Northwest **Power** and
Conservation Council

June 4, 2024

MEMORANDUM

TO: **Council Members**

FROM: **Dor Hirsh Bar Gai, Power System Analyst**

SUBJECT: **GENESYS Enhancements and Early 2029 Adequacy Assessment Results**

BACKGROUND:

Presenters: Dor Hirsh Bar Gai, John Ollis

Summary: Staff will present summaries of (1) GENESYS modeling enhancements and assumptions incorporated since 2027 adequacy assessment, and (2) the early resource adequacy assessment results for the 2029 operating year using the Council's multi-metric adequacy approach.

The enhancements include improving (1) risk representation of future hydro uncertainty, (2) renewable generation and load forecast error, and (3) WECC-wide representation of resources. For assumptions, staff modified (1) new in-region solar shapes, (2) hydro reserve allocation, (3) thermal start up costs, and (4) deficit interpretation.

Early findings from the 2029 assessment indicate that keeping on track with the implementation of the 2021 Power Plan resource strategy - including holding 6,000 MW of balancing up reserves – alongside system changes in the region of announced non-retirements of thermal plants and expanded transmission capability, will result in an adequate power supply in 2029, despite forecasted load growth from transportation electrification and data centers.

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GENESYS Enhancements & Early 2029 Adequacy Assessment Results

Council Meeting
June 11, 2024

Dor Hirsh Bar Gai
John Ollis

Agenda

- Review of GENESYS Enhancements & Assumptions
- Reminder of Adequacy Assessment
- 2029 Market Buildout
- 2029 Assessment Scenarios & Results

GENESYS Enhancements & Assumptions

Modeling Updates

Enhancements

Future value of hydro
Fine tuned forecast error
WECC-wide resources

Assumptions

New in-region solar shapes
Hydro reserve allocation
Thermal Startup costs
Interpreting deficits

Future Value of Hydro

Goal

- Enhance representation of hydro uncertainty risk to mitigate over optimization

Status

- Created functionality to isolate risk-informed hydro inventory allotment

Fine-Tuned Forecast Error

Goal

- Improve representation of forecast error by renewable resource type and load to better capture system risk

Status

- Disaggregated forecast error values for wind, solar, and load
- Re-evaluate error parameters as needed towards Plan

WECC-wide resources

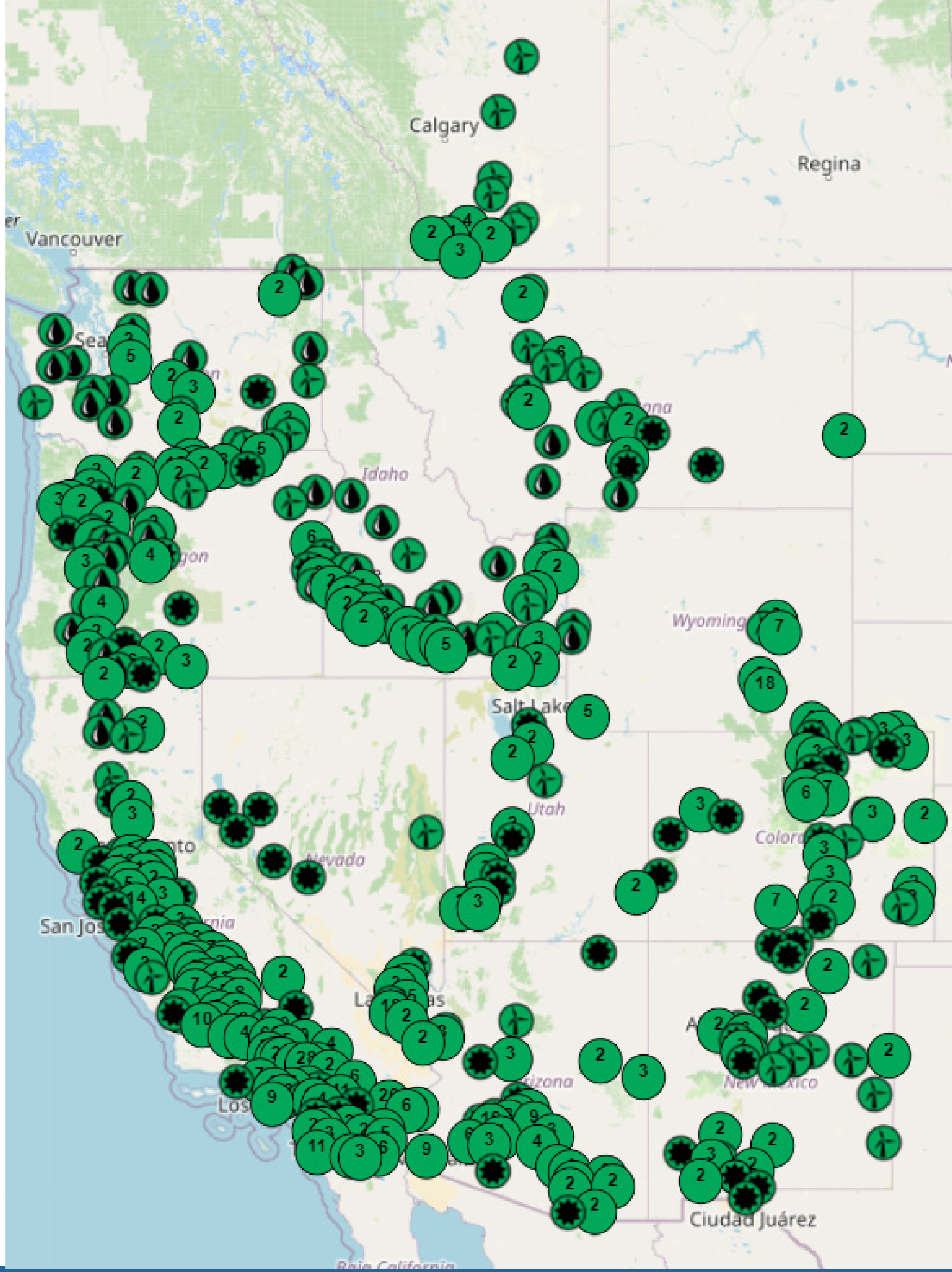
RAAC Requested

Goal

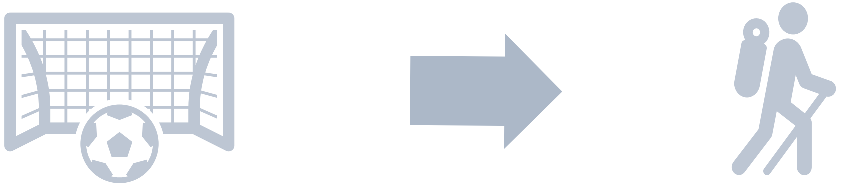
- Represent market risk of renewable generation across the WECC (due to forecast error)

Status

- Modeled ~2,000 individual renewable resources
- Need to evaluate tradeoff of this assumption (run time vs impact)



