Advancing resource adequacy analysis with the GridPath RA Toolkit

A case study of the Western US

Elaine Hart, *Moment Energy Insights*

Ana Mileva, *Blue Marble Analytics*

ESIG Webinar

October 6th, 2022

GridLAB MOMENT ENERGY INSIGHTS Blue Marble Analytics

GridLAB

GridPath RA Toolkit

Open-source Toolkit for conducting RA analysis in the Western US using publicly available data.

The Toolkit consists of:

- **GridPath**, Blue Marble's open-source power system platform, which includes capacity expansion, production cost, and RA modeling: https://github.com/blue-marble/gridpath
- **Accompanying code** to develop and post-process RA runs in GridPath: https://github.com/MomentEI/GridPath_RA_Toolkit
- **Western US Dataset**, which includes the load, resource, and transmission data for conducting RA assessments of the Western US in 2026: www.gridlab.org/GridPathRAToolkit

Users can customize the datasets to evaluate other systems, years, or portfolios. Users can also modify the code to leverage additional capabilities in GridPath or to create new functionality.

GridLAB

GridPath RA Toolkit

Key features for RA analysis

Weather correlations

Two modes available for capturing key weather correlations between load and resource availability over very large geographical areas: Monte Carlo Simulation and Weather-Synchronized Simulation.

Energy-limited resources

Dynamic dispatch of energy-limited resources, like hydropower, energy storage, and hybrid resources to avoid lost load.

Transmission and regional coordination

Dynamic transmission flow modeling provides transparency into weather-coherent and transmission-constrained market availability.

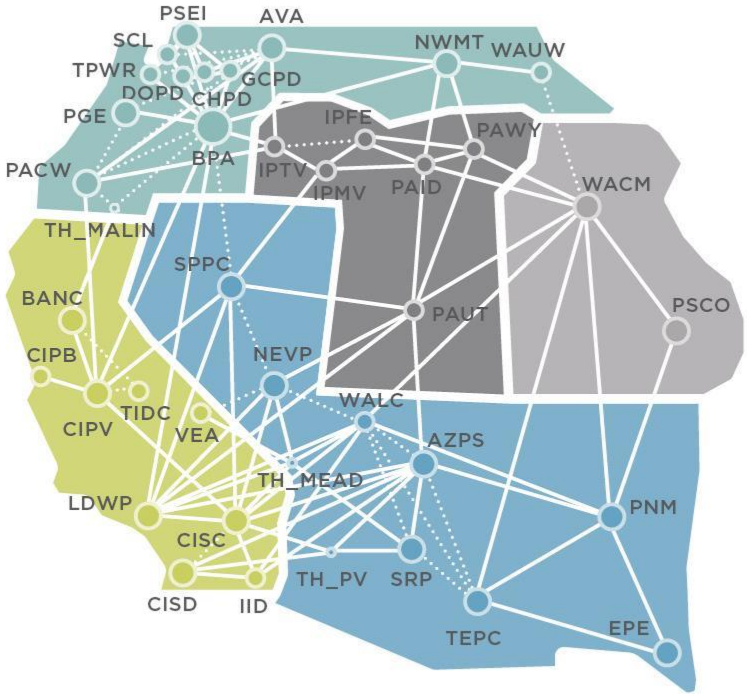
GridLAB

Western US Case Study

Monte Carlo simulation used to explore 3 scenarios:

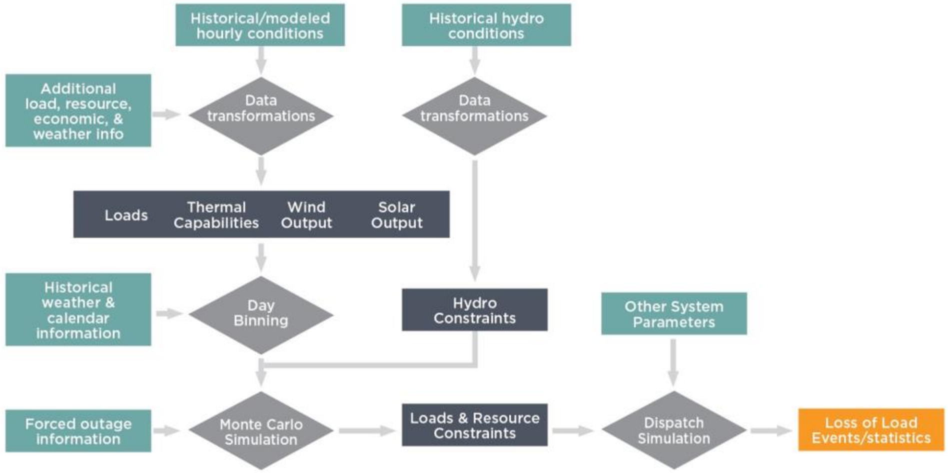
- *No Additions Scenario* – planned retirements, but no planned additions through 2026
- *California Additions Scenario* – layers on CPUC Preferred System Plan additions through 2026
- *Less Coal Scenario* – removes an additional 11 GW of coal resources from the California Additions Scenario
- Also includes subregional analysis for CAISO- and WRAP-like footprints

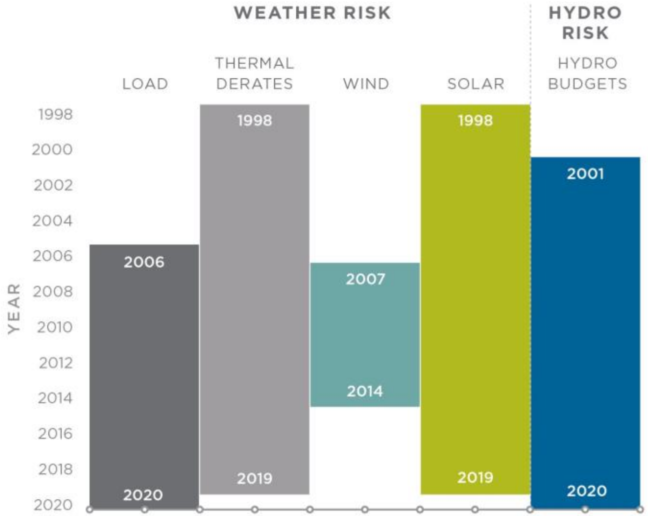
Weather-Synchronized simulation used for a deep dive into the No Additions Scenario



GridLAB

Monte Carlo simulation

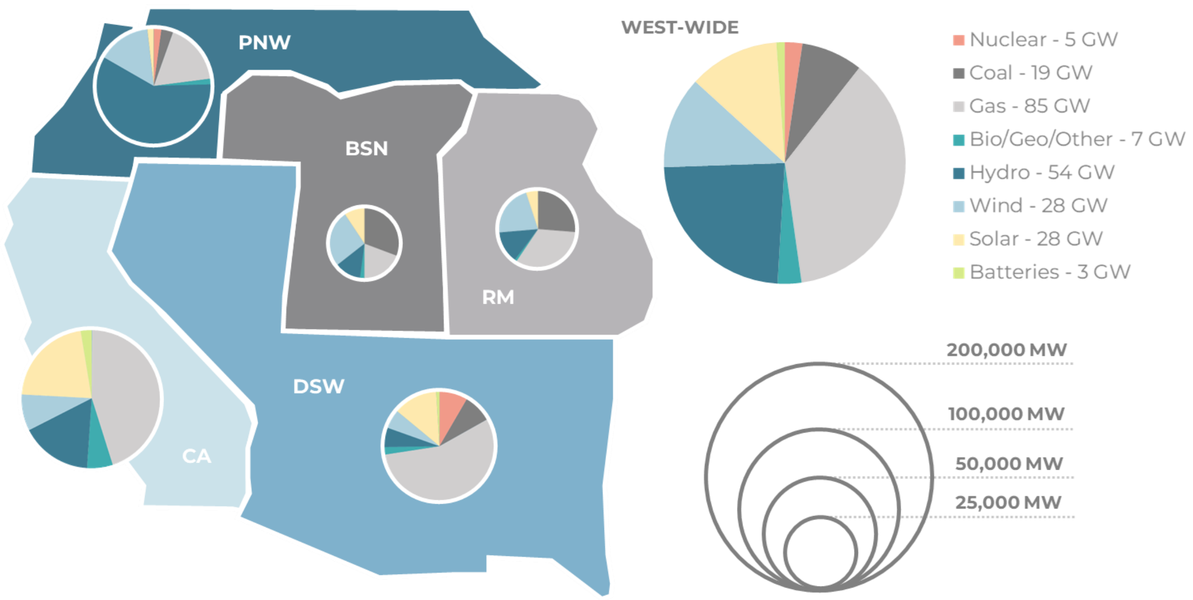




- Mixes and matches shapes from similar historical days
- Can generate many possible conditions, leading to high precision
- Conditions are not fully physically consistent and may not fully preserve all correlations

