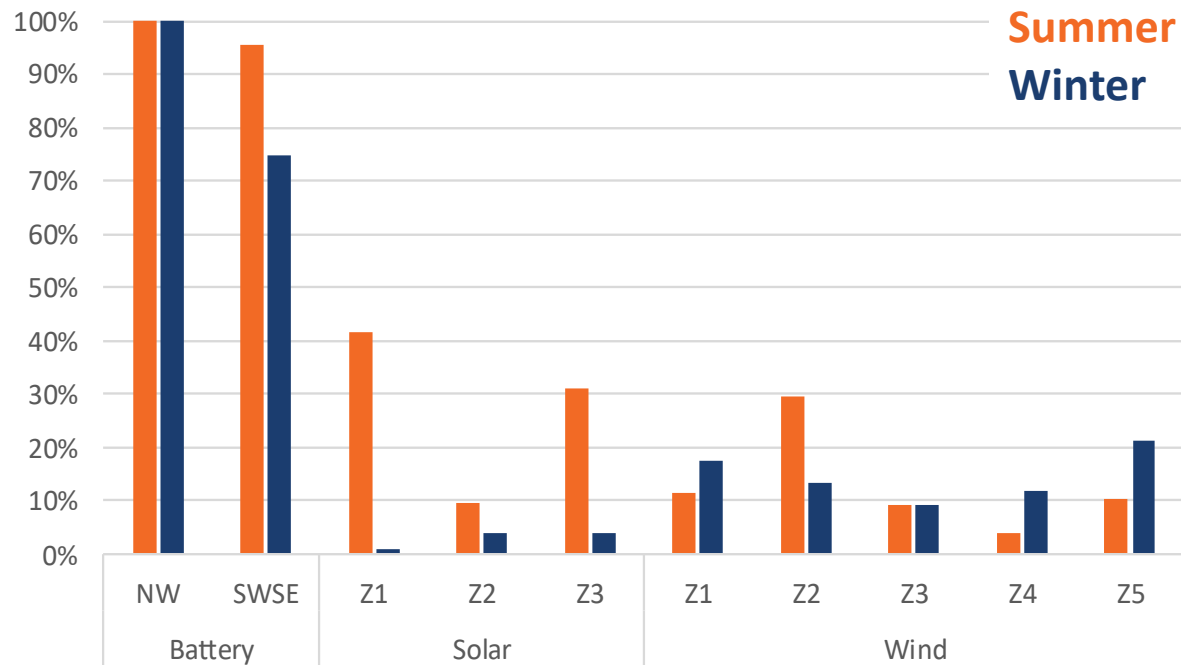
Note:

- 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.

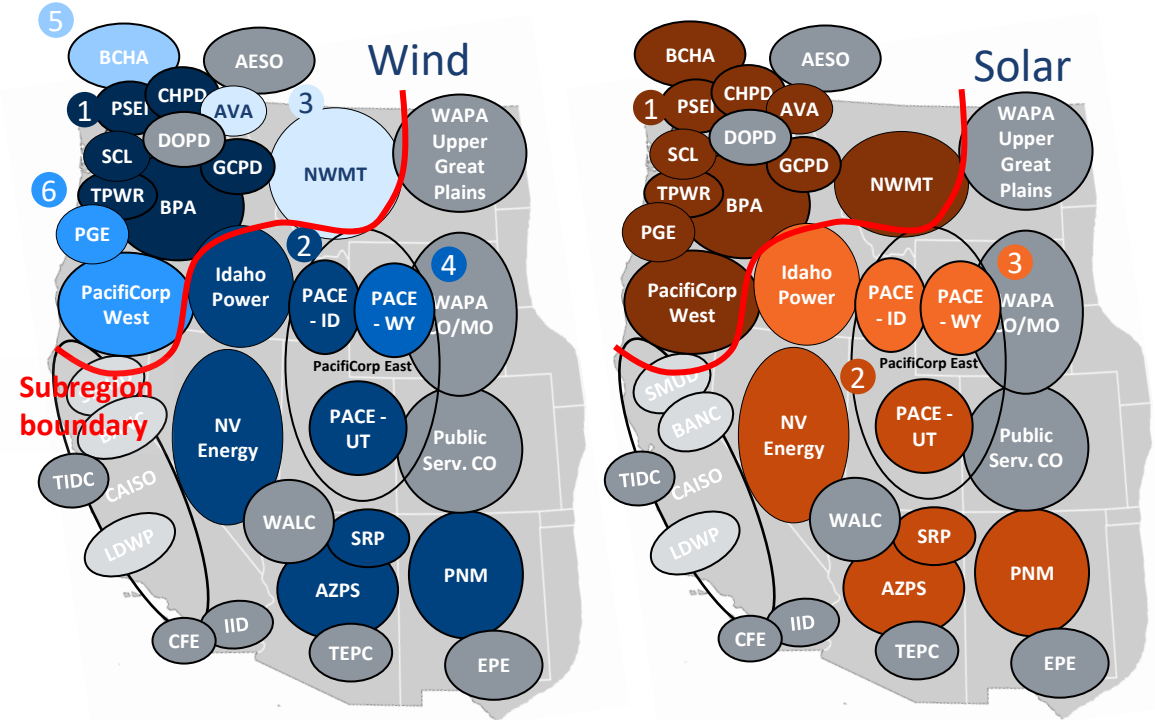
# WRAP Seasonal ELCC by VER Zones and Sub-regions

## 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.

# **Speak Bio & Additional Resources**



# Presented By

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Dr. Kai Van Horn leverages electricity system modeling, analysis, and visualization to illuminate and navigate the opportunities and challenges presented by the energy transition.

He has worked with market participants, market operators, utilities, and an array of other stakeholders on a diverse range of matters. He has experience with energy and capacity market design, transmission and generation planning, the modeling and analysis of financial transmission rights, carbon pricing issues, on- and offshore renewables integration, and transmission benefits analysis.

Dr. Van Horn has nearly a decade of experience analyzing wholesale market designs, planning, and operations via the development of large-scale power system models in commercially available software packages, as well as custom-built simulation and analysis platforms. He has led numerous teams in the deployment of such models and worked with clients to develop new modeling approaches that meet the evolving needs of the energy transition

# Examples of Brattle Work on Resource Adequacy

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- [Regional Resource Adequacy Program Footprint PRM Study](#)
- [Are Resource Adequacy Markets Adequate?](#)
- [SPP Future Energy & Resource Needs Study \(FERNS\)](#)
- [MISO Reliability Attributes "Solution Space:" Initial Assessment of Promising Solutions](#)
- [Modeling Storage and Resource Adequacy in Capacity Expansion Models](#)
- [Industry Changes in Resource Adequacy Requirements, Metrics, and Design Elements](#)
- [Estimation of the Market Equilibrium and Economically Optimal Reserve Margins for the ERCOT Region](#)
- [Alternative Resource Adequacy Structures for New Jersey](#)
- [Alternative Resource Adequacy Structures for Maryland](#)
- [Quantitative Analysis of Resource Adequacy Structures in New York](#)
- [Impacts of Renewable Integration on Resource Adequacy in Michigan](#)
- [Resource Adequacy in Western Australia: Alternatives to the Reserve Capacity Mechanism](#)
- [Resource Adequacy Requirements: Reliability and Economic Implications \(for FERC\)](#)
- [ERCOT Investment Incentives and Resource Adequacy](#)
- [The Economics of Reliability and Resource Adequacy Planning](#)
- [Resource Adequacy in California: Options for Improving Efficiency and Effectiveness](#)
- [Resource Adequacy Requirements, Scarcity Pricing, and Electricity Market Design Implications](#)
- [Best Practices in Resource Adequacy](#)