New In-Region Solar Shapes

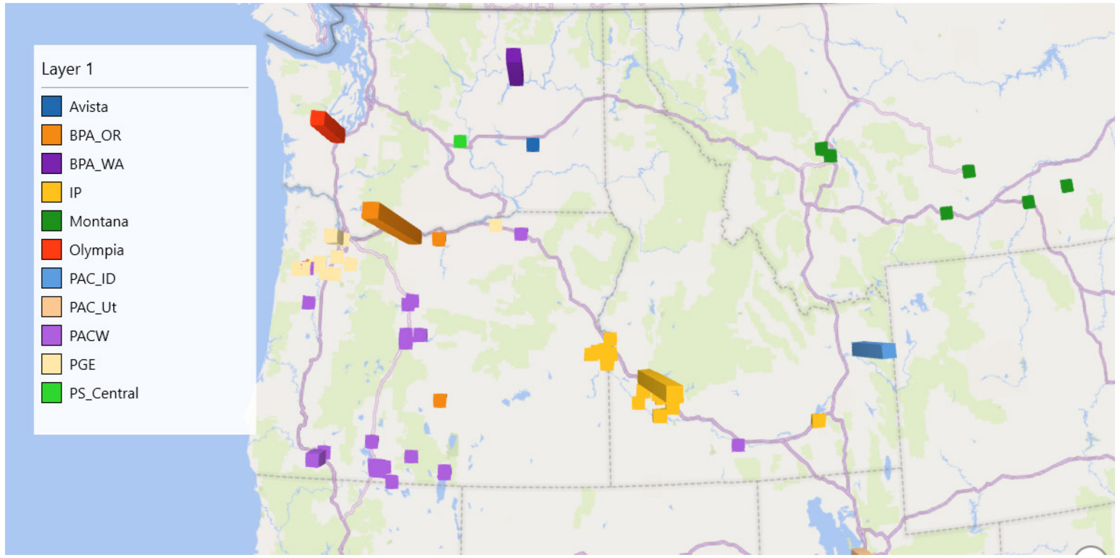


Goal

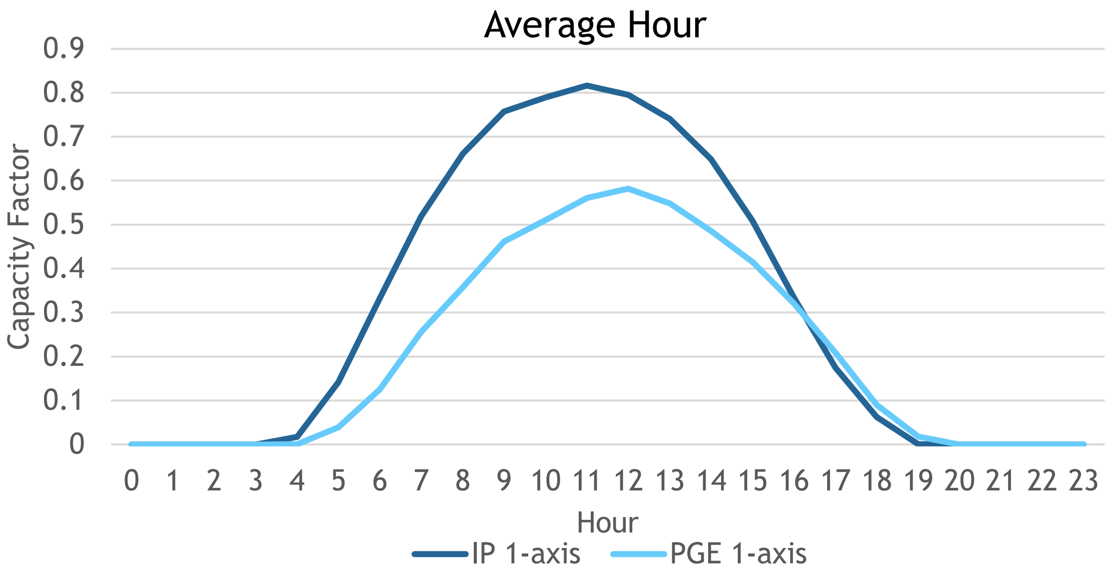
- Improve geographic representation of solar in the PNW

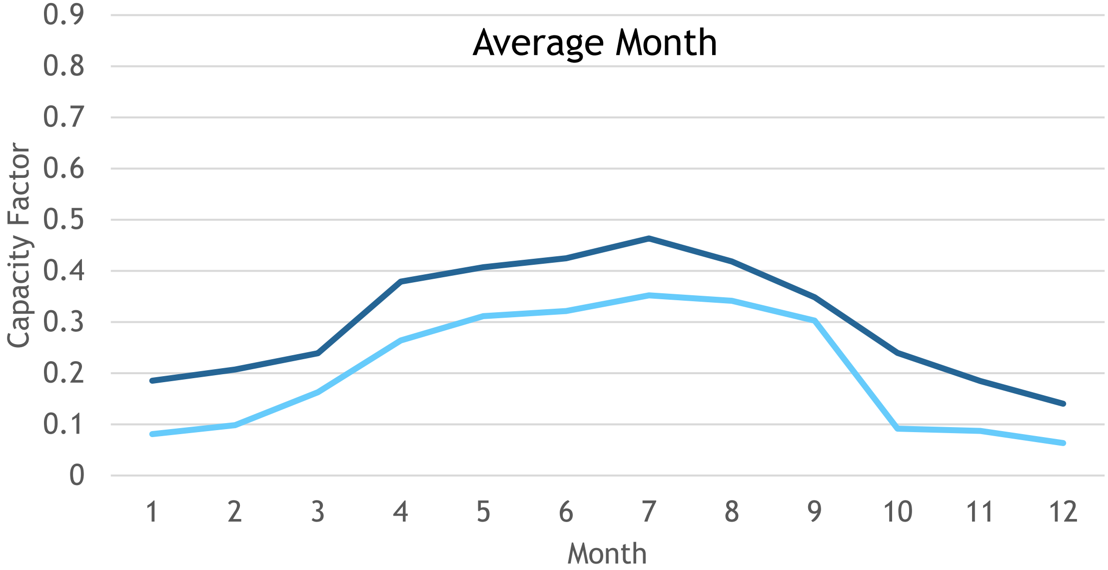
Status

- Created solar capacity factors by Balancing Authority



Examples of Idaho Power and PGE solar capacity factor comparison





Existing Hydro & Thermal System

Goal

- Improve representation of existing hydro and thermal utilization

Status

- Applied limitations on hydro reserve allocation by plant
- Incorporated thermal start up costs

Interpreting Deficits from the Model

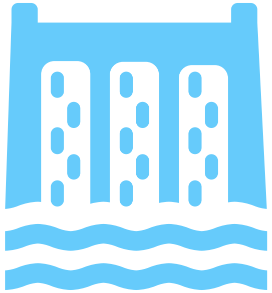
Goal

- Utilize true-up stage for reporting model deficits and calculating adequacy metrics