No Additions Scenario

Planned retirements,
but no planned additions

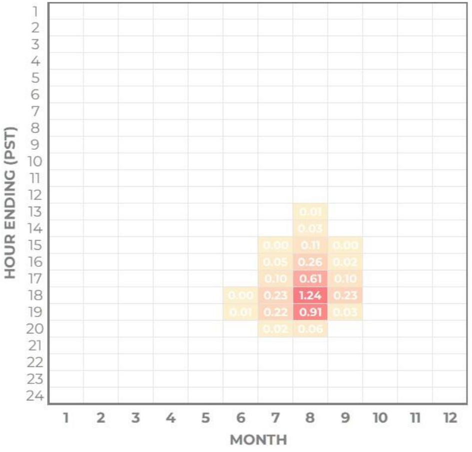


GridLAB

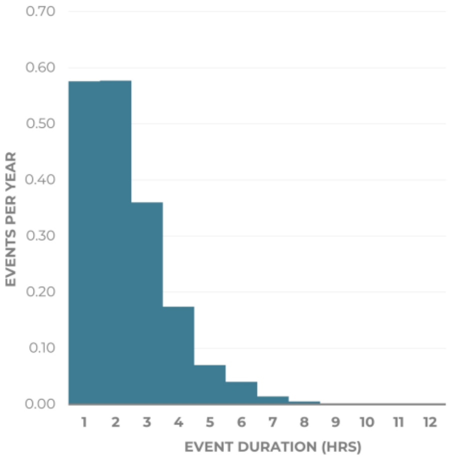
No Additions Scenario

Loss of load metrics

Loss of load hours per year



Event duration distribution



Metric	Value
$LOLP_{year}$	69%
$LOLE$ (days/10yrs)	18.2
$LOLH$ (hrs/yr)	4.23
EUE (MWh/yr)	13,797
EUE_{norm} (ppm)	19.4
Average Event Duration (hrs)	2.33

West-wide loss of load events/risk:

- Are concentrated in the evening on hot summer days
- Peaks during HE 18 (6-7pm PDT) in August
- No shortages longer than 8 hours

Energy and capacity shortages

Expected days of lost load in 10 years

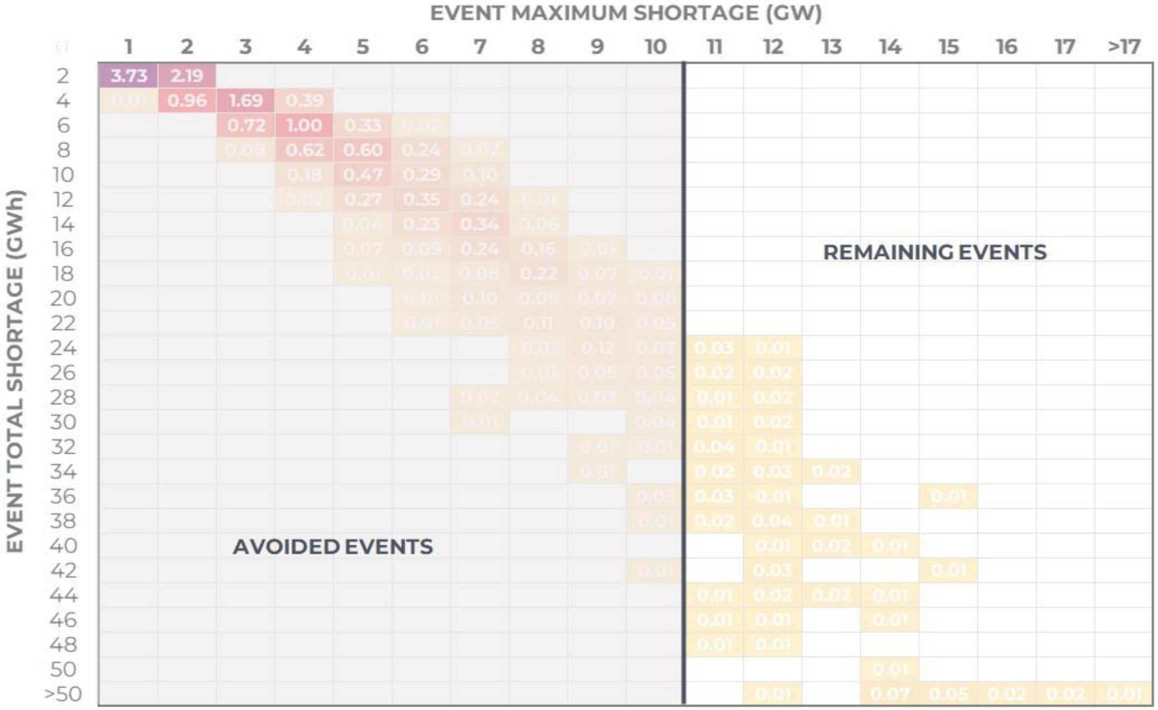
EVENT MAXIMUM SHORTAGE (GW)

EVENT TOTAL SHORTAGE (GWh)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	>17
2	3.73	2.19																
4	0.01	0.96	1.69	0.39														
6			0.72	1.00	0.33	0.02												
8			0.08	0.62	0.60	0.24	0.02											
10				0.18	0.47	0.29	0.10											
12				0.02	0.27	0.35	0.24	0.01										
14					0.04	0.23	0.34	0.06										
16					0.07	0.09	0.24	0.16	0.01									
18					0.01	0.02	0.08	0.22	0.07	0.01								
20						0.01	0.10	0.09	0.07	0.06								
22						0.01	0.05	0.11	0.10	0.05								
24								0.01	0.12	0.07	0.03	0.01						
26								0.01	0.05	0.05	0.02	0.02						
28							0.02	0.04	0.03	0.04	0.01	0.02						
30							0.01			0.04	0.01	0.02						
32									0.01	0.01	0.04	0.01						
34									0.01		0.02	0.03	0.02					
36										0.03	0.03	0.01			0.01			
38										0.01	0.02	0.04	0.01					
40												0.01	0.02	0.01				
42										0.01		0.03			0.01			
44											0.01	0.02	0.02	0.01				
46											0.01	0.01		0.01				
48											0.01	0.01						
50														0.01				
>50												0.01		0.07	0.05	0.02	0.02	0.01