# Appendix



# **Summary of Modeling Methodology & Key Assumptions**



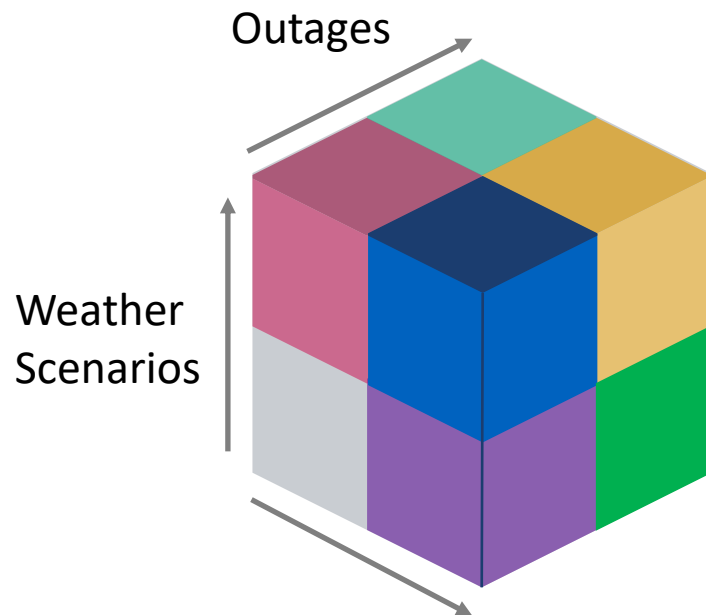
# Resource Adequacy (RA) Simulations

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

## Input Data:

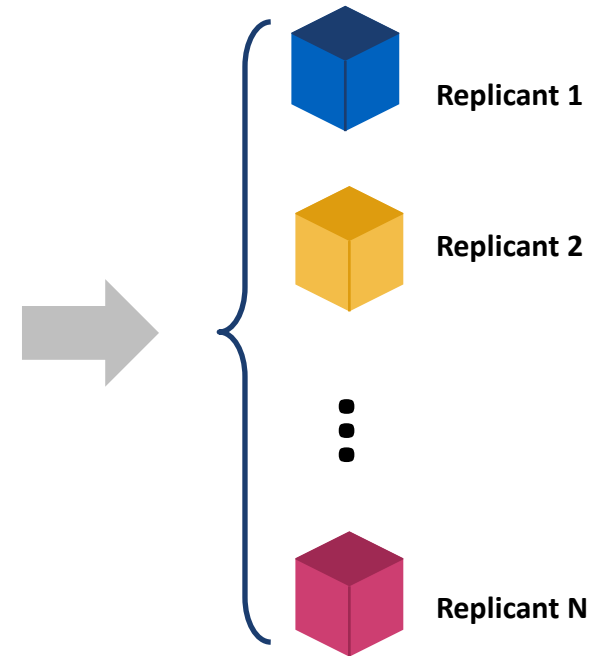
- Weather Scenarios
- Outage parameters
- Load forecast uncertainty
- Capacity contract data
- Historical interchange
- Resource mix
- Topology

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



Peak Load Forecast Uncertainty (LFU)  
*[may be captured by weather scenarios]*

Simulated dispatch for each replicant tests for shortages



$N = \# \text{ outage draws}$   
 $\times \# \text{ weather scenarios}$   
 $\times \# \text{ LFU draws}$   
*(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

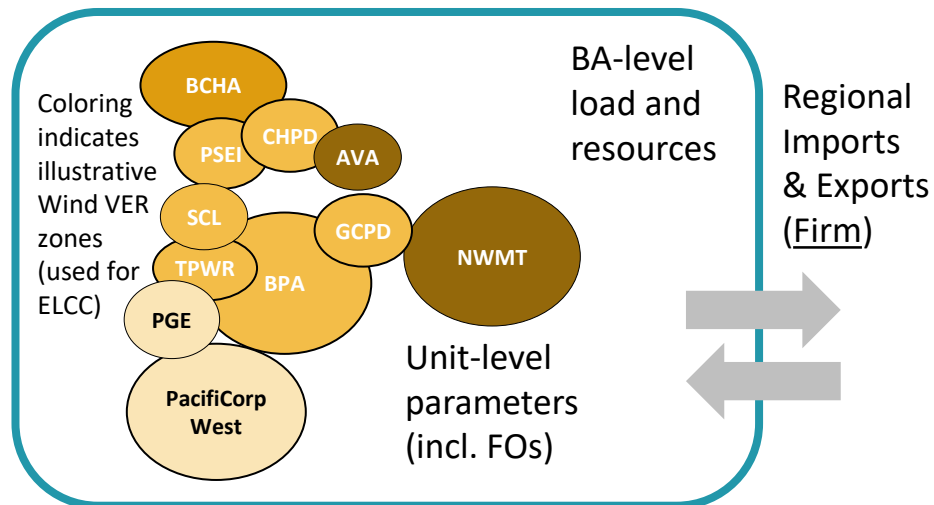
Other results:

- Hourly dispatch & cost

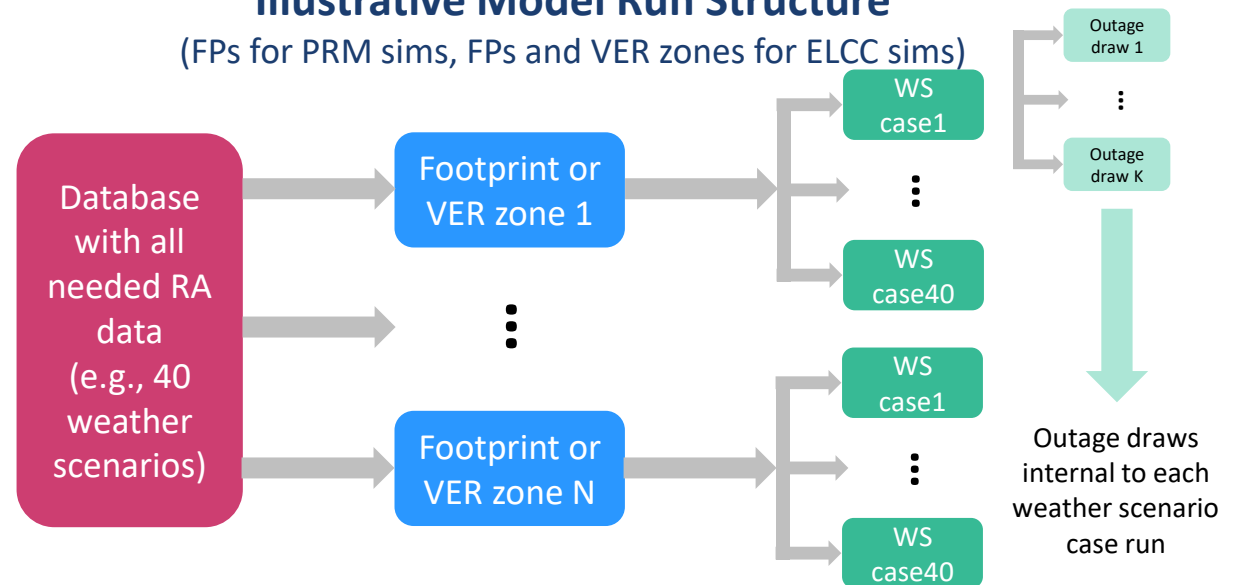
# Detailed RA simulation is a Key Input to PRM for the RRA Footprints