Status

- Resolved true-up issue

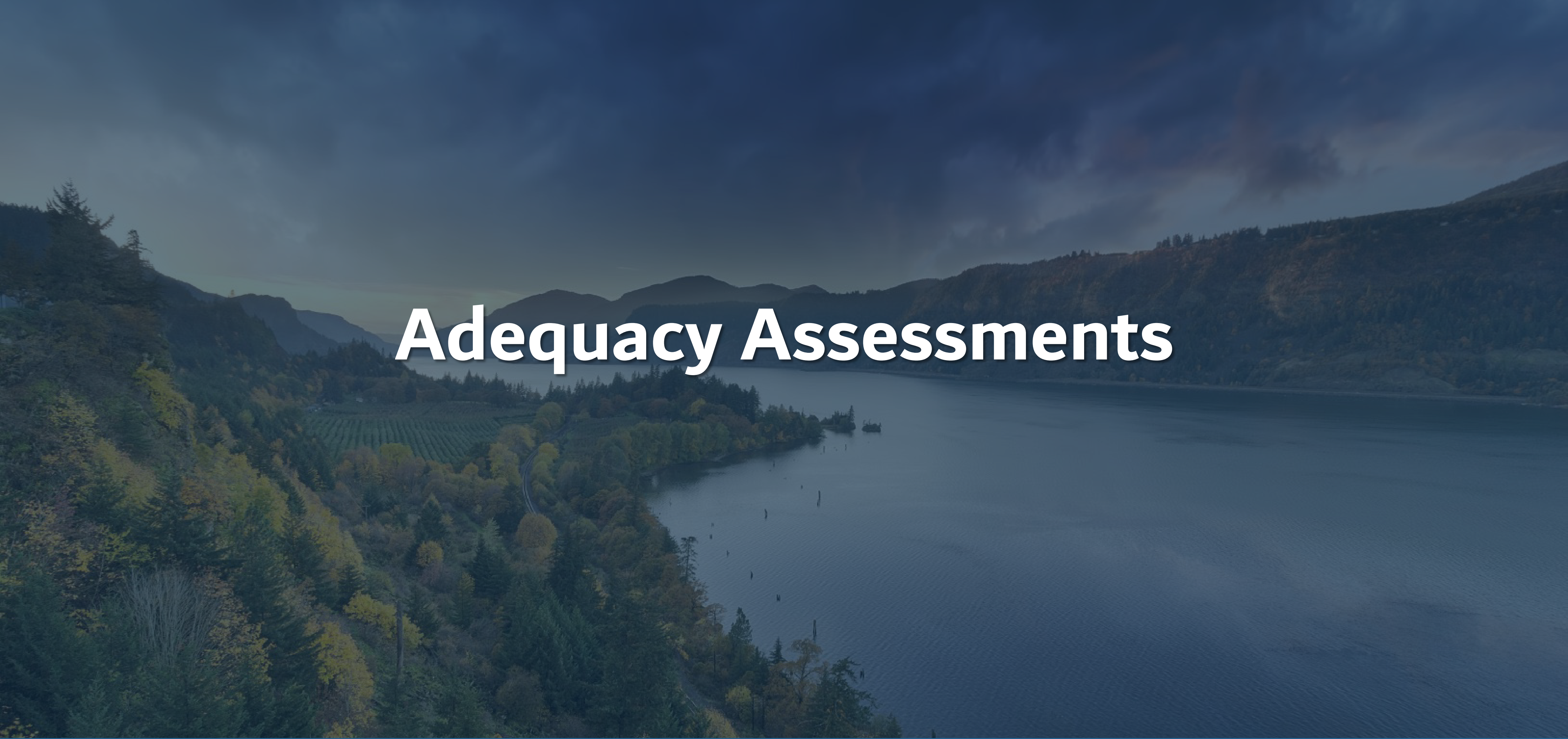
U.S. Commitments Reminder



Spill operations in Lower Snake and Lower Columbia updated according to Appendix B of US Commitments

Based on follow-up conversations, reviewing and considering improvements we can make to representing these operations, specifically treatment of reserves

Adequacy Assessments



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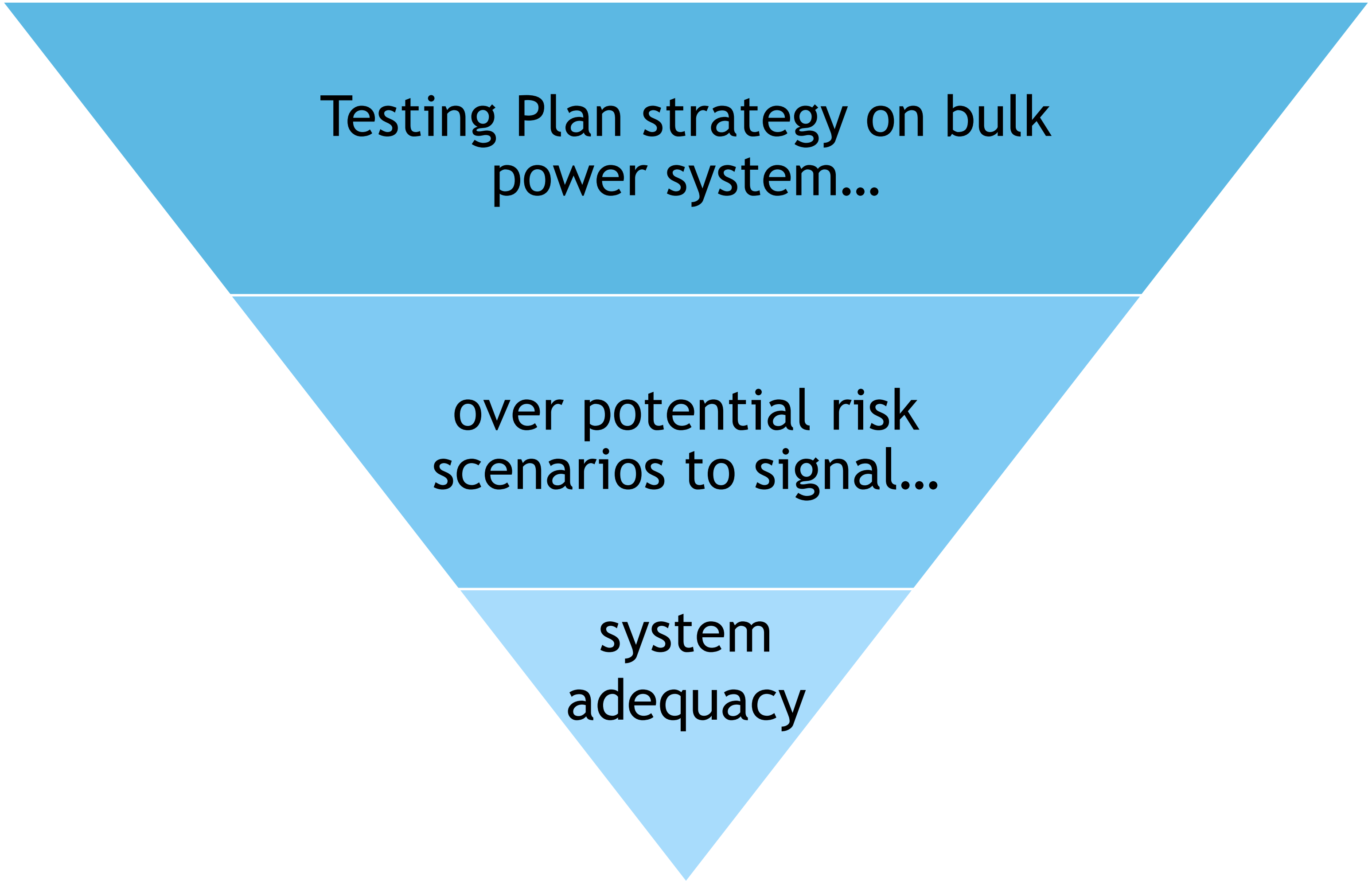
What Are Adequacy Assessments?