GridLAB

Perfect capacity additions

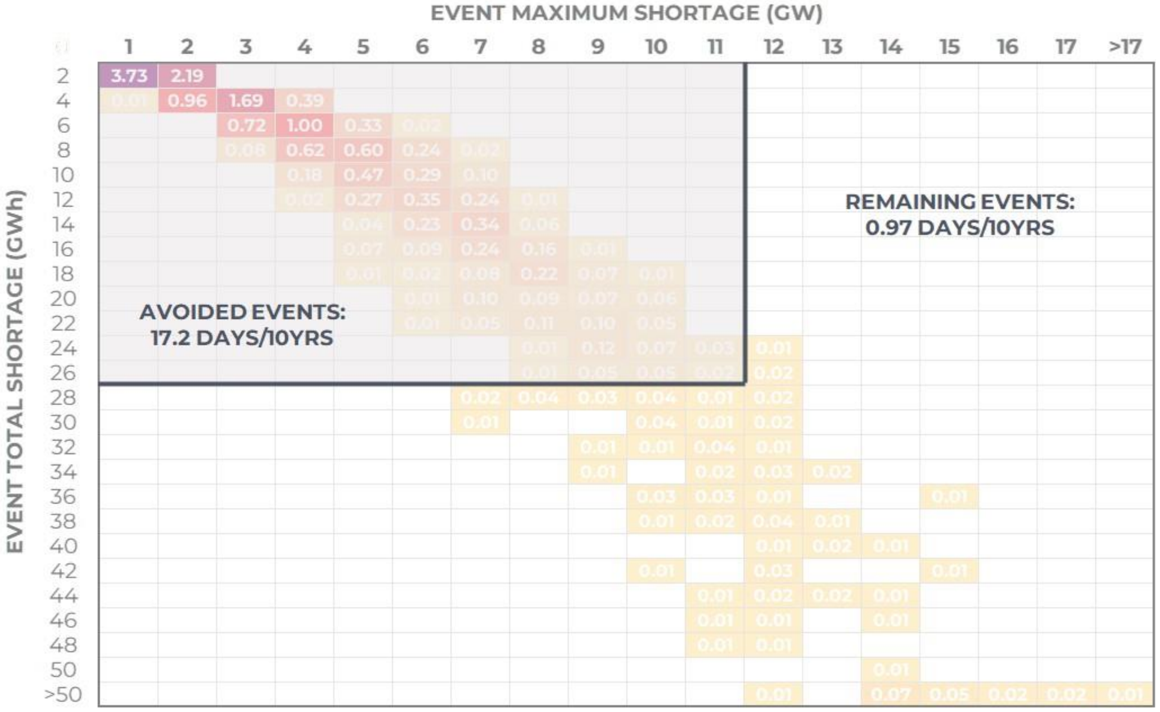
Expected days of lost load in 10 years



GridLAB

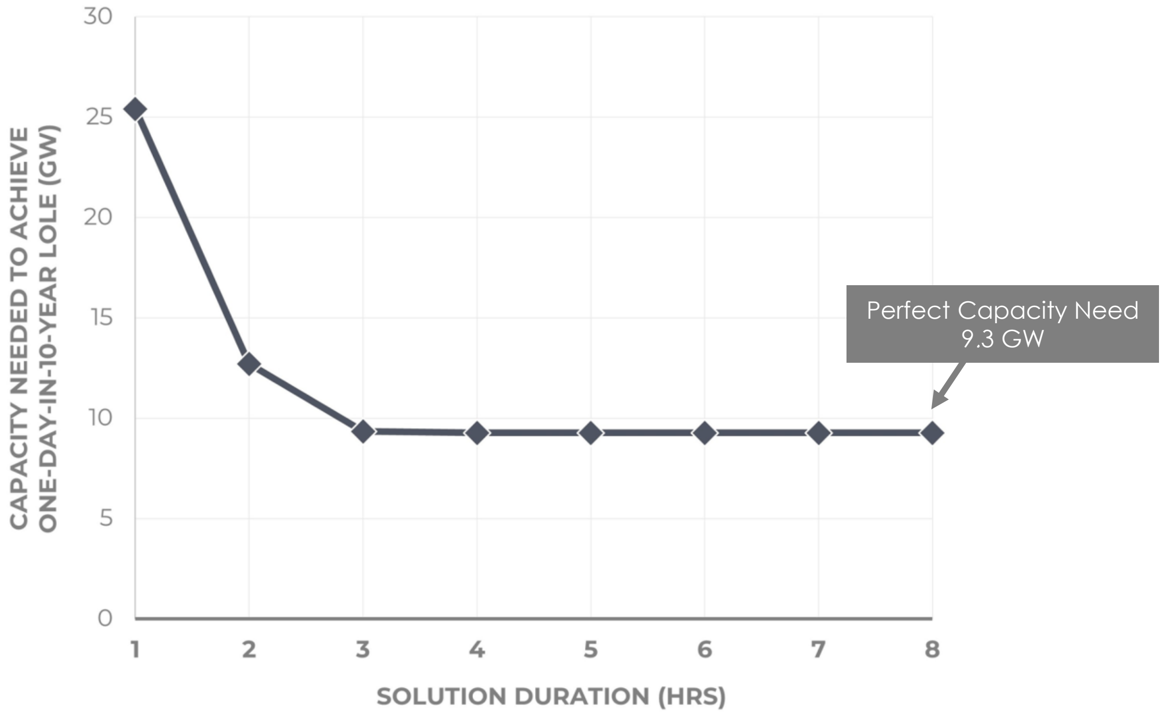
Targeted energy-limited capacity additions

Expected days of lost load in 10 years



Targeting solutions – an efficient frontier

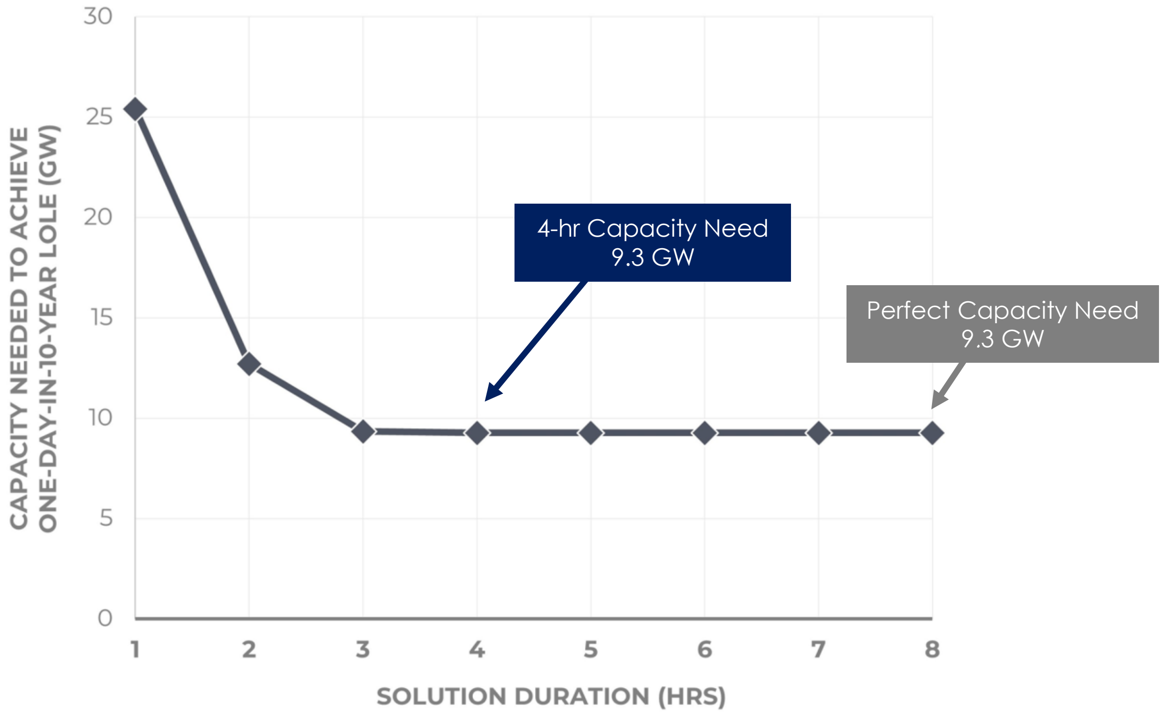
Capacity and duration efficient frontier



GridLAB

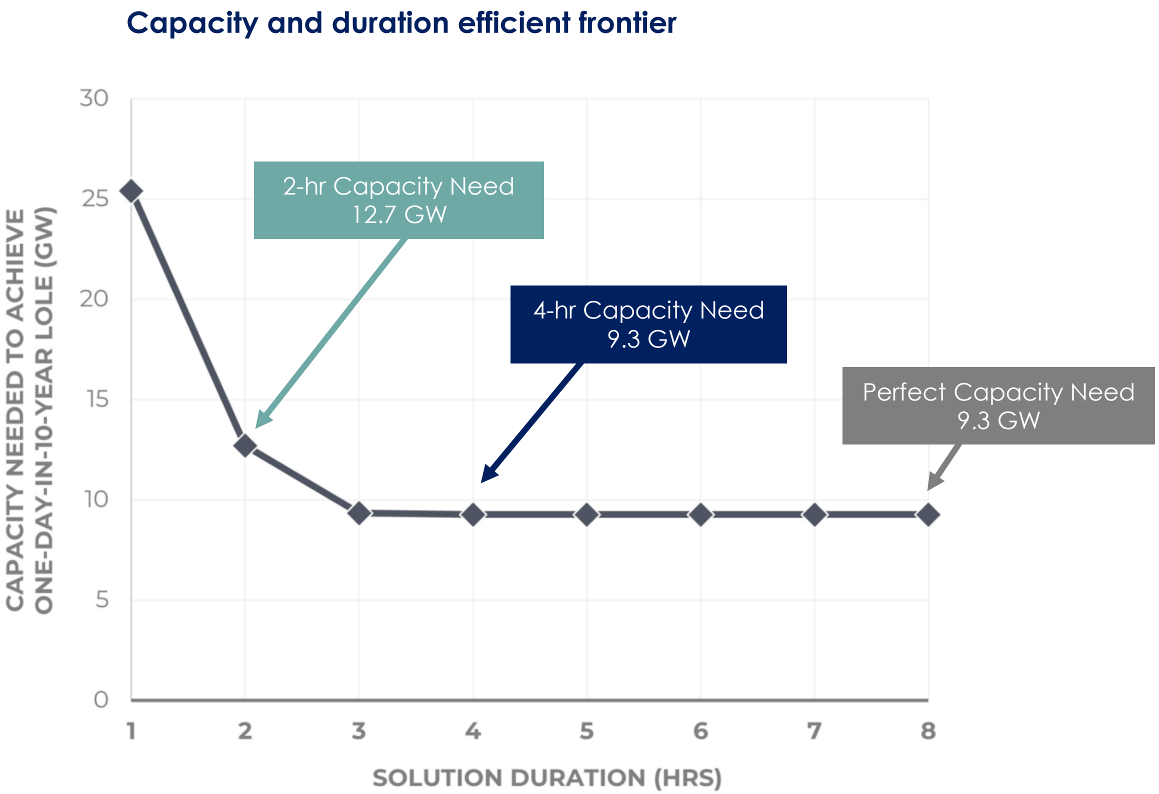
Targeting solutions – an efficient frontier