- 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

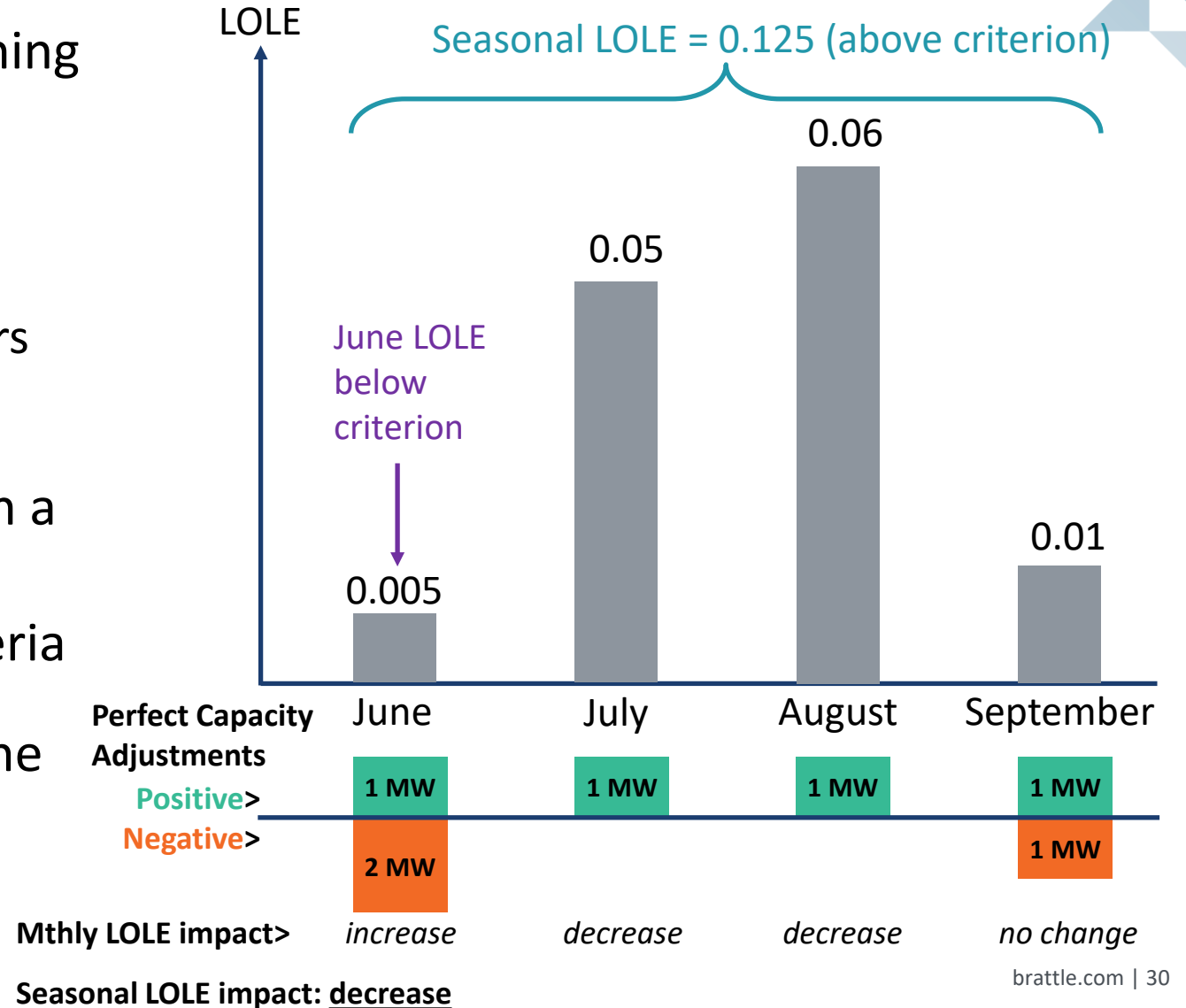
WRAP has two RA criteria for establishing the seasonal and monthly PRMs:

- 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

Example: Seasonal/Monthly LOLE Adjustment

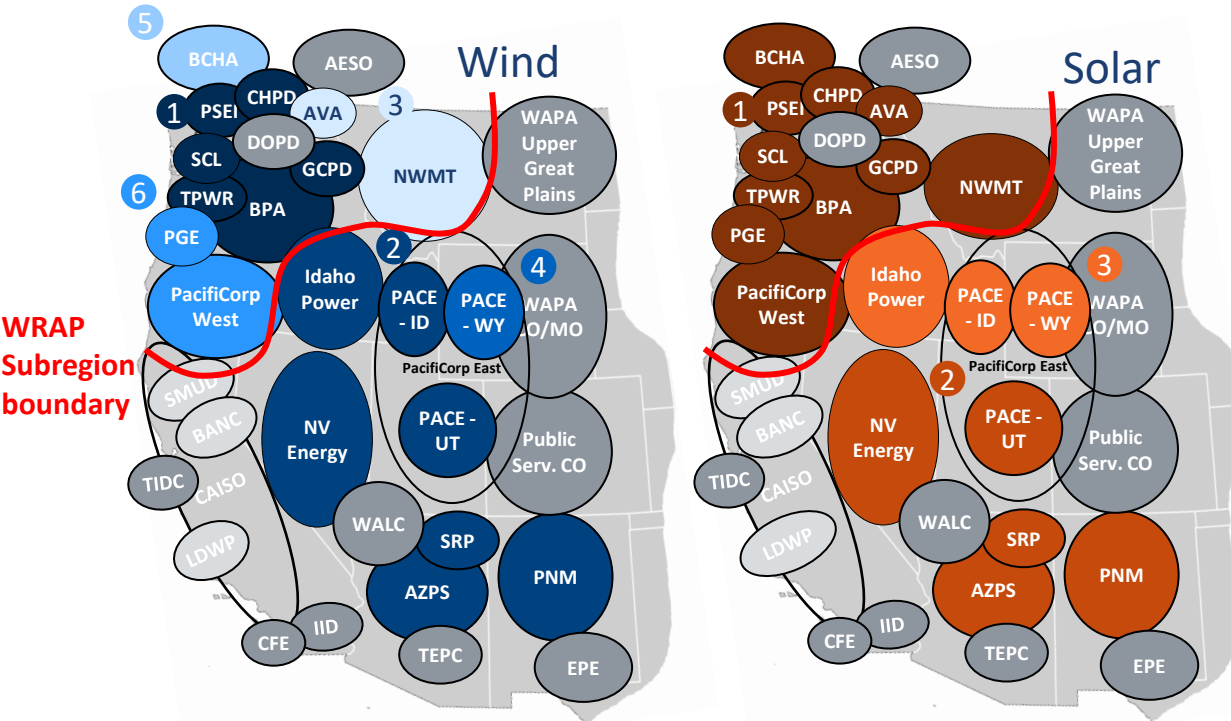


# In addition to PRM footprints, We Analyzed Twenty VER Zones

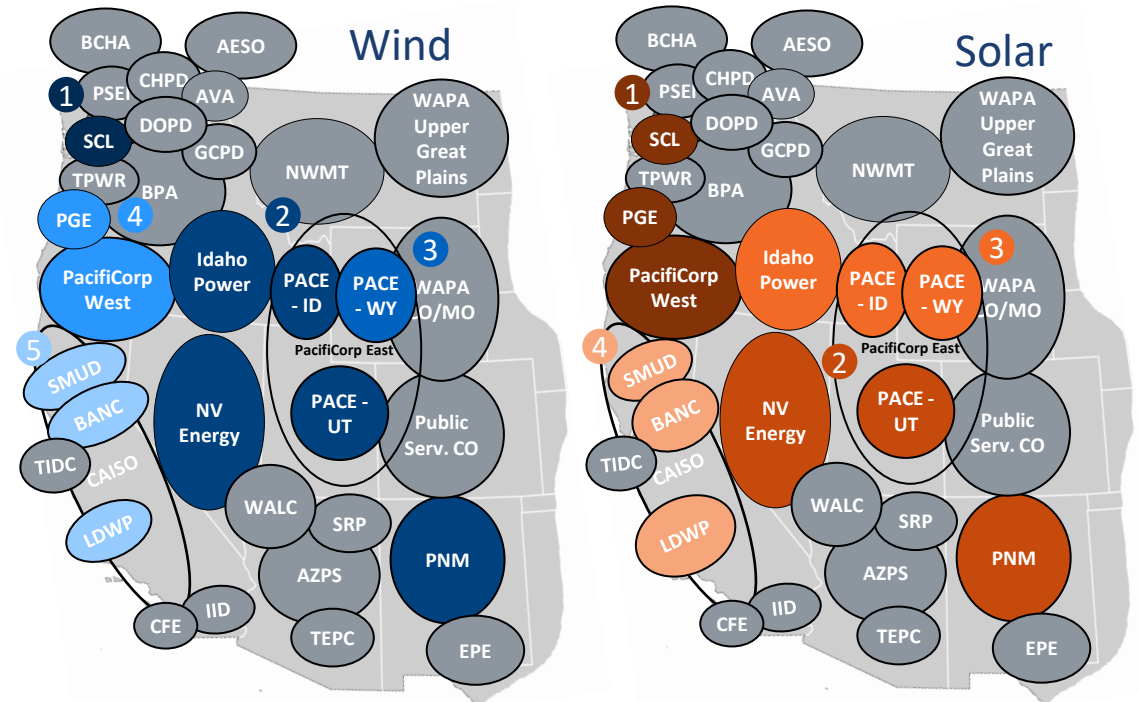
We used VER zones to assess wind and solar ELCC as an input into the PRM calculation