Objectives for the 2029 Adequacy Assessment

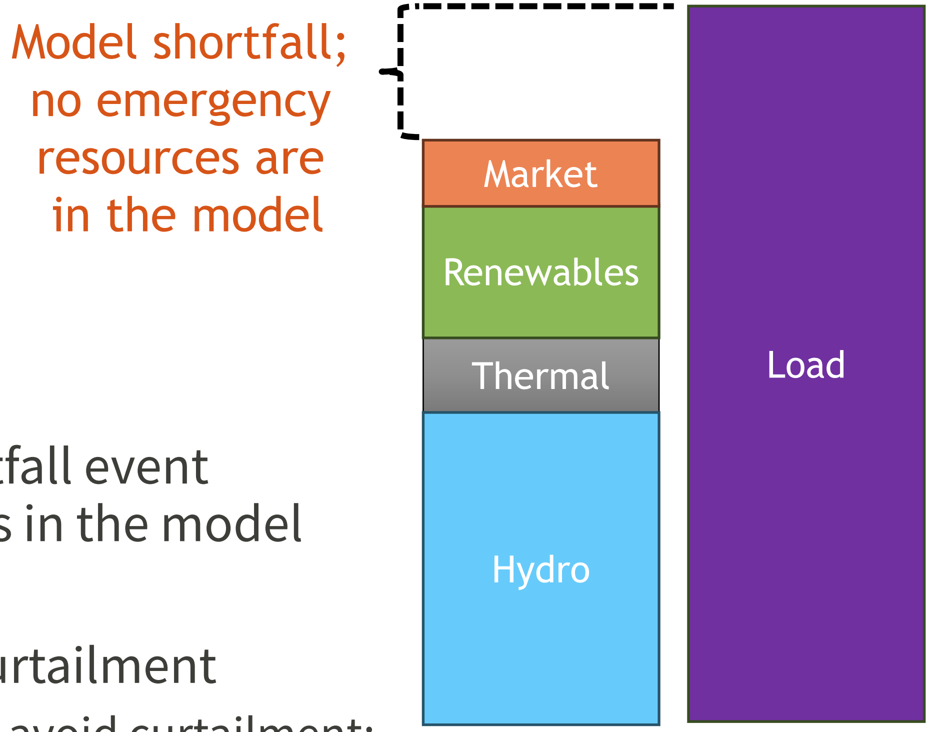
- The two primary objectives for this assessment are as follows:

  1. Provide the 2nd look of whether the 2021 Power Plan continues to provide appropriate direction to ensure an adequate system 5-years out
  2. Test utilization of new multi-metric approach for characterizing system adequacy

To facilitate achieving those objectives:

- **Staff will share modeling results** relative to the new metrics
- **Staff is seeking member discussion** on what the results mean relative to the 2021 Power Plan strategy

Adequacy Approach



- Adequacy studies simulate the NW power system to meet NW load
- In each simulation, representing one year, a simulated model shortfall event occurs over a time period when load cannot be served by resources in the model
- However, a shortfall in the model **does not** necessitate an actual curtailment
  - Rather, it signals non-modeled emergency measures are necessary to avoid curtailment:

Type 1: Within utility control

- High operating cost resources not in utility's active portfolio
- High-priced market purchases over max import limits
- Load buy-back provisions
- Industry backup generators

Type 2: Extraordinary measures

- Official's call for conservation
- Reduce less essential public load (e.g., gov't buildings, streetlights, etc.)
- Utility emergency load reduction protocols
- Curtail F&W hydro operations

- Adequacy metrics evaluate shortfalls to inform risk of using emergency measures

The Metrics and Thresholds

Protection against frequent deficits

Protection against tail-end (extreme) deficits

LOLEV	Duration VaR 97.5	Peak VaR 97.5	Energy VaR 97.5
0.1 in summer 0.1 in winter + report annual	8-hour	1,200 MW + report NVaR	9,600 MW + report NVaR

2029 Market Buildout

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Out of Region Market Buildout Update

Initial adequacy results are informed by market fundamentals per outside the region market resources with buildout from AURORA

1. Resource buildout challenges (modified timeline and enhancement expectations)

2. Recommend draft buildout to inform adequacy assessment results

Resource Buildout Challenges

- AURORA Issues completing buildout.
  - Currently working with Energy Exemplar debugging

- Possible draft market buildout could be improved but deemed reasonable by the RAAC for the assessment.

Overview of Input Assumption Change Status

Already Implemented Inputs

- Updated to 2023-2024 vintage out of region load forecast
- Updated gas prices to December 2023 Council Fuel Price forecast

Draft Input Information

- Updated new resource costs to reflect IRA provisions (mostly ITC/PTC changes)
- Updated zonal transfer to reflect updated limits for pricing run (not for buildout)
- Updated new resource information to include Long Duration Energy Storage (LDES)
- Per SAAC suggestion, updated timing on Proxy Clean resource availability from 2035 to 2030

Yet to be Implemented Updates (On Hold waiting for an AURORA fix)

- Existing resources (still 2022 update vintage)
- Any modification of IRA interpretation
- Additional planned increases in transmission capability

Solar, Solar Plus Storage, Battery, LDES and Pumped Storage Build Comparisons (*installed capacity in megawatts*)

WECC

Year	Draft 2024 Baseline	2022 Baseline	2021 Plan Baseline
2025	2,153	21,528	51,538
2030	14,355	42,206	89,838
2035	15,355	45,141	100,357
2040	17,355	56,494	135,054
2045	19,200	75,890	147,554

Year	Draft 2024 Baseline	2022 Baseline	2021 Plan Baseline
2025	27,813	13,634	6,004
2030	35,875	13,940	6,004
2035	46,903	13,965	6,004
2040	104,016	14,861	6,004
2045	129,751	18,390	6,055

Year	Draft 2024 Baseline	2022 Baseline	2021 Plan Baseline
2025	0	23,386	46,600
2030	2,261	60,503	86,600
2035	5,301	60,503	145,500
2040	20,156	63,429	179,800
2045	39,906	63,429	198,000

Year	Draft 2024 Baseline	2022 Baseline	2021 Plan Baseline
2025	0	0	0
2030	1,300	0	4,900
2035	1,300	2,200	5,650
2040	2,840	2,200	6,050
2045	3,840	2,200	9,690

Year	Draft 2024 Baseline
2025	0
2030	5,913
2035	17,943
2040	34,321
2045	46,214

Wind, Gas, Offshore Wind and Proxy Clean Build Comparisons (*installed capacity in megawatts*)

WECC

Wind

Year	Draft 2024 Baseline	2022 Baseline	2021 Plan Baseline
2025	2,211	12,155	16,775
2030	16,031	18,634	35,175
2035	16,031	27,906	37,063
2040	30,222	38,221	43,657
2045	36,887	69,769	51,481

Offshore Wind

Year	Draft 2024 Baseline	2022 Baseline	2021 Plan Baseline
2025	0	0	0
2030	0	0	6,463
2035	0	0	7,663
2040	10,000	0	10,000
2045	10,000	0	10,000

Gas

Year	Draft 2024 Baseline	2022 Baseline	2021 Plan Baseline
2025	4,523	7,305	11,351
2030	11,403	14,332	14,873
2035	14,185	14,806	16,058
2040	14,614	15,235	16,532
2045	16,330	15,235	16,532

Proxy Clean

Year	Draft 2024 Baseline	2022 Baseline	2021 Plan Baseline
2025	0	0	0
2030	684	1,368	0
2035	684	3,420	0
2040	684	3,420	0
2045	4,104	7,524	0