Capacity and duration efficient frontier



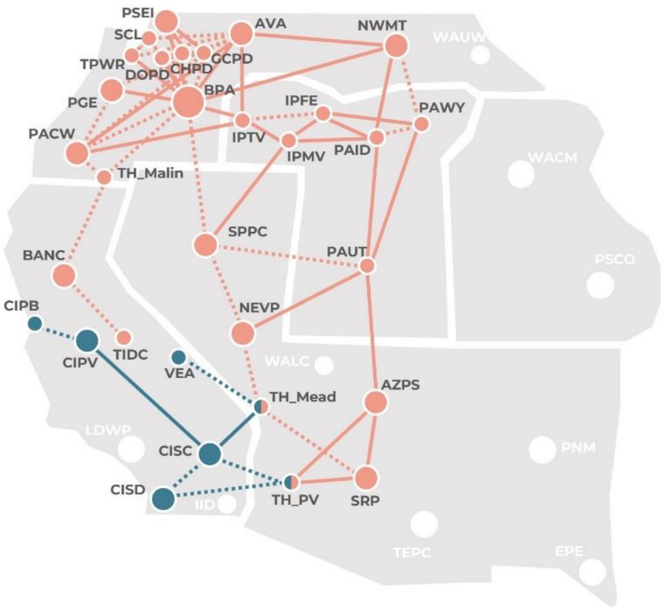
GridLAB

Targeting solutions – an efficient frontier



GridLAB

Subregional analysis approach



Subarea	WECC BAAs/Zones
CAISO	CIPB, CIPV, CISC, CISD, VEA, TH_Mead (partial), TH_PV (partial)
WRAP	AVA, AZPS, BANC, BPAT, CHPD, DOPD, GCPD, IPFE, IPMV, IPTV, NEVP, NWMT, PACW, PAID, PAUT, PAWY, PGE, PSEI, SCL, SPPC, SRP, TIDC, TPWR, TH_Malin, TH_Mead (partial), TH_PV (partial)
Excluded	EPE, IID, LDWP, PNM, PSCO, TEPC, WACM, WALC, WAUW

Weather-coherent and transmission-constrained imports:

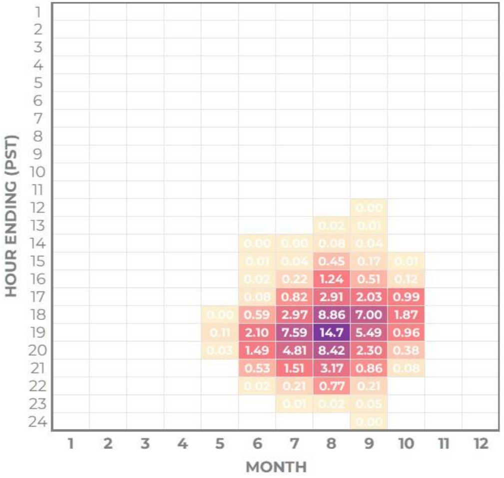
When imports are allowed, unserved energy for a given subarea (CAISO or WRAP) is only recorded to the extent that it was observed in the islanded simulation AND in the West-wide simulation under the same weather conditions

GridLAB

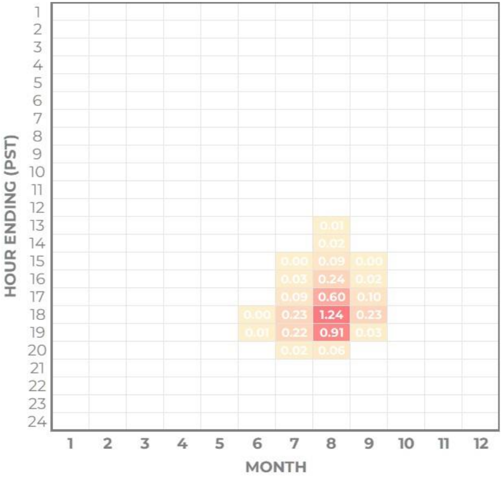
CAISO subarea analysis

No Additions Scenario

CAISO – Islanded
Loss of load hours per year



CAISO – With imports
Loss of load hours per year



Metric	CAISO as an Island	CAISO w/ imports
$LOLP_{year}$	100%	69%
LOLE (days/10yrs)	335	18.2
LOLH (hrs/yr)	86.8	4.15
EUE (MWh/yr)	225,373	12,134
EUE_{norm} (ppm)	1,083	58
Average Event Duration (hrs)	2.59	2.29
Perfect Capacity Need (GW) One-day-in-10-year std.	**11.2**	**8.2**

Accounting for imports:

- Significantly reduces the LOLE & LOLH
- Reduces perfect capacity need by 3 GW
- Concentrates identified loss of load risk into fewer months and hours of the day
- Reduces event durations

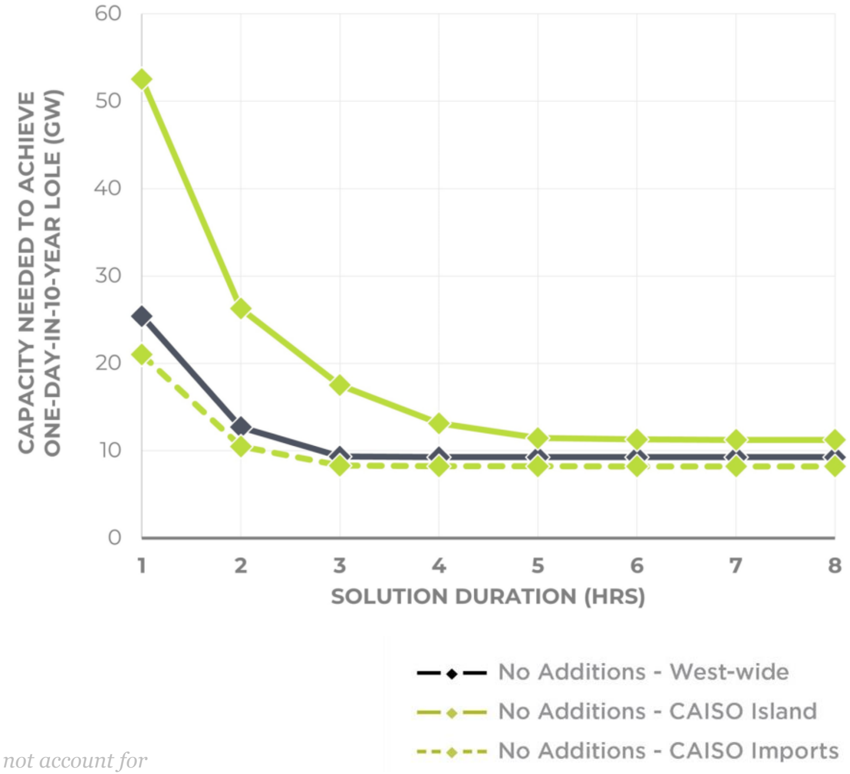
Note: This study uses a physical representation of CAISO and does not account for resources outside of CAISO that are contractually obligated to serve LSEs within CAISO

CAISO subarea analysis

No Additions Scenario

Accounting for imports has the greatest impact on resource needs when RA solutions are duration-limited

Capacity and duration efficient frontier
No Additions Scenario - CAISO subarea



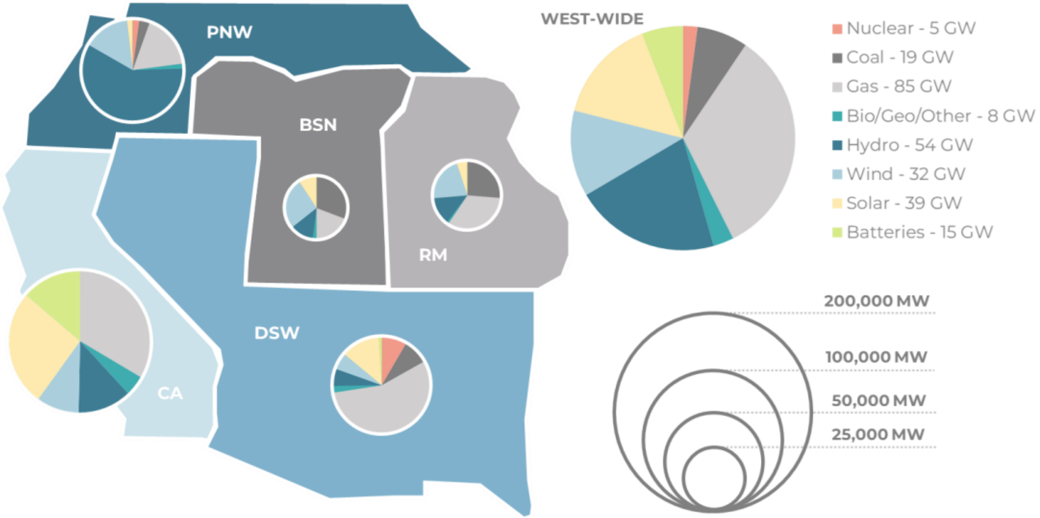
Note: This study uses a physical representation of CAISO and does not account for resources outside of CAISO that are contractually obligated to serve LSEs within CAISO