## WRAP VER Zones



## EDAM Footprint VER Zones



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

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

# We Conducted Analysis to Calculate FSPRM For Each Footprint

$$FSPRM (\%) = \frac{UCAP_{1-in-10} - \text{Regional P50 Load Forecast}}{\text{Regional P50 Load Forecast}} * 100 \rightarrow \text{See WRAP BPM 102 for more details}$$

FSPRM components:

- $UCAP_{1-in-10}$ : 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

***FS Capacity Requirement = FS Capacity Requirement Unadjusted + Contingency Reserve Adjustment***

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

and  
***Contingency Reserve Adjustment***  
*= Contingency Reserve Adjustment\_Generation + Contingency Reserve Adjustment\_Load*

# WRAP UCAP Methodologies

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

→ 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

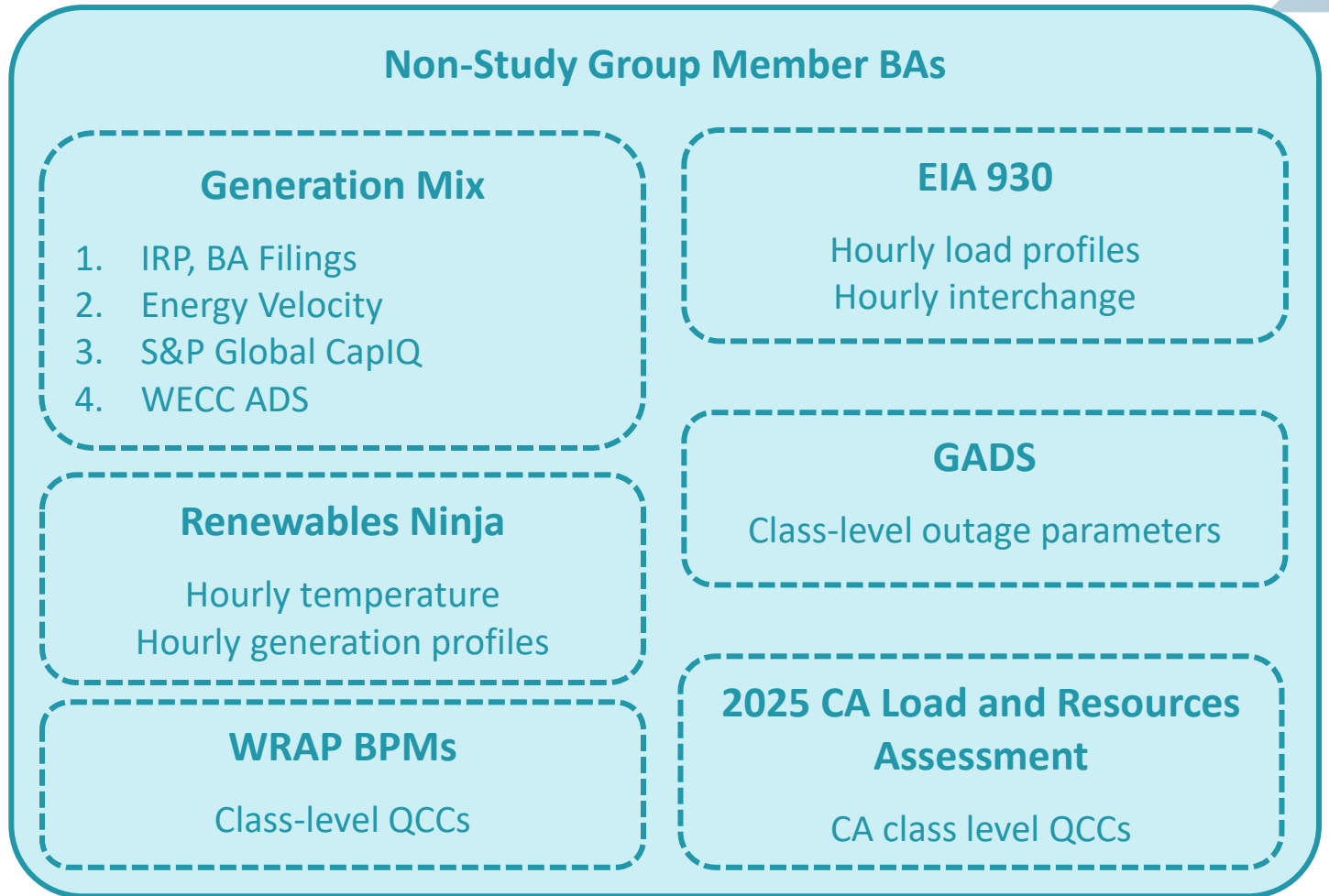
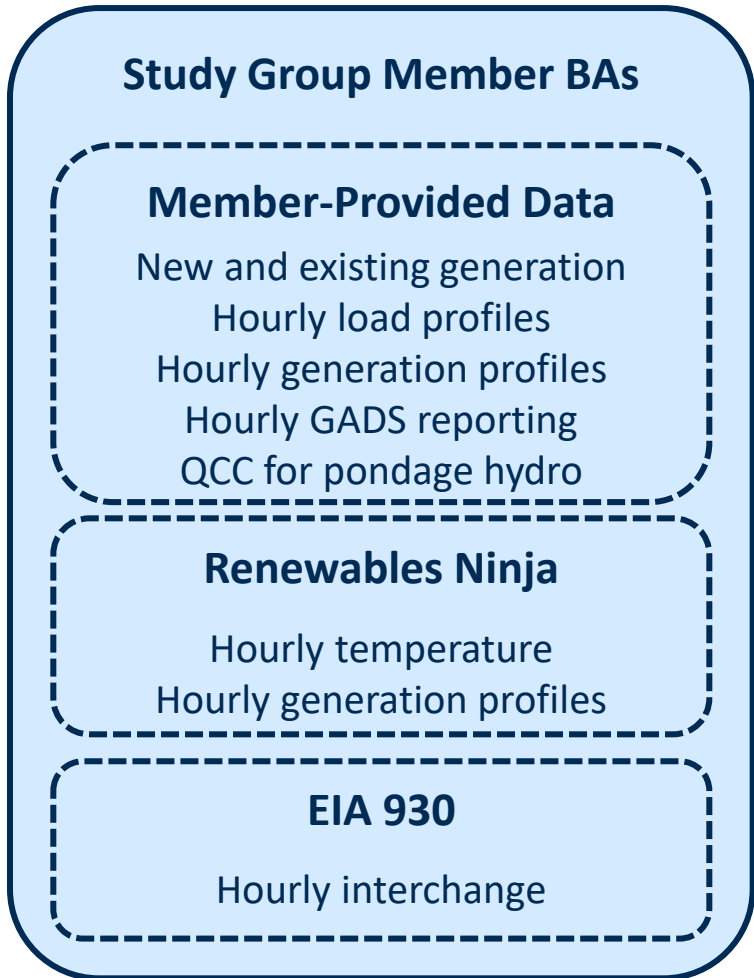
→ Based on historical load, resource output