Draft Buildout in 2029 Outside the Region

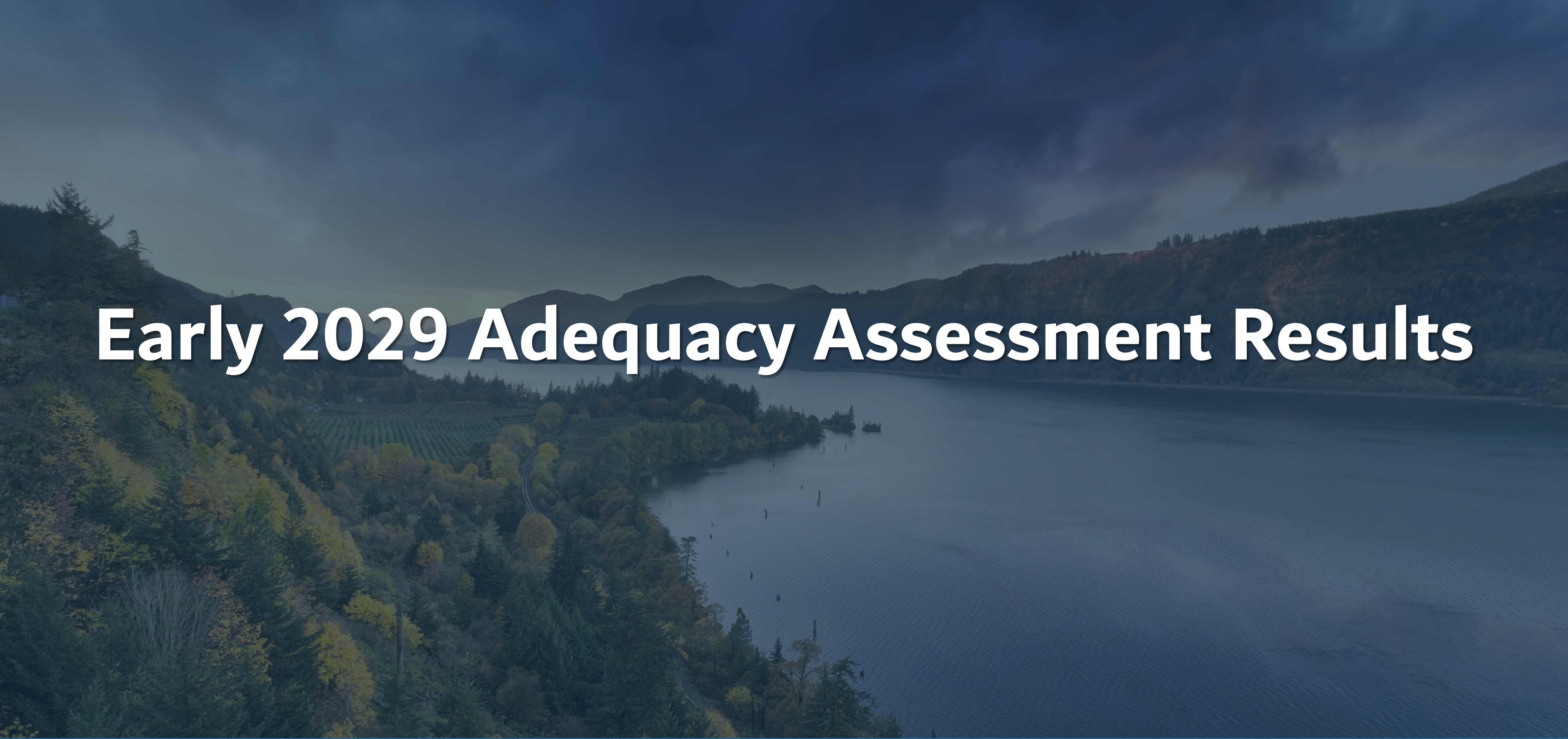
- Canada
  - Other than Site C in BC, all builds are in Alberta
  - 6 GW of solar, 15.6 GW of wind, 3.4 GW of natural gas
- California
  - 17 GW of 4-hour storage and 1.8 GW of LDES
- Desert Southwest (NV, AZ, NM)
  - 450 MW of solar, 470 MW of natural gas, 5.7 GW of 4-hour storage, 900 MW of LDES
- Baja
  - 2.3 GW of natural gas, 1.5 GW of 4-hour storage, 200 MW LDES
- Mountain West (UT, CO, WY)
  - 1.1 GW of solar, 2.4 GW of gas, 6.9 GW of storage

Observations

- More storage resources than energy resources added in early years.
  - Further modifications to IRA implementation may cause larger VER build early but unclear

- Some coal to gas plant conversions seems to be deferring the needs for builds to maintain planning reserve margins and reducing early need for new gas build

- The buildout will likely change for the market study, but likely to be larger outside the region. A larger buildout would likely only improve adequacy results, so we recommend moving forward with this buildout for the 2029 assessment to stick to the timeline.



Early 2029 Adequacy Assessment Results

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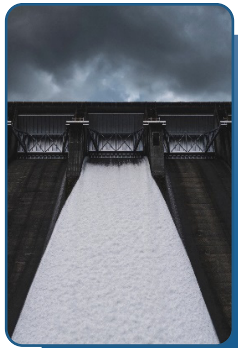
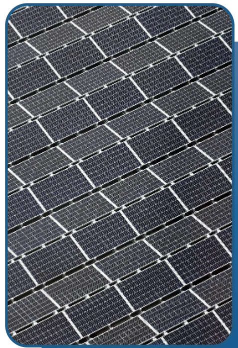
2021 Power Plan Resource Strategy reminder



Existing System: Increase Reserves

To reduce regional needs and support integration of renewables, the region needs to double the assumed reserves. This can most cost-effectively be done through more conservative operation of the existing system (both thermal and hydro units).



Renewables: At least 3,500 MW by 2027

Renewables are recommended due to their low costs, interruptibility, and carbon reduction benefits. Long-term build out will impact the transmission system and should be done mindful of the cumulative impacts of the new resources.

Energy Efficiency: 750-1,000 aMW by 2027

Significantly less acquisition than prior plan due being less cost-competitive, a slower build resource, not inherently dispatchable, and sensitive to market prices. Efficiency that supports system flexibility is most valuable.

Demand Response: Low-Cost Capacity

Highest value products are those that can be regularly deployed at a low-cost and with minimal to no impact on customer. The Council identified demand voltage regulation and time of use rates as two products, estimating 720 MW of potential.

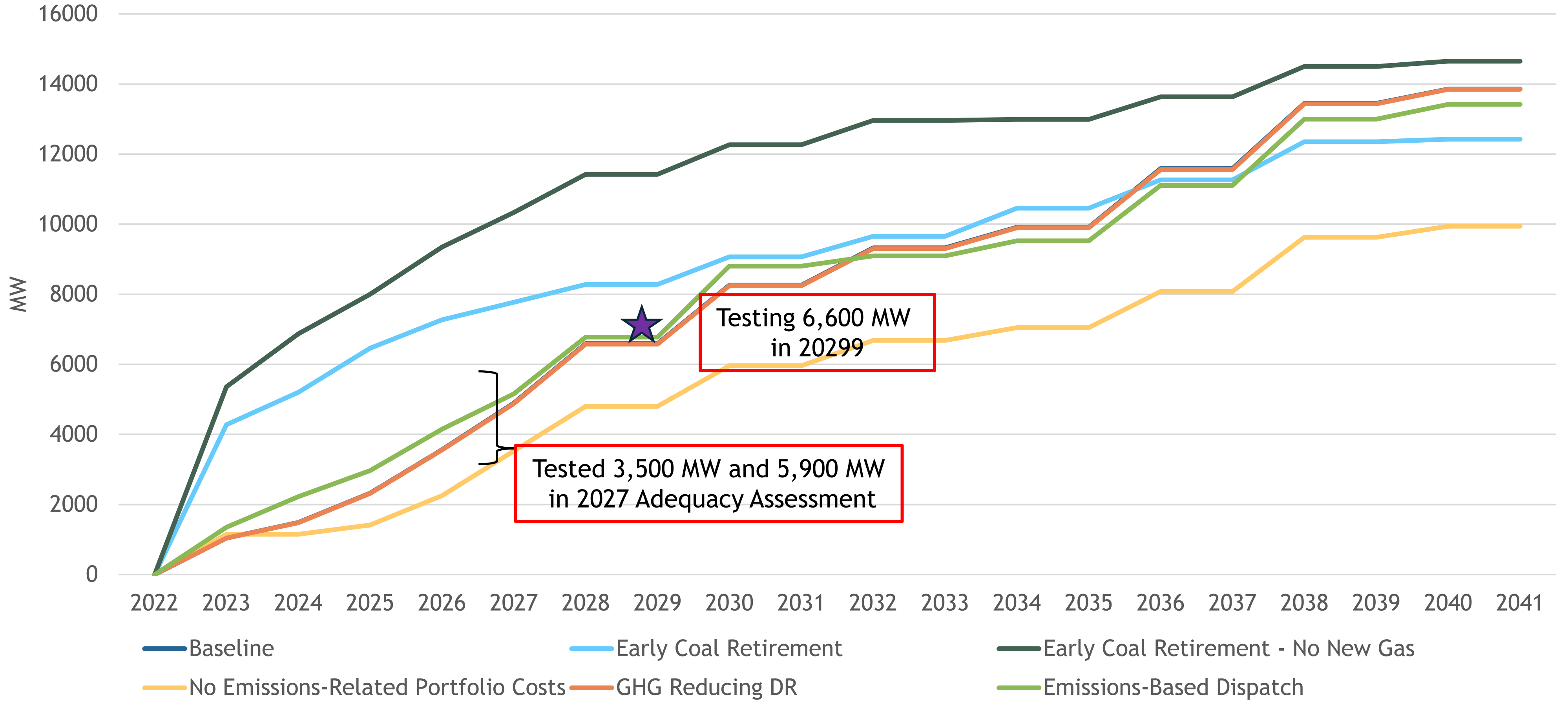
The 2029 Resource Strategy – the Reference