California Additions Scenario

Additional 28 GW of clean energy in CA

Resource	Total CAISO Additions
Biomass MW	+107
Geothermal MW	+184
Wind MW	+3,673
Utility-scale solar MW	+11,000
Storage MW	+12,749
Storage MWh	+51,780
Total MW	**+27,713**

**Additions are roughly consistent with the CPUC Preferred System Plan in 2026*

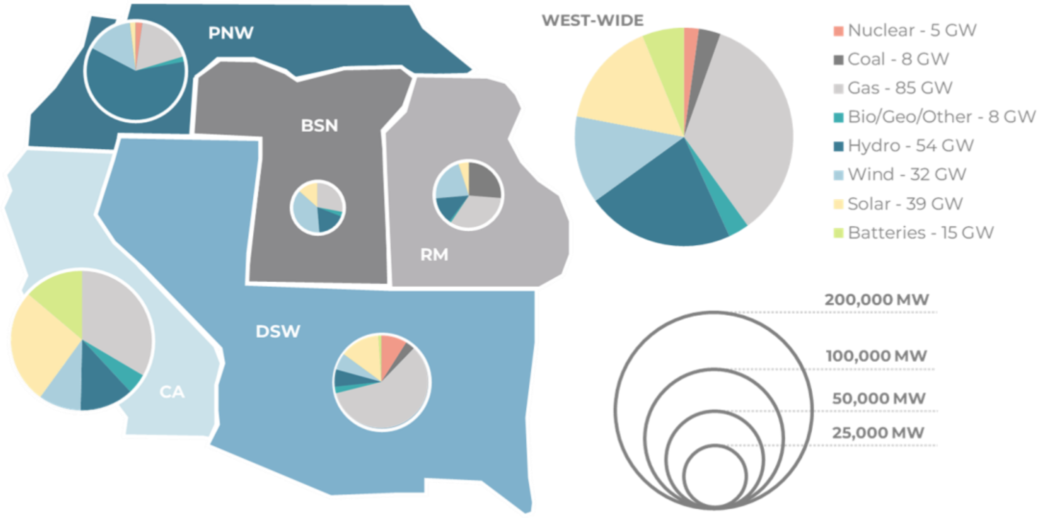


This simulation identifies only 7 events in 1,000 years of simulated conditions, easily meeting all of the tested RA standards

Less Coal Scenario

Incorporates CA additions, retires ~11 GW of coal

Resource	Net West-Wide Additions
Biomass MW	+107
Geothermal MW	+184
Wind MW	+3,673
Utility-scale solar MW	+11,000
Storage MW	+12,749
Storage MWh	+51,780
Coal MW	-10,922
Total MW	+16,791

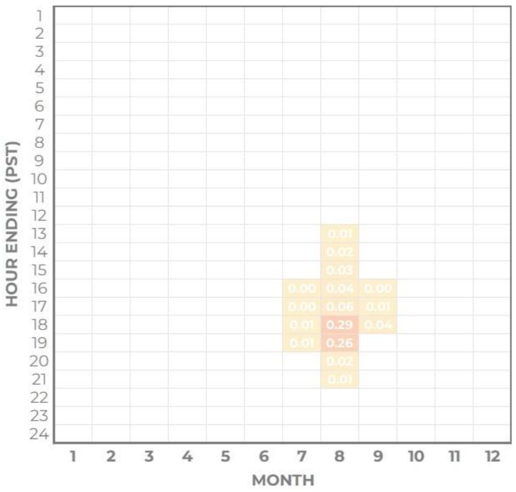


GridLAB

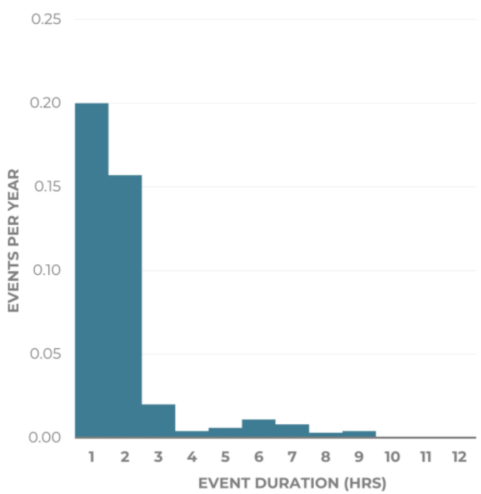
Less Coal Scenario

Loss of load metrics

Loss of load hours per year



Event duration distribution



Metric	Less Coal Scenario	No Additions Scenario
$LOLP_{year}$	29%	69%
LOLE (days/10yrs)	4.13	18.2
LOLH (hrs/yr)	0.80	4.23
EUE (MWh/yr)	2,126	13,797
EUE_{norm} (ppm)	3.0	19.4
Average Event Duration (hrs)	1.94	2.33
Perfect Capacity Need (GW) One-day-in-10-year standard	**3.8**	**9.3**

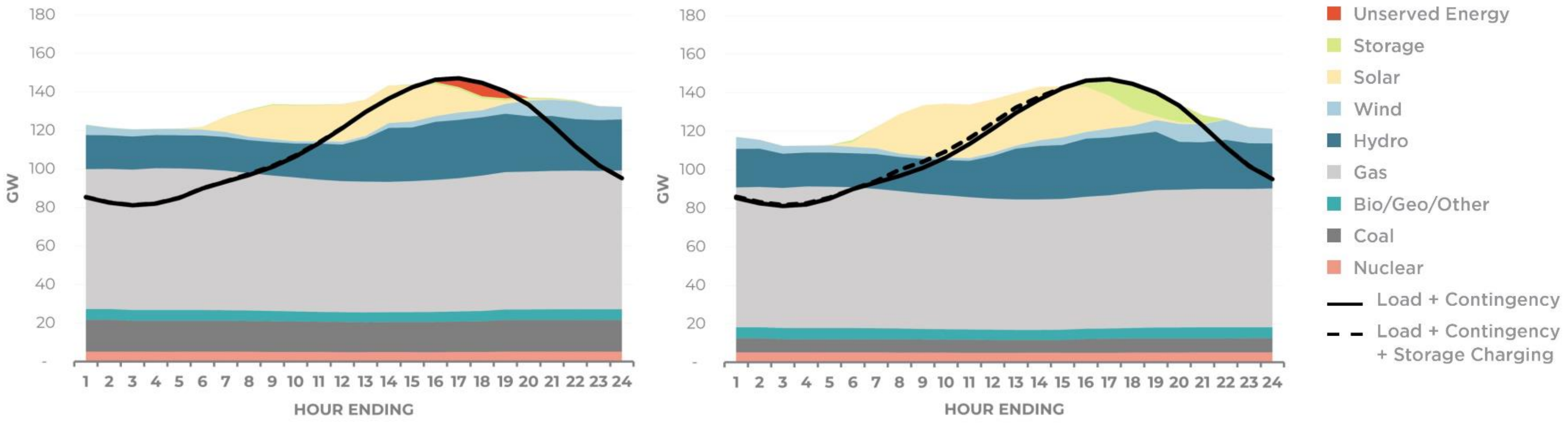
Adding the CPUC Preferred System Portfolio resources and retiring ~11 GW of additional coal (beyond current plans):

- Reduces LOLE, LOLH, and capacity need
- Further concentrates loss of load risk into August HE 18-19 (6-8pm PDT)
- Limits most events to 2 hours

Less Coal Scenario

Solar plus storage helps eliminate shortfalls, despite additional coal retirements

No Additions Scenario | **Less Coal Scenario**

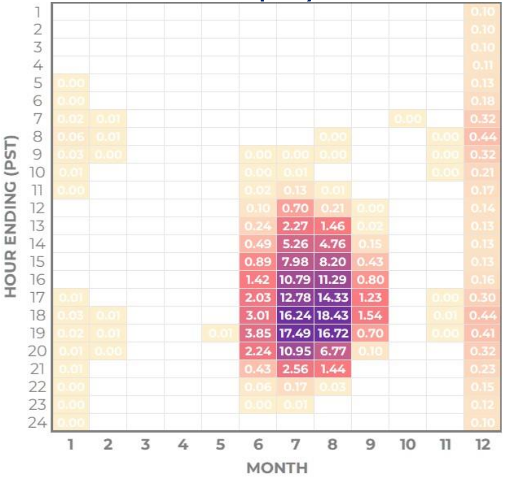


Note: Plots represent resource availability to serve load and provide contingency reserves in each hour