→ Input from participants

→ Output from PRM RA simulations

Source: WRAP BPM 105 – Forward Showing Qualifying Resources

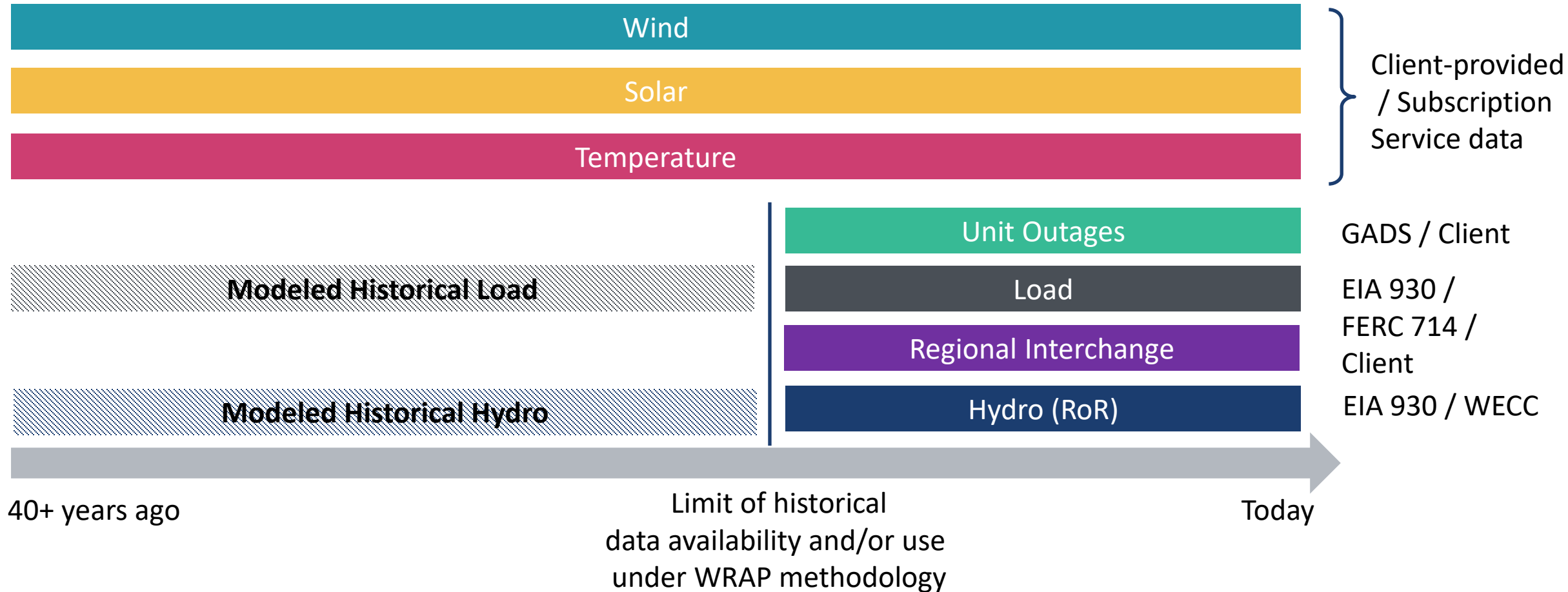
# Overview of Study Data & Data Sources



# 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

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

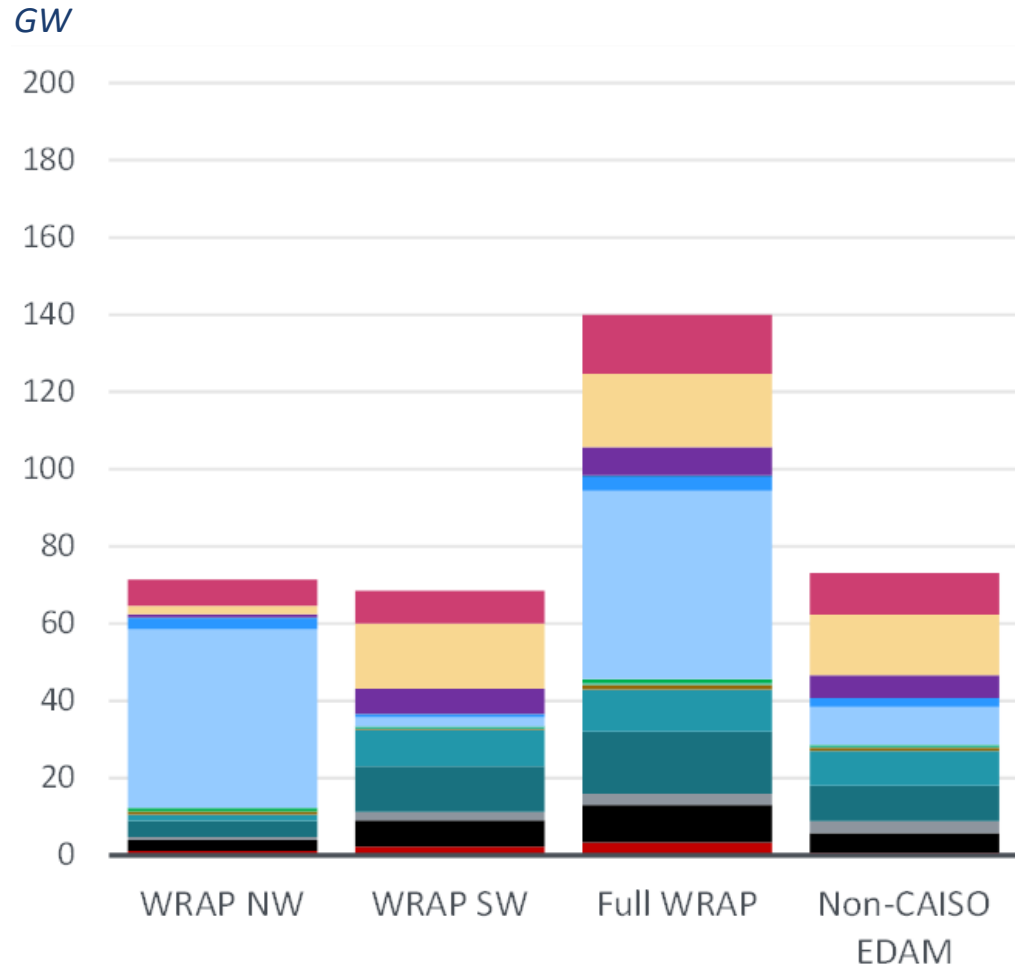
**We updated the resource mixes for non-study group members** using available public data. We reviewed the following sources, and considered them in the following order:

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

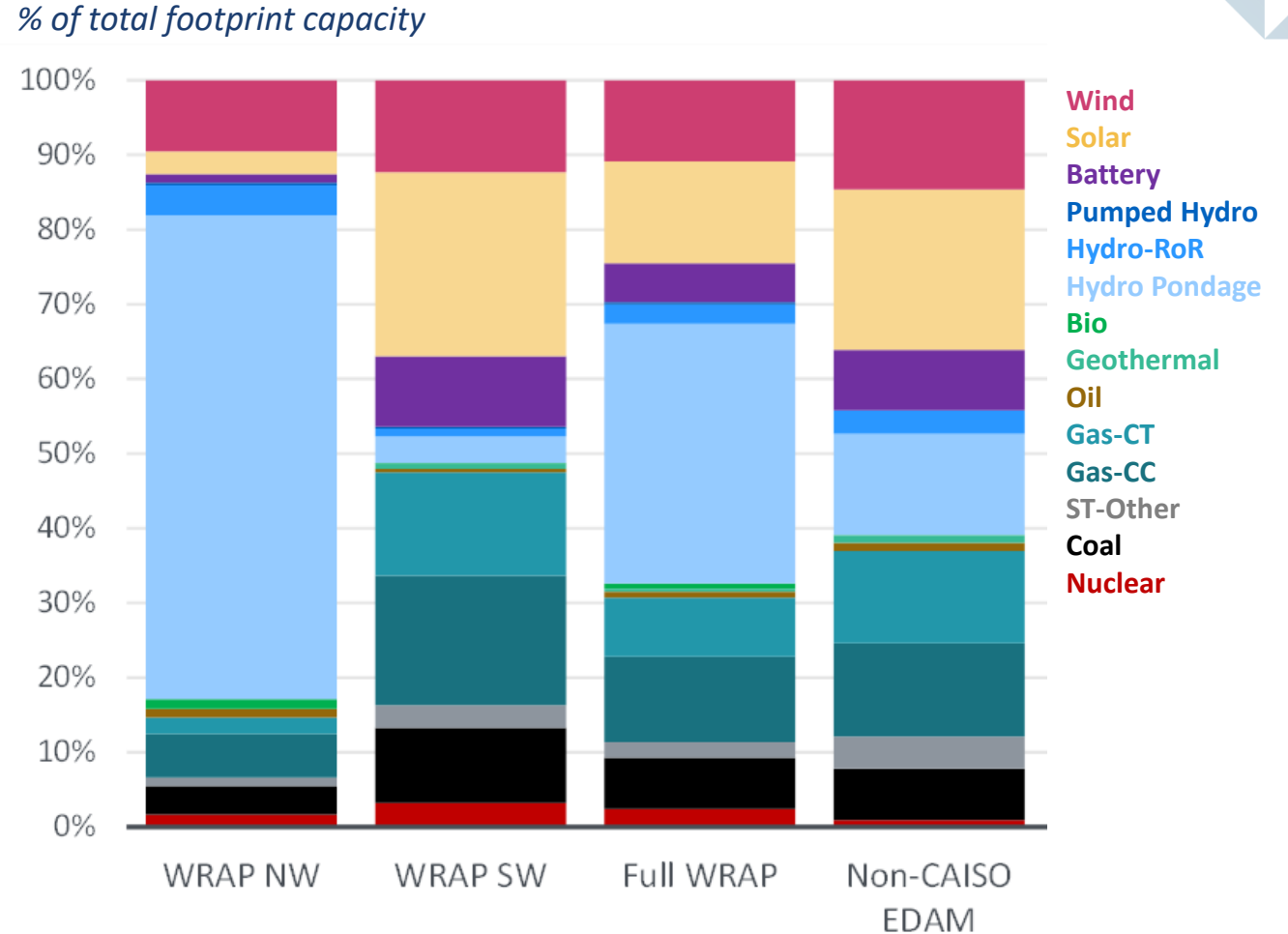
**We forecasted monthly load for the winter 2027/2028 and summer 2028 binding seasons** using WRAP-established methodology, which relies on historical monthly peak load data.