- Our goal for this assessment was to assume the same trajectory of the strategy used in the reference case for the 2027 Adequacy Assessment

Portfolio	2029 Adequacy Assessment	2027 Adequacy Assessment
Renewables	6,600 MW	5,900 MW
EE	1,300 aMW	1,000 aMW
DR	720 MW	720 MW
Reserves	6,000 MW	6,000 MW

2021 Plan Buildout Trajectories

Not shown here: Early coal retirement, with limits on gas, and the deep decarbonization scenario resulted in the highest builds (~36 GW in 2041)



Other System Changes Across all Studies

- Announced changes to several thermal plants not retiring (~1,480 MW)
  - Valmy 1 & 2 (138.6 & 134 MW)
  - Bridger 1 & 2 (~1,200 MW)
  - Currently modeled same as before → possible new modeling as gas conversion when new information will be available
- Expanded transmission capacity
  - 12,700 MW of added transmission capacity
  - Only 1,000 MW in region (B2H)

Planned Transmission	New Capacity (MW)	Path	Online Date	GENESYS Buses	Existing Today (MW)	New 2029 capacity (MW)
Ten West Link	3,200	SCE to APS	2024	So_Cal to Arizona	1,400	4,600
SunZia	3,000	PNM to APS	2026	New Mexico to Arizona	1,700	4,700
Transwest Express	3,000	WAPA Wyoming to PACE UT	2027	wapa RM to PAC_UT	650	3,650
	1,500	PACE UT to Nev South	2027	PAC_Ut to Neveda South	250	1,750
SWIP North	1,000	IP to North Nevada	2027	IP to north Nevada	350 | 185	1,350|1,185
B2H	1,000	IP to BPA_OR	2026	IP to BPA_OR	2,000	3,000

Potential Scenarios

- Reference
- Higher data center load (in region)

Developed, simulated, analyzing, discussing today

- In-region gas supply limitations
- Earlier availability of transmission (reconductoring in region)
- Delayed availability of transmission and emerging tech in WECC
- Emission pricing

Pushed to 9th Plan

- Alternative Trajectories within Resource Strategies

In progress

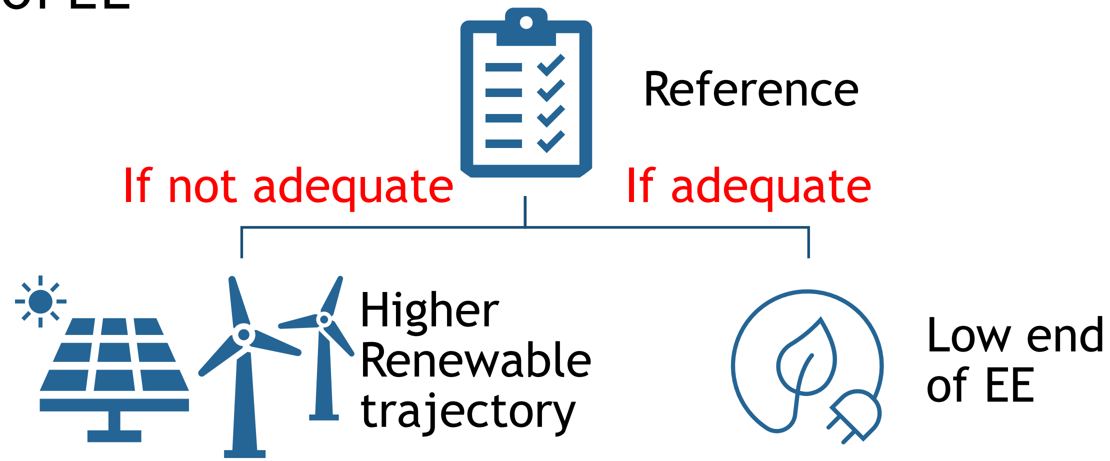
Incremental Load Differences in 2029

	EE Savings aMW	EV Loads aMW	Data Center Loads aMW
2029 Reference scenario	1,300	1,048	2,386
2029 High Data Center scenario	1,300	1,048	3,976

Consideration of Alternative Trajectories within the Resource Strategy

Two alternative trajectories depending on results of the Reference study

- Testing the low end of the cost-effective range of EE
  - ~1,000 aMW of EE by 2029, instead of the 1,300 aMW tested in the reference case



- Testing ~12,000 MW of renewables in 2029 instead of 6,600 MW
  - Planned renewable buildout for 2029 is 11,907 MW (within 2021 Power Plan range)

Draft Results

	Metric	Threshold	Reference 4 event-years 2.2% LOLP Adequate	High Data Center 24 event-years 13.3% LOLP Non-Adequate
Frequency	Winter LOLEV	0.1	0.022	1.294
	Summer LOLEV	0.1	0.017	0.3
Duration	Duration VaR 97.5	8	0	20.6
Magnitude	Peak VaR 97.5	1,200	0	3,076
	Energy VaR 97.5	9,600	0	196,324
Reported metrics (non-binding)	Annual LOLEV	0.1	0.05	1.644
	Peak NVaR 97.5	~3%*	0	9%
	Energy NVaR 97.5	~0.0052%*	0	0.09%

* Approximate

LOLEV

Total events:

Metric	Months	Threshold	Reference (9 events)	High Data Center (296 events)
Winter LOLEV	Dec-Feb	0.1	0.022	1.294
Summer LOLEV	Jun-Aug	0.1	0.017	0.3
Annual LOLEV	All	0.1	0.05	1.644
Spring LOLEV	Mar-May	0.1?	0.011	0.039
Fall LOLEV	Sep-Nov	0.1?	0.000	0.011

Food for thought:
as discussed, relying on winter and summer without an annual perspective overlooks potential spring and fall deficits.