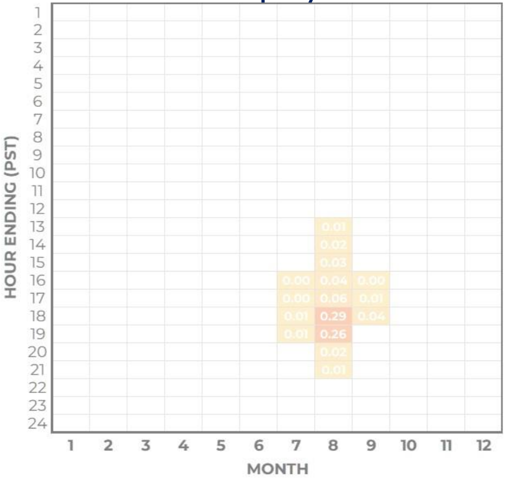
WRAP subarea analysis

Less Coal Scenario

WRAP – Islanded
Loss of load hours per year



WRAP – With imports
Loss of load hours per year



Metric	WRAP as an Island	WRAP w/ Imports
$LOLP_{year}$	100%	29%
LOLE (days/10yrs)	451	4.13
LOLH (hrs/yr)	196	0.80
EUE (MWh/yr)	275,929	2,118
EUE_{norm} (ppm)	808	6.2
Average Event Duration (hrs)	4.34	1.94
Perfect Capacity Need (GW) One-day-in-10-year std	**10.1**	**3.8**

Accounting for imports:

- Significantly reduces LOLE & LOLH
- Reduces perfect capacity need by 6 GW
- Eliminates identified winter risk and concentrates summer risk into fewer months and hours of the day
- Significantly reduces event durations

Note: This study uses a physical approximation of the WRAP footprint, which includes loads and resources in the following WECC BAs: AVA, AZPS, BANC, BPAT, CHPD, DOPD, GCPD, IPFE, IPMV, IPTV, NEVP, NWMT, PACW, PAID, PAUT, PAWY, PGE, PSEI, SCL, SPPC, SRP, TIDC, TPWR

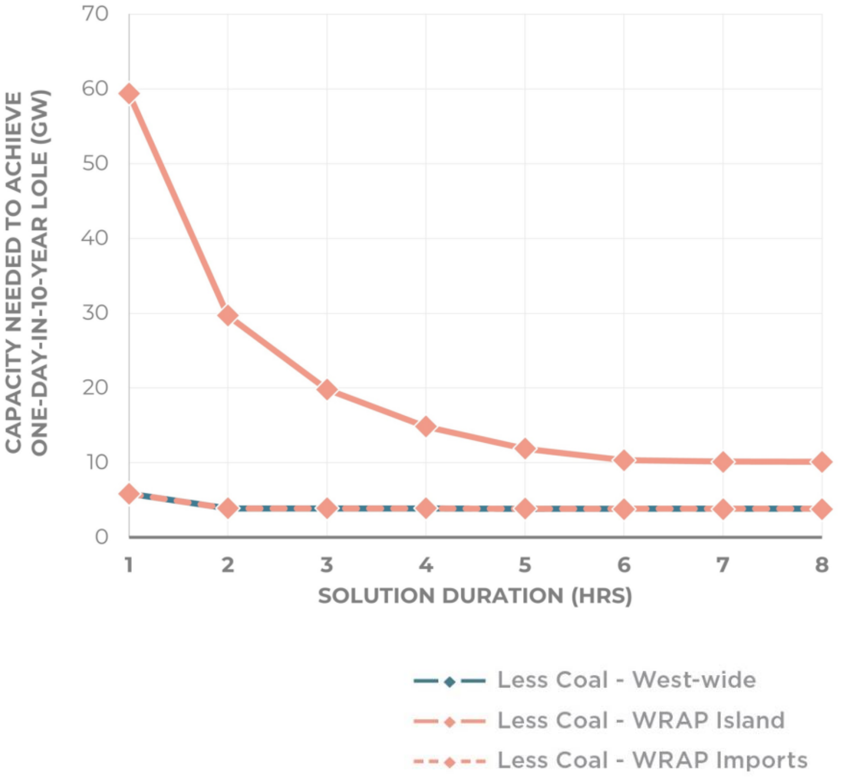
WRAP subarea analysis

Less Coal Scenario

As more coal is retired, identified needs outside of CA become highly sensitive to import assumptions

Note: This study uses a physical approximation of the WRAP footprint, which includes loads and resources in the following WECC BAs: AVA, AZPS, BANC, BPAT, CHPD, DOPD, GCPD, IPFE, IPMV, IPTV, NEVP, NWMT, PACW, PAID, PAUT, PAWY, PGE, PSEI, SCL, SPPC, SRP, TIDC, TPWR

Capacity and duration efficient frontier
Less Coal Scenario - WRAP subarea



GridLAB

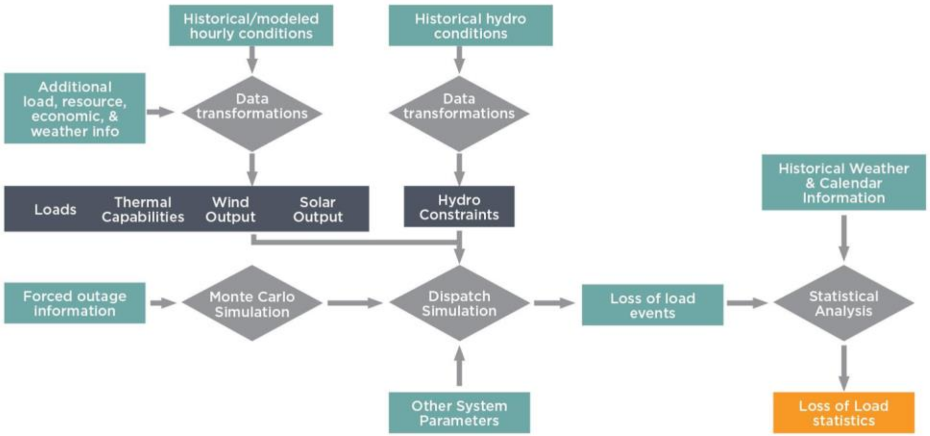
Key Takeaways

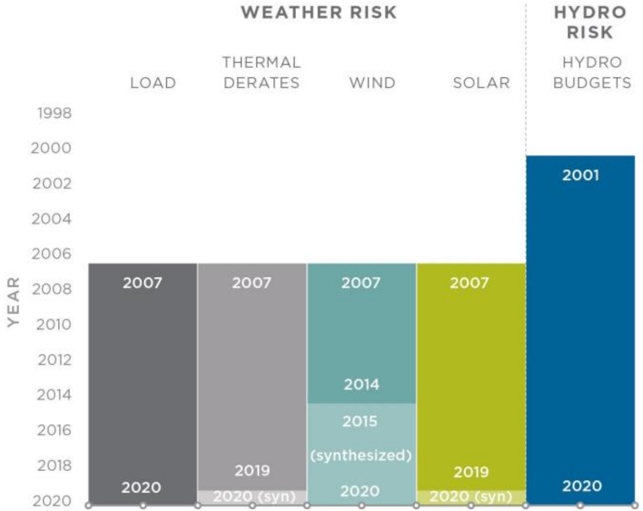
Western US Scenarios

- Without accounting for utility plans, the West was physically short in 2026
- Shortages were short in duration (mostly 4 hours or less) and occurred on hot summer evenings
- Incorporating planned additions in California resulted in a resource adequate system in 2026
- If utilities execute on current plans, accelerating 11 GW of additional coal retirements does not pose an insurmountable RA challenge
- Resource needs are highly sensitive to import assumptions
- Import policies that account for coherent weather conditions across the West and transmission constraints can be used to recognize regional weather risk, while reducing the potential for overbuild

GridLAB

Weather-Synchronized simulation



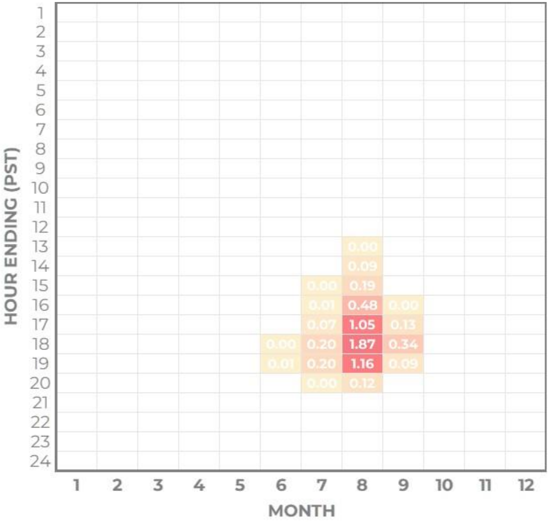


- Simulated days are limited to conditions with coherent high resolution hourly data
- Ensures that conditions are physically consistent and preserves all correlations
- Allows for transparent investigation into the weather patterns that drive loss of load risk