# Resource Mix by Footprint

Capacity by Footprint and Resource Type



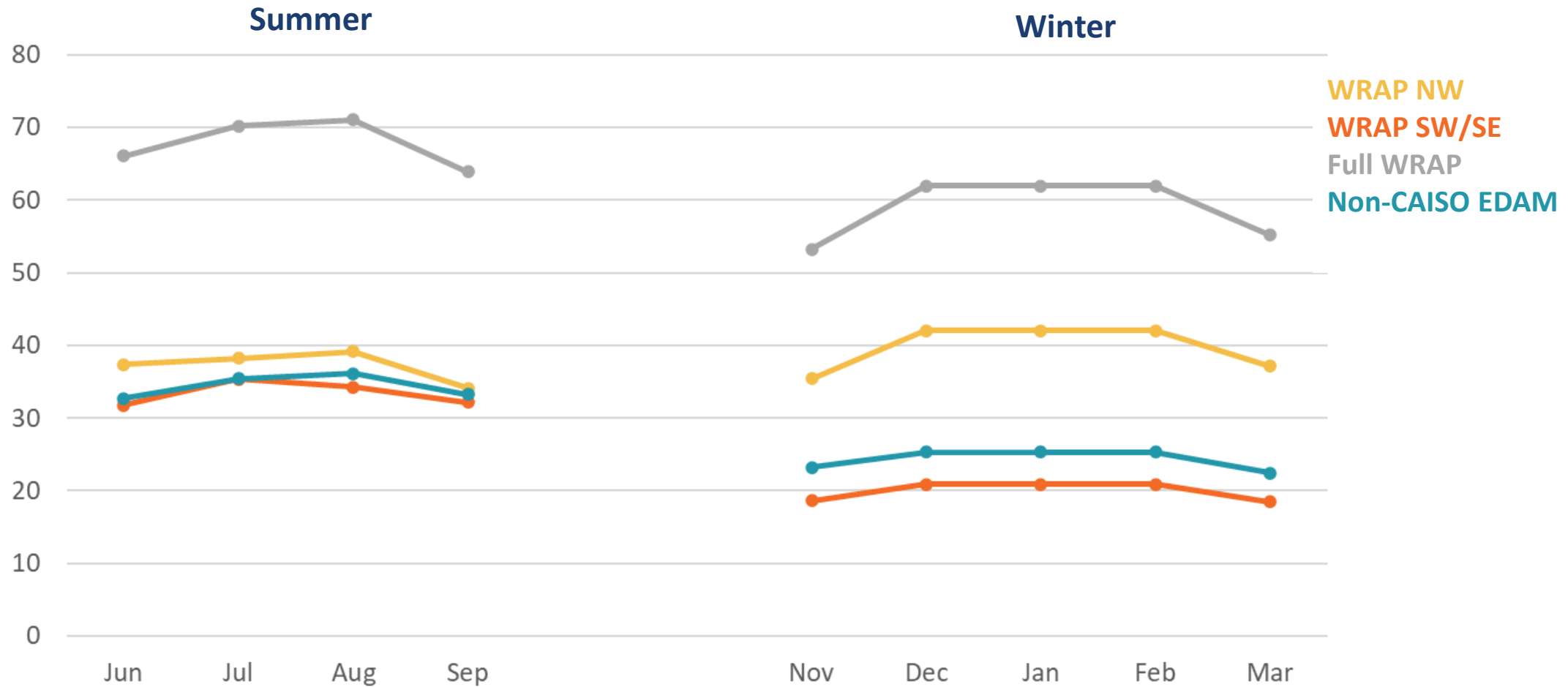
Capacity Composition by Footprint and Resource Type



# 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

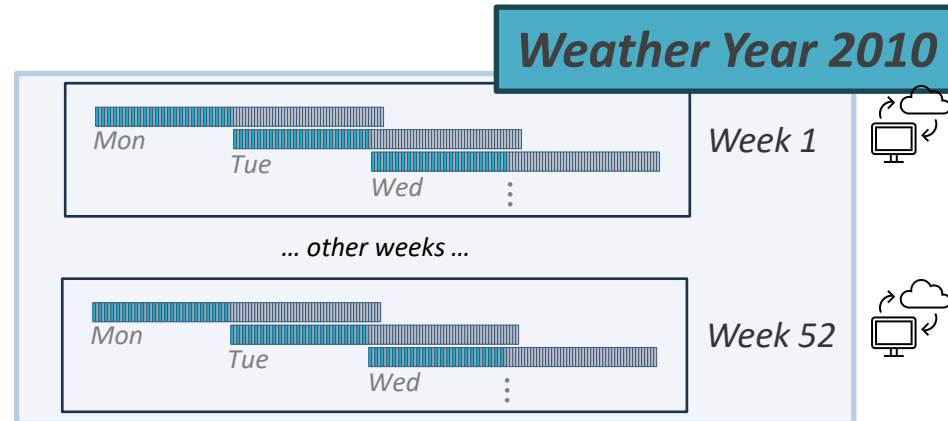
- Uses chronological Monte Carlo modeling with
  - Simulated outages of resources and weather correlated availability of variable resources
- Can be applied to many timeframes including short-term
- Can include physical and operational details of the system
- In addition to conventional reliability metrics, 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

# Planning Use Case

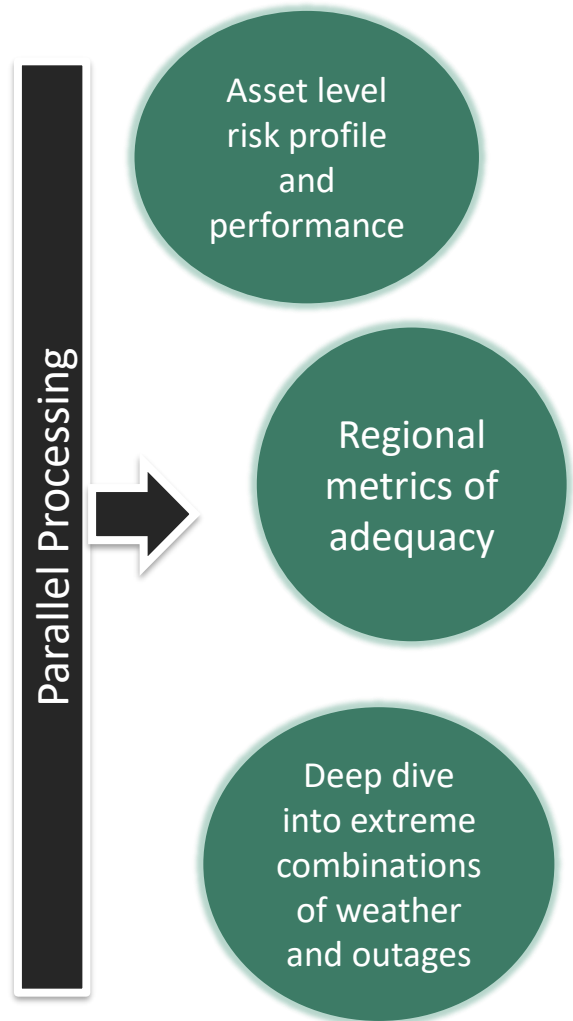
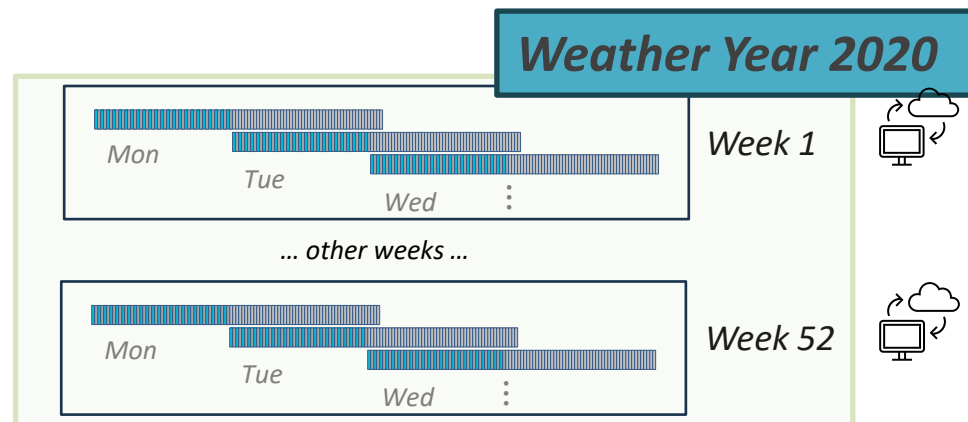
Assessment of adequacy for system annual planning