Quick Reminder on Climate Studies

Study Simulations = 180 years → 60 for each climate scenario → 10 water-load years * 6 regional wind profiles

In other words: 10 water-load combinations that repeat 6 times, once for each different regional wind profile

Scenario	Winter Hydro Generation	Summer Hydro Generation	Winter HDDs	Summer CDDs
CanESM (A)		*low*	*low*	*high*
CCSM (C)	*high*	*low*		
CNRM (G)	*low*	*high*	*high*	*low*

(Red circle) High loads and low water conditions might cause adequacy events

Simulation Scenario Cipher

(3 scenarios)	(6 profiles)	(10 profiles)
Cimate Scenario_	Wind Profile,	Hydro-Load Profile
↓	↓	↓
A	0	0
C	1	1
G	2	2
	3	3
	4	4
	5	5
		6
		7
		8
		9

Recall that a VaR 97.5 value of 0 does not mean no shortfalls;
rather it is a probabilistic representation signaling the shortfall risk 39 out of 40 years

Events in Reference Scenario

Maximum event duration and peak

event_index	Sim_Scenario	Sim_scenario_event_index	Month	Day	event_duration (hour)	event_max (MW)	event_sum (MWh)
1	A_40	1	7	13	1	525	525
2	C_31	1	3	30	1	46	46
3	G_5	1	7	18	1	27	27
4	G_33	1	1	17	4	960	3,368
5	G_33	2	1	18	1	589	589
6	G_33	3	1	19	1	844	844
7	G_33	4	1	19	1	899	899
8	G_33	5	5	27	1	359	359
9	G_33	6	7	23	1	222	222

Maximum annual energy 6,281 MWh

Main challenge is one simulation:
climate scenario G_33

Major Shortfall Events in High DC Scenario

	event_index	Sim_Scenario	Sim_scenario_ event_index	Month	Day	event_ duration (hour)	event_ max (MW)	event_ sum (MWh)	Max energy rank
Longest Duration Events	286	G_53	7	1	16	119	1,096	105,349	1st
	265	G_43	3	1	16	48	1,096	46,151	
	242	G_33	4	1	16	45	1,096	41,667	
Highest Peak Events	191	A_56	14	12	27	19	8,863	61,763	2nd
	192	A_56	15	12	28	9	8,407	38,898	
	189	A_56	12	12	26	17	6,688	61,604	3rd

Events in High Data Center

Scenario A:
More events (226),
greater peaks and energy

Scenario G:
Longest events,
single greatest energy deficit

Scenario	Event frequency	Event Duration Average	Event Duration Max	Event Peak Average	Event Peak Max	Event Energy Average	Event Energy Max
A_16	25	6.4	18	1,796	6,117	10,414	51,440
A_26	51	4.0	16	1,193	4,392	5,017	32,118
A_29	1	1.0	1	38	38	38	38
A_31	1	1.0	1	93	93	93	93
A_36	45	3.9	22	1,576	6,440	6,147	51,200
A_37	1	1.0	1	455	455	455	455
A_48	2	1.0	1	496	788	496	788
A_56	48	4.9	19	2,164	8,863	9,198	61,763
A_6	51	5.0	22	1,234	5,500	5,787	38,044
A_60	1	1.0	1	454	454	454	454
C_12	1	1.0	1	1,217	1,217	1,217	1,217
C_19	1	1.0	1	199	199	199	199
C_34	2	1.0	1	289	296	289	296
C_56	4	1.5	3	270	537	537	1,606
G_16	1	2.0	2	551	551	1,101	1,101
G_33	23	5.8	45	730	1,096	4,544	41,667
G_40	1	2.0	2	436	436	804	804
G_43	14	9.4	48	826	1,096	7,312	46,151
G_48	2	1.5	2	1,209	1,621	1,417	1,621
G_49	1	1.0	1	331	331	331	331
G_53	15	10.5	119	698	1,096	8,702	105,349
G_55	1	1.0	1	34	34	34	34
G_60	1	1.0	1	351	351	351	351
G_8	3	1.0	1	200	485	200	485

G challenging years – 33, 43, and 53

"A" challenging years – 16, 36 , and 56 (6, 26)
All have similar low water throughout the year

High Data Center Monthly Events

More summer and winter challenges

Scenario	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Dec
A_16	13	1						5		6
A_26	11	8				1		8		23
A_29				1						
A_31					1					
A_36	13	12					1	12		7
A_37								1		
A_48								1	1	
A_56	22	6			1			4		15
A_6	16	11						8		16
A_60							1			
C_12			1							
C_19					1					
C_34						1	1			
C_56						4				
G_16						1				
G_33	23									
G_40							1			
G_43	14									
G_48	1							1		
G_49									1	
G_53	15									
G_55							1			
G_60								1		
G_8			1		1			1		

Discussion Points

- The studies encompass a wide range of hydro, load, and renewable generation profile combinations.
- The risk of low wind generation is captured across a variety of hydro and load conditions → and poses adequacy challenges in limited scenarios

Reference Case

- Limited adequacy risk associated with one scenario (G_33) having normal winter hydro generation coupled with high loads and low wind generation
- However, similar hydro and load conditions had no adequacy issues across other wind generation profiles (G_3, 13, 23, 43, 53)

Higher Data Center Load Case

- Increased loads caused adequacy issues not present in the Reference with similar hydro & wind conditions (G_43, 53)
- However, other similar coupled hydro and wind conditions remain with no adequacy challenges due to increased loads (G_3, 13, 23)
- Increased loads worsen winter and summer adequacy challenges across additional climate scenarios (mostly A, a bit in C) not observed in the Reference

Overall Finding

- Assuming the reference case is the trajectory:
  - Continued implementation of the strategy, including ensuring sufficient reserves and acquiring another two years of energy efficiency and renewables, not retiring thermal plants, and expanded transmission capacity offset the adequacy challenge of increased loads of anticipated data centers and EV electrification

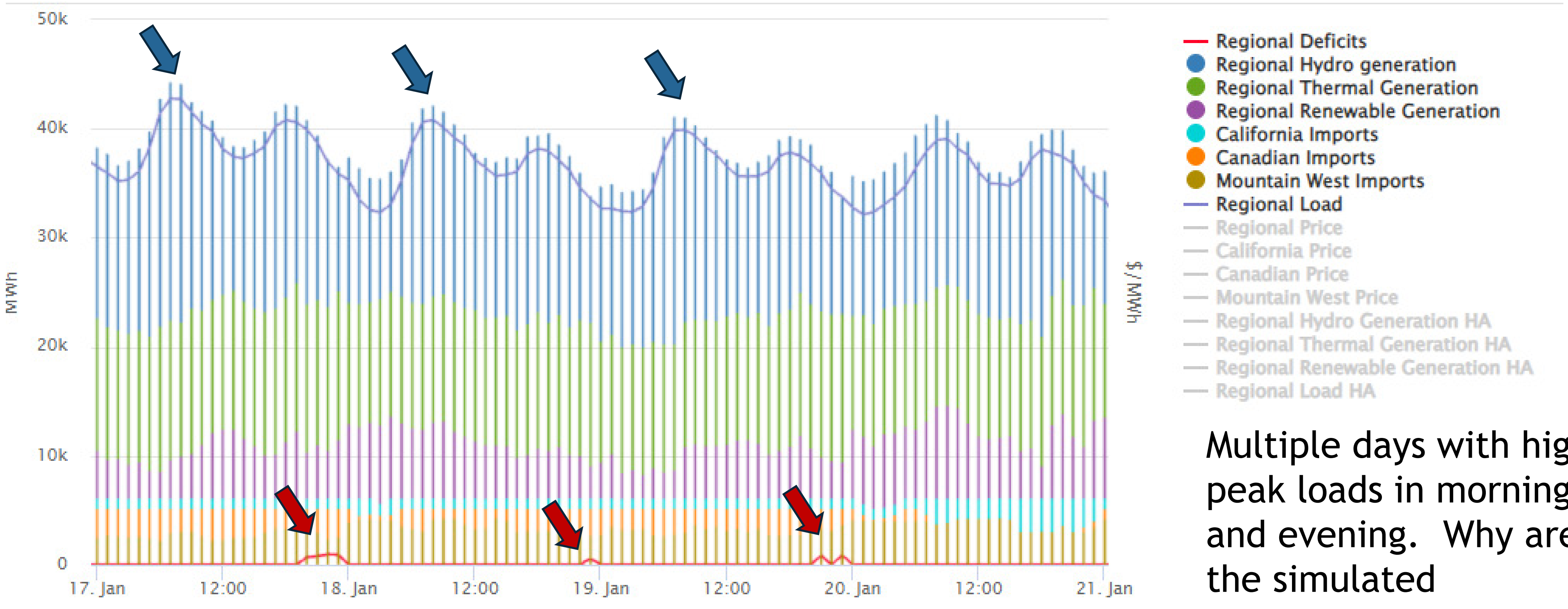
- If the higher data center case is more likely:
  - The ~1,600 MW of increased load associated with **additional** data center load growth above the reference case causes adequacy challenges
  - The plan is to study the impact and resource strategy associated with increased load uncertainty in the upcoming Power Plan.