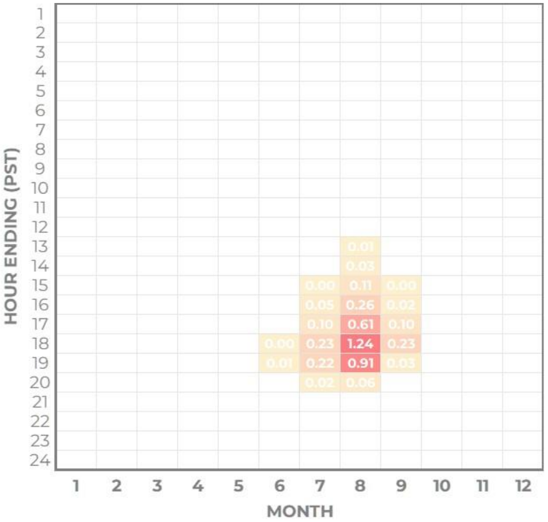
Weather-Synchronized simulation

Comparison to Monte Carlo

No Additions Scenario – Weather-Synch.
Loss of load hours per year



No Additions Scenario – Monte Carlo
Loss of load hours per year



Both methods identify similar risks

Loss of load risk is slightly more concentrated in Weather-Synchronized simulation

GridLAB

Weather-Synchronized simulation

Comparison to Monte Carlo

Simulation	Perfect capacity needed for one-day-in-10-year standard (GW)
No Additions Scenario (Monte Carlo)	9.3
No Additions Scenario (Weather-Synchronized 2007-2020)	11.1
No Additions Scenario (Weather-Synchronized 2007-2014)	6.4

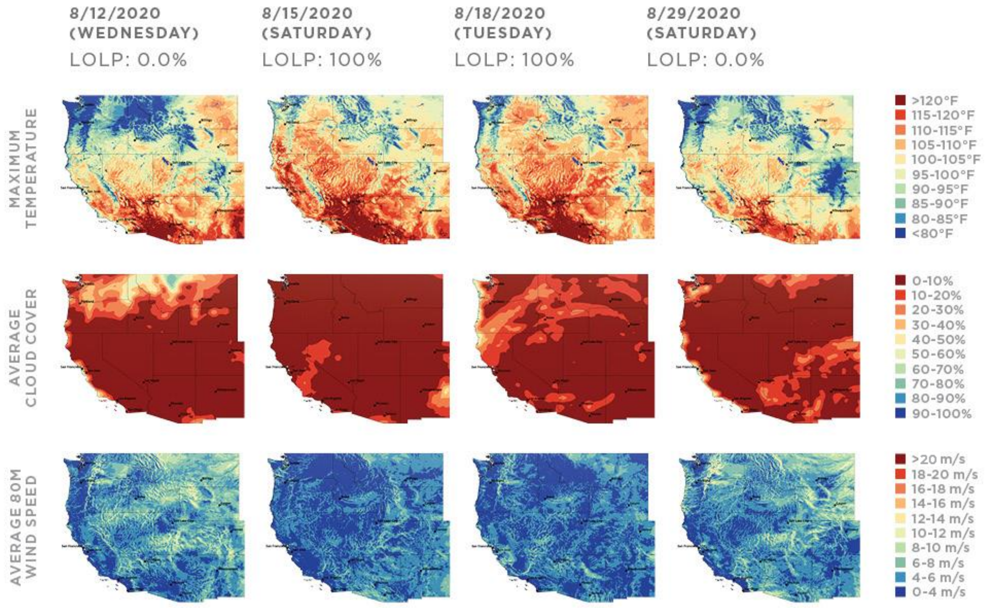
Weather-Synchronized simulation identifies greater needs if recent (synthesized) years are included, and smaller needs if they are not

Publicly available wind data after 2014 will be critical for evaluating RA risk, particularly for higher renewable penetrations

GridLAB

Weather insights

An application of Weather-Synchronized simulation



High LOLPs driven by wide-spread heat events across Western load centers

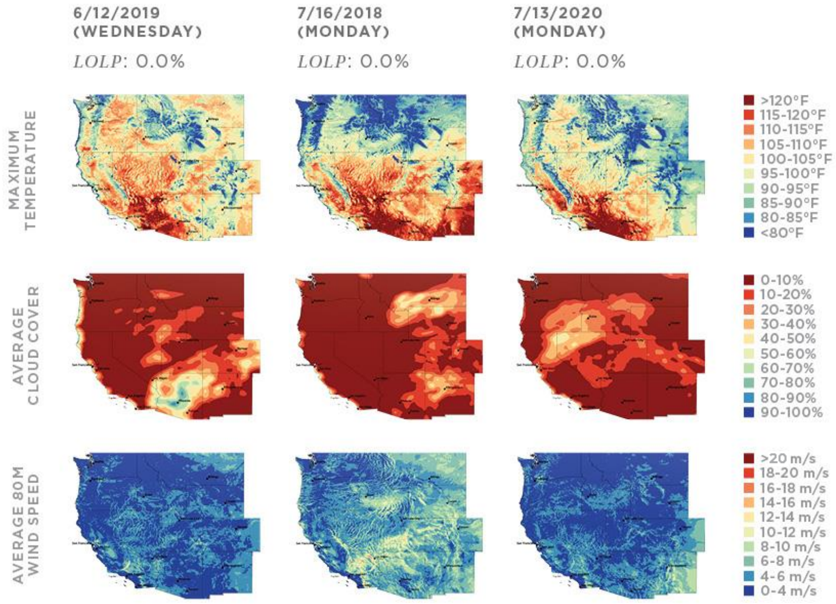
These events also see relatively low wind speeds

[Data source: NOAA High-Resolution Rapid Refresh (HRRR) Data Archive: AWS Open Data Program (https://mesowest.utah.edu/html/hrrr/)]

GridLAB

Weather insights

An application of Weather-Synchronized simulation



[Data source: NOAA High-Resolution Rapid Refresh (HRRR) Data Archive: AWS Open Data Program (https://mesowest.utah.edu/html/hrrr/)]

June 12, 2019

Seattle: 95°F
Portland: 98°F
Sacramento: 103°F
Phoenix: 112°F
Los Angeles: 72°F
San Diego: 74°F

July 16, 2018

Seattle: 92°F
Portland: 98°F
Phoenix: 105°F
San Francisco: 69°F
LA & San Diego: 79°F

July 13, 2020

Seattle: 76°F
Portland: 80°F
Phoenix: 114°F

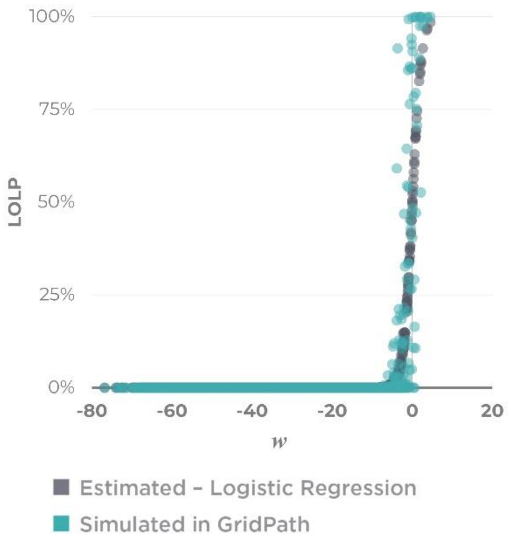
Geographically isolated heat does not result in high LOLP due to load diversity

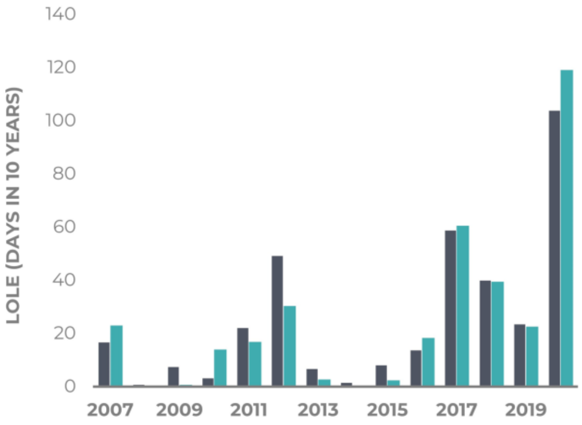
Individual utility plans may overemphasize these events