Is there sufficient capacity available for Day-Ahead commitment?

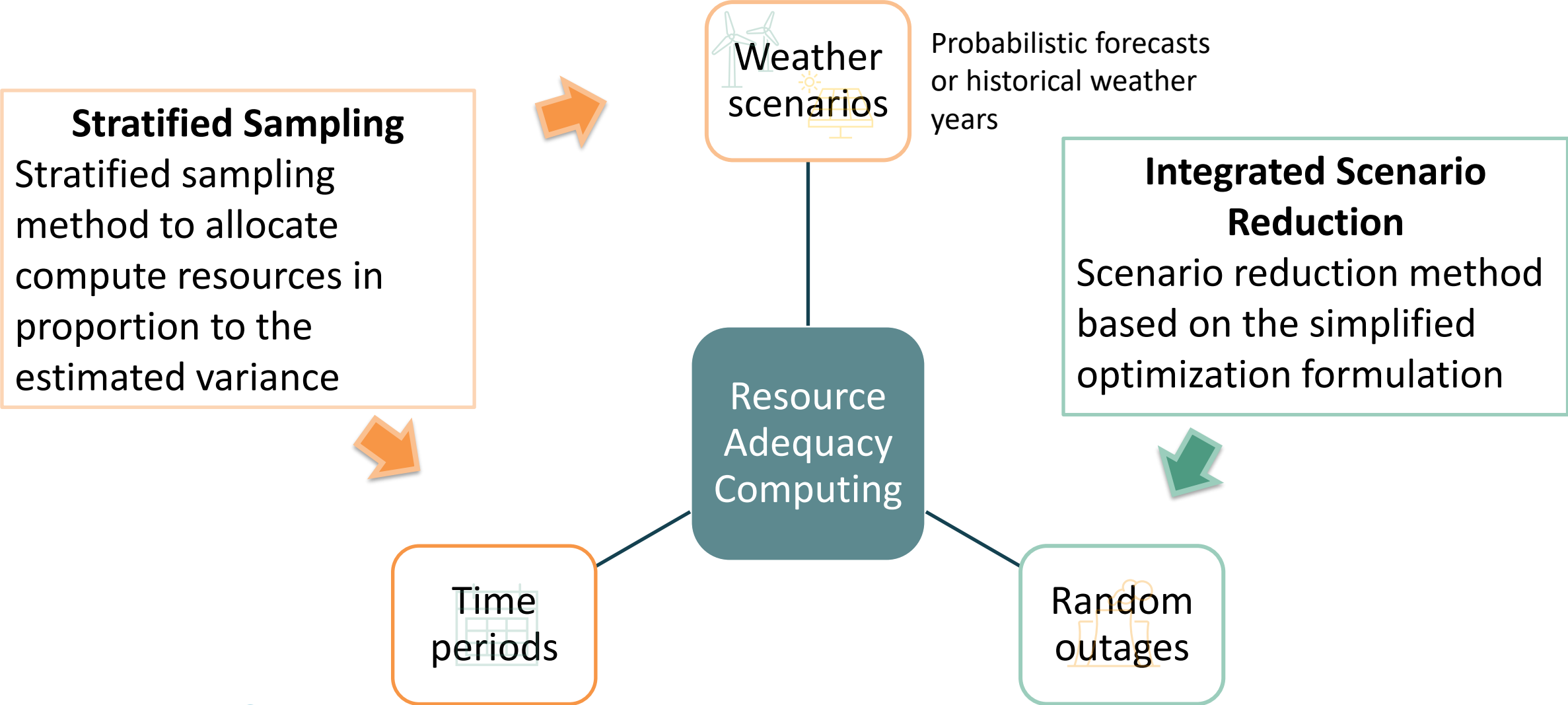


... other weather years ...



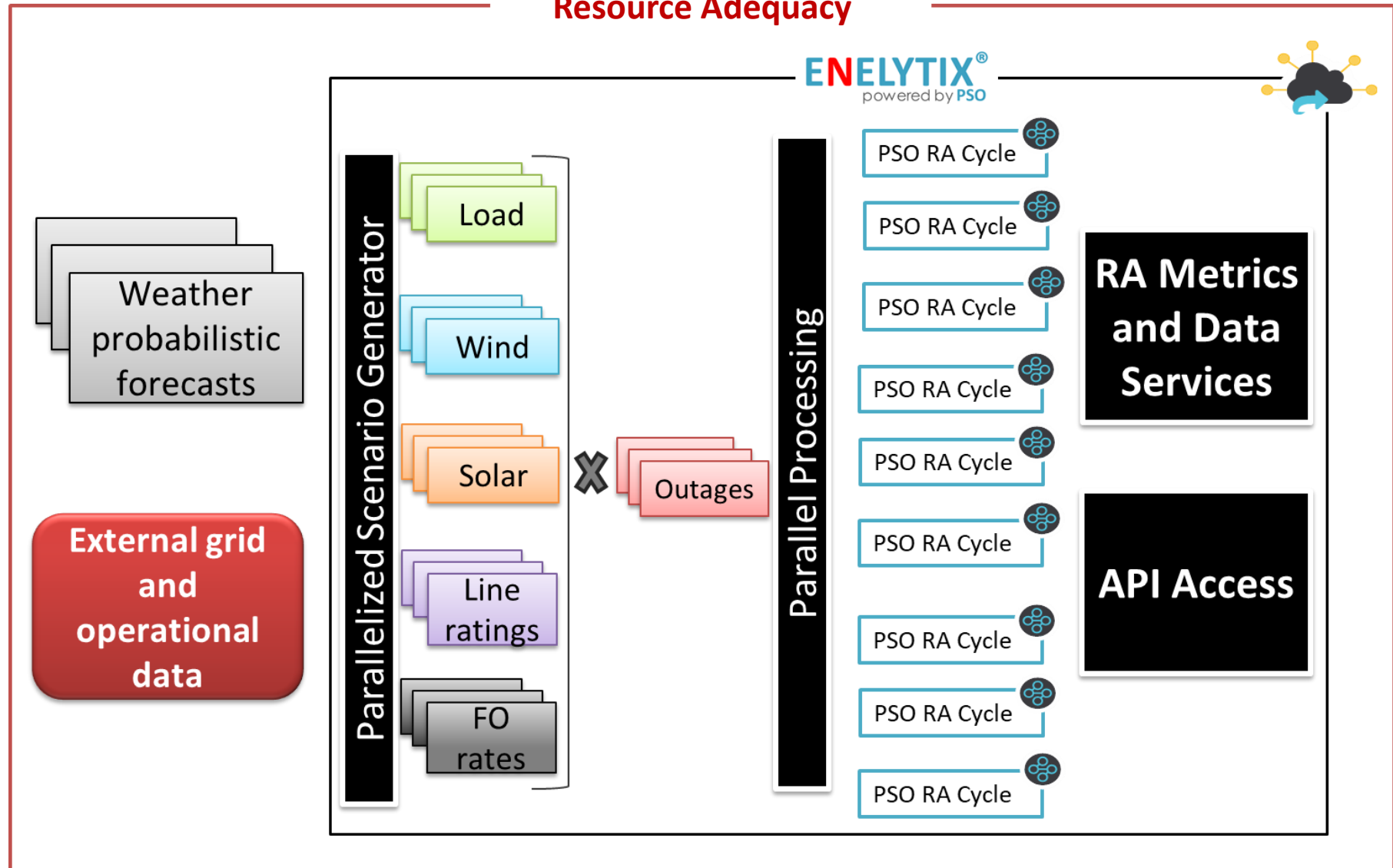
**Use historical weather correlations for forward-looking planning studies:**  
What are the reliability impacts of decisions under multiple weather correlation scenarios?