GridLAB

Estimating LOLP based on weather

An application of Weather-Synchronized simulation





Logistic regression approach:

$$LOLP_{ij} = 1/(1 - e^{-w_{ij}})$$

$$w_{ij} = aX_i + bY_i + cz_{ij} + d$$

daily weather variables

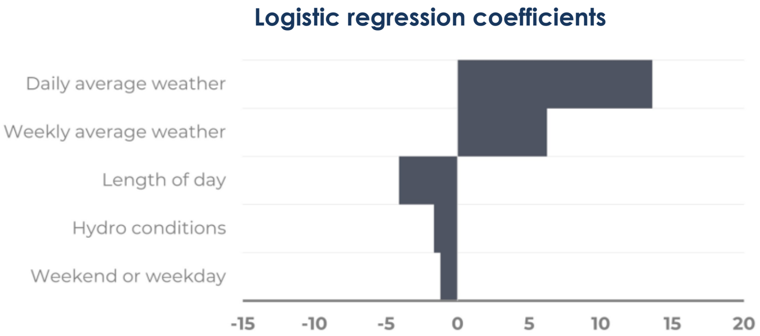
daylight hours & weekend indicator

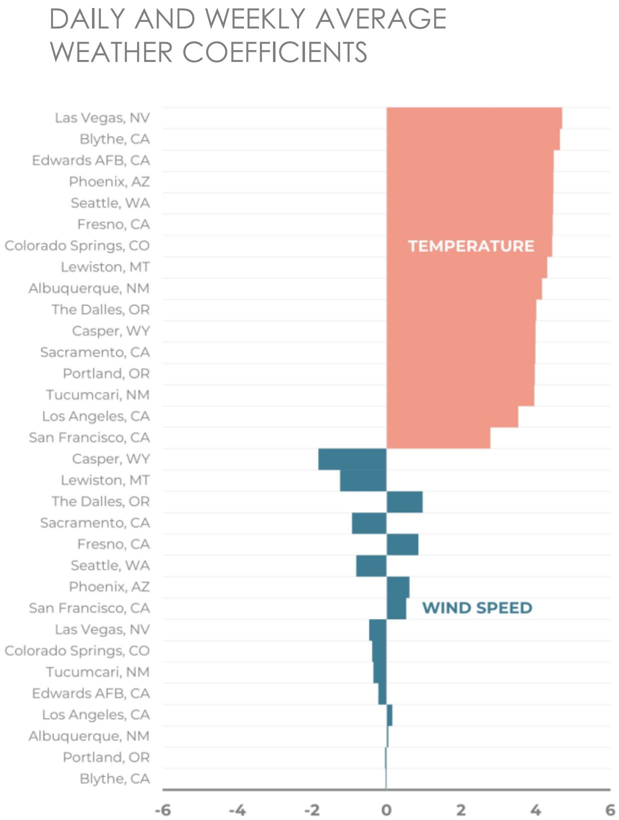
hydro conditions

Technical note: the very small number of loss of load days makes it challenging to avoid overfitting with these types of models. See report for more discussion of this issue and the steps we took to avoid overfitting.

Identifying drivers of RA risk

An application of Weather-Synchronized simulation





In 2026, weather is the biggest driver of RA risk, high temperature conditions in particular

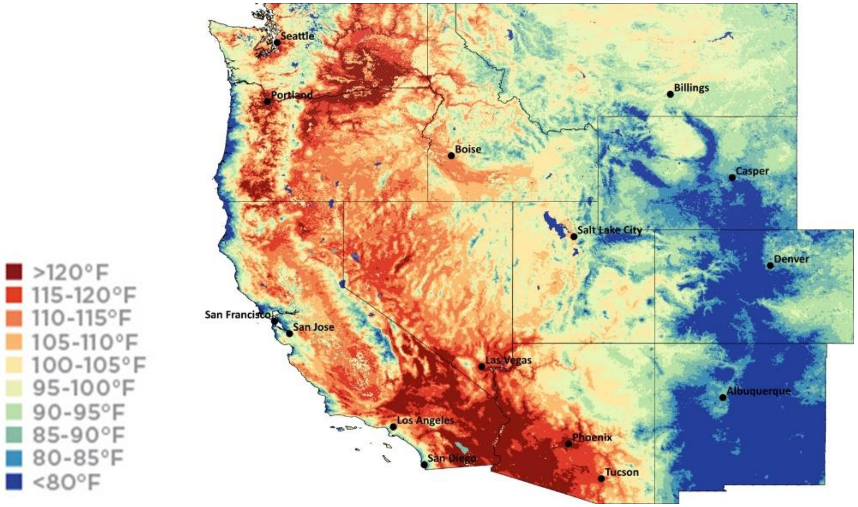
Other systems, for example more highly renewable systems and/or more electrified systems, may have more complex drivers

GridLAB

Estimating RA risk under conditions not modeled

An application of Weather-Synchronized simulation

June 2021 heat dome event



[Data source: NOAA High-Resolution Rapid Refresh (HRRR) Data Archive: AWS Open Data Program (https://mesowest.utah.edu/html/hrrr/)]

June 28, 2021

Seattle: 108°F
Portland: 116°F

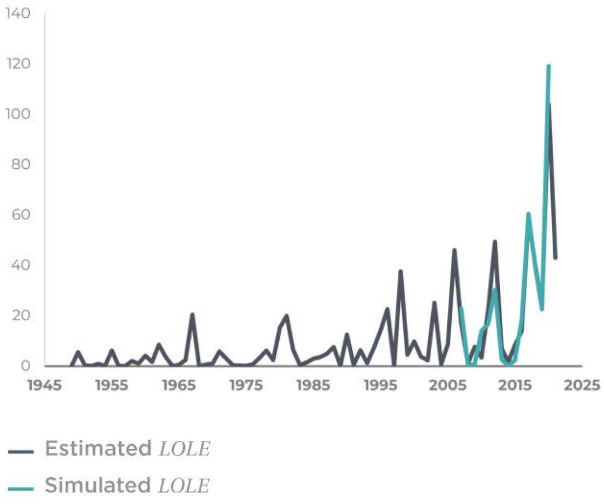
Estimated LOLP: 1.2%

Despite the historic heat dome in the Pacific Northwest, milder conditions in the rest of the West mitigate RA risk

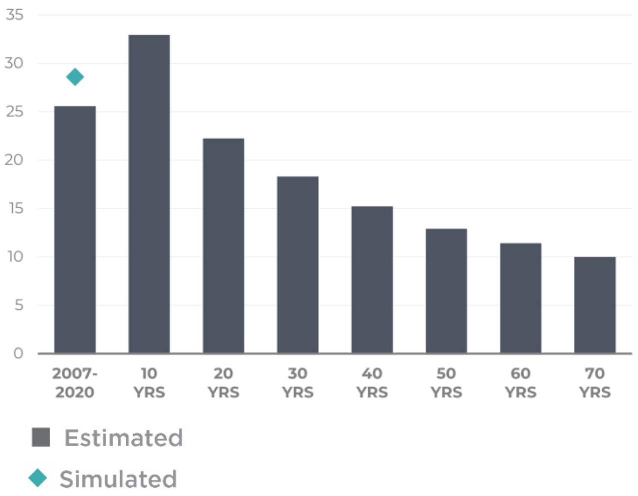
Examining impacts of weather trends

An application of Weather-Synchronized simulation

LOLE (DAYS EVERY 10 YEARS)



LOLE (DAYS EVERY 10 YEARS)



Longer term weather record may not be indicative of the near future. The selection of which weather years to consider is a policy decision

Key Takeaways

Weather-Synchronized simulation

- Weather-Synchronized simulation is a viable alternative to Monte Carlo
- Captures physical relationships/correlations between key variables and across time
- Improved transparency relative to Monte Carlo
- Allows for weather-based analysis and estimation
- Does not seem to miss extreme conditions, primarily because the most extreme hot weather is in the recent historical record
- Could be severely limited by data availability – public wind data for years after 2014 is critical

Practical uses

How can stakeholders use the GridPath RA Toolkit?

- Can be leveraged by regulators, utilities, and others to conduct independent and publicly accessible RA analysis
- Ready-to-use platform for 2026 and three scenarios
- Algorithms and datasets can be adapted to different conditions
- Can be customized for LSEs and RA programs by layering ownership and contractual information
- Researchers and analysts may explore questions not in this study, such as future climate sensitivities and increased electrification

Questions?

Final report and data will be made available at:
www.gridlab.org/GridPathRAToolkit

For more information about GridPath or this project, please reach out to us:

Ana Mileva
ana@bluemarble.run

Elaine Hart
elaine@momentenergyinsights.com