# ENELYTIX/PSO RA Computational Methodology



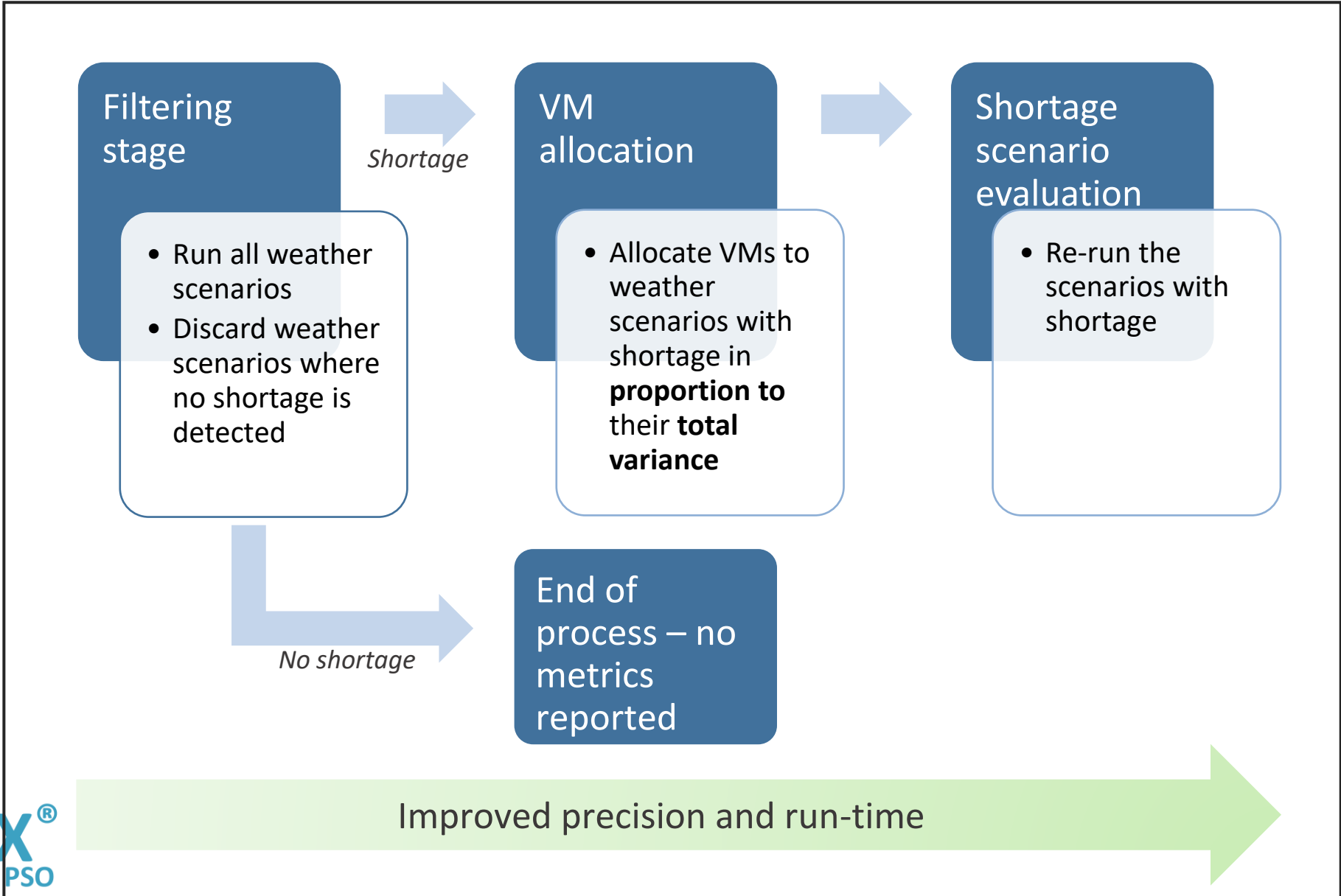
# Probabilistic World of RA

## Resource Adequacy



# RA Stratified Sampling Process

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

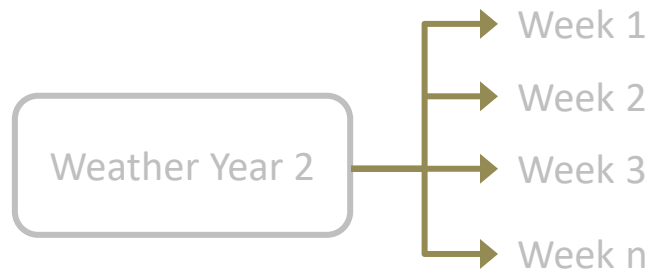
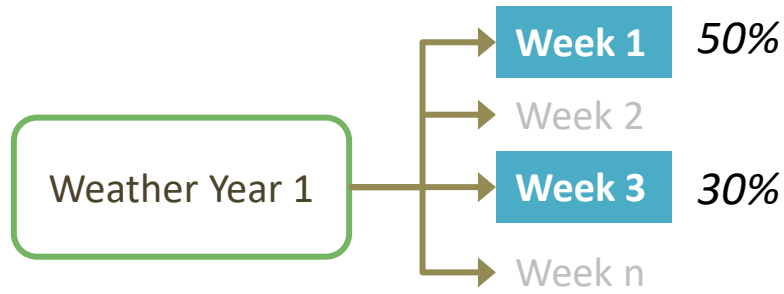


RA metrics

# Stratified Sampling for Weather and Time Dimension

## Stage 1

### Variance contribution



⋮



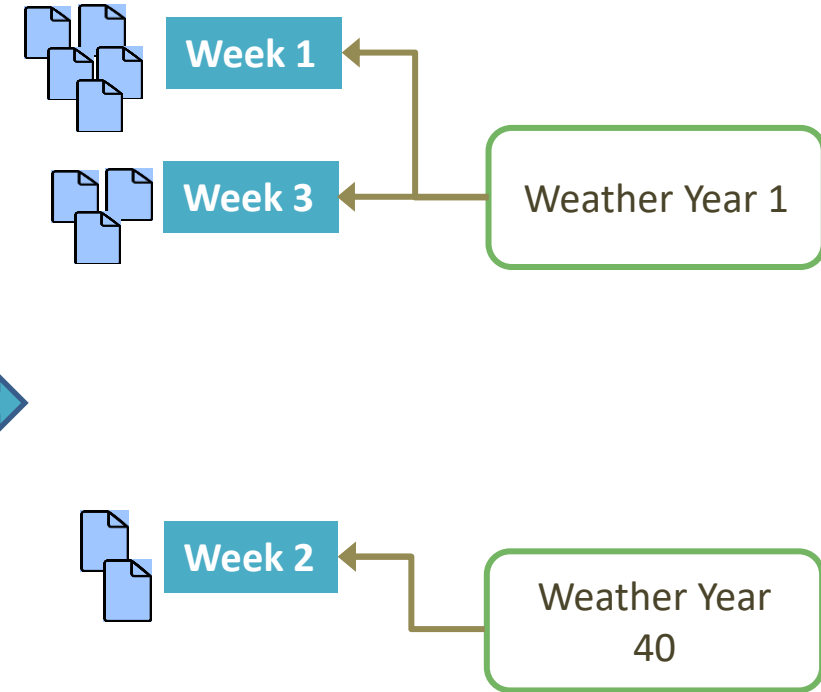
Filtering stage evaluation shows shortage in:

- 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**



## Stage 2



# Final Metrics Calculation Methodology after Stratified Sampling

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