Early 2029 Adequacy Assessment Results
Winter Event Example

2029 Adequacy Assessment Reference Case – Scenario 33 Simulated Shortfalls in January

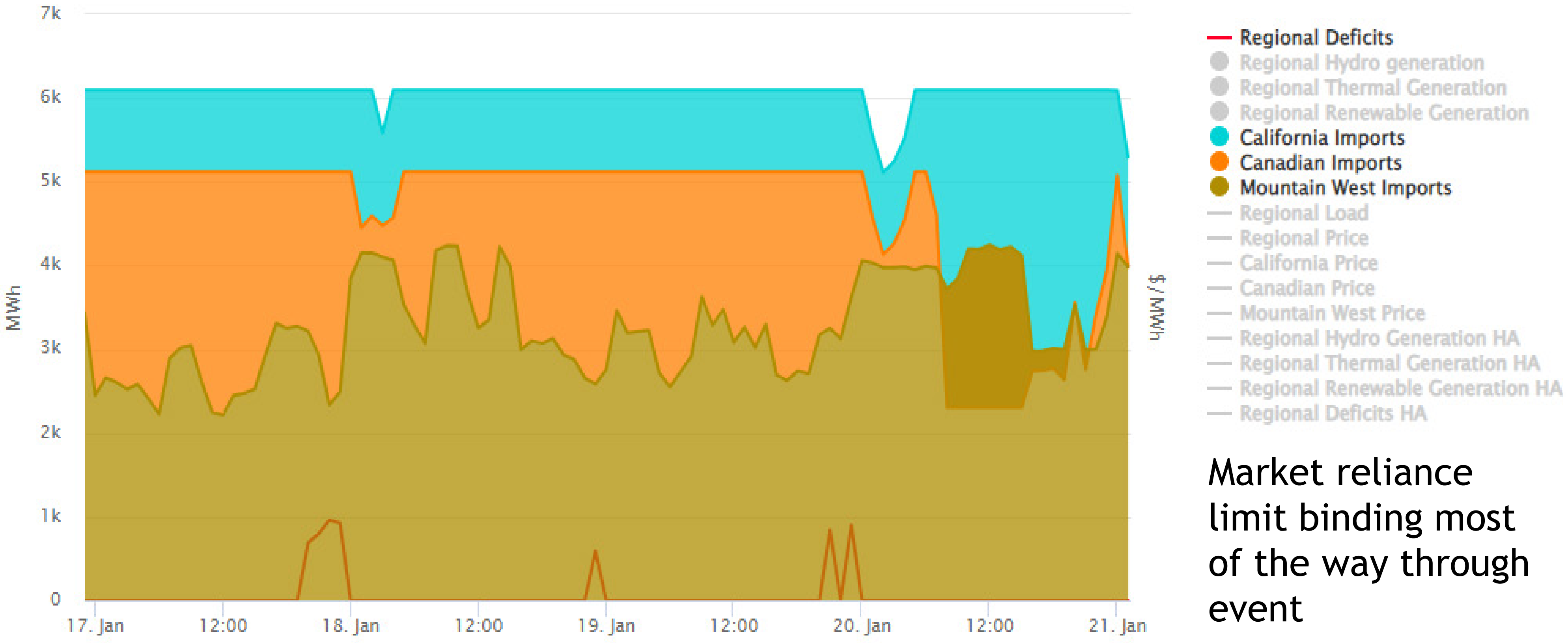
Simulated shortfalls in the evening, during a period of very high peak loads

2029 Adequacy Assessment Reference Case – Scenario 33 Load Resource Balance



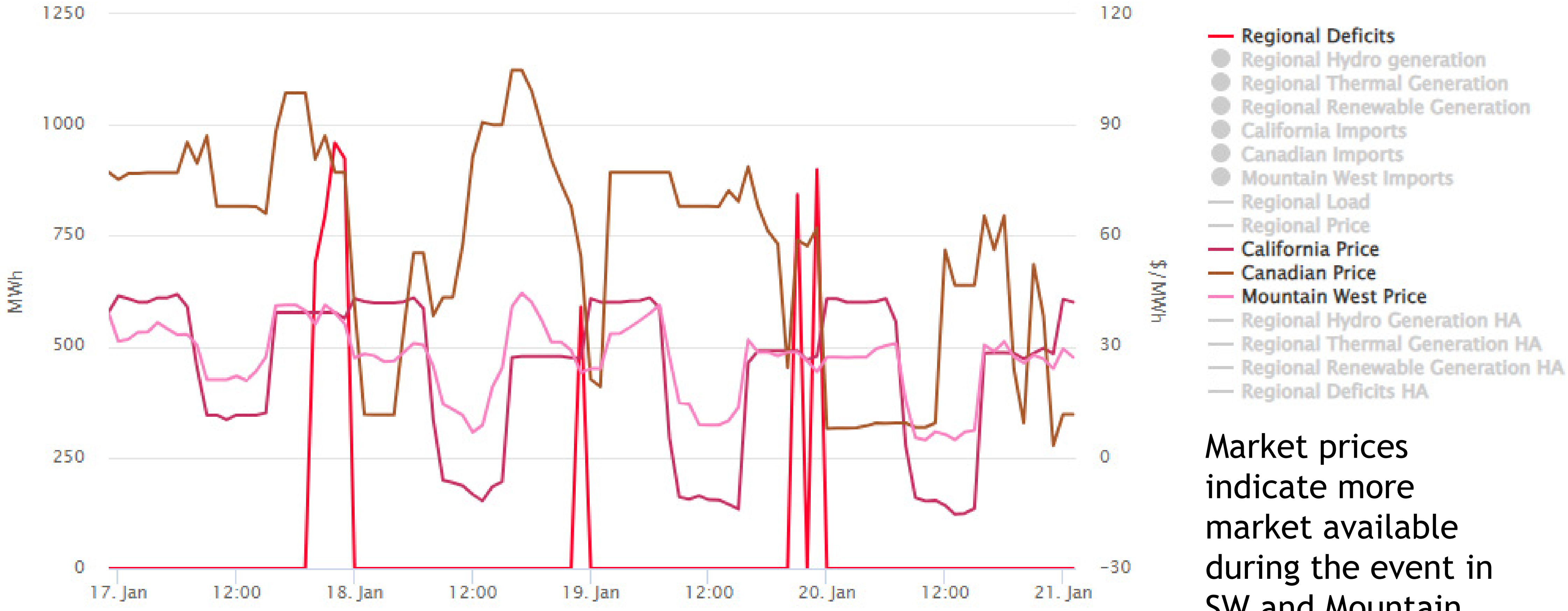
Multiple days with high peak loads in morning and evening. Why are the simulated shortfalls during the lower evening peak?

2029 Adequacy Assessment Reference Case – Scenario 33 Market Reliance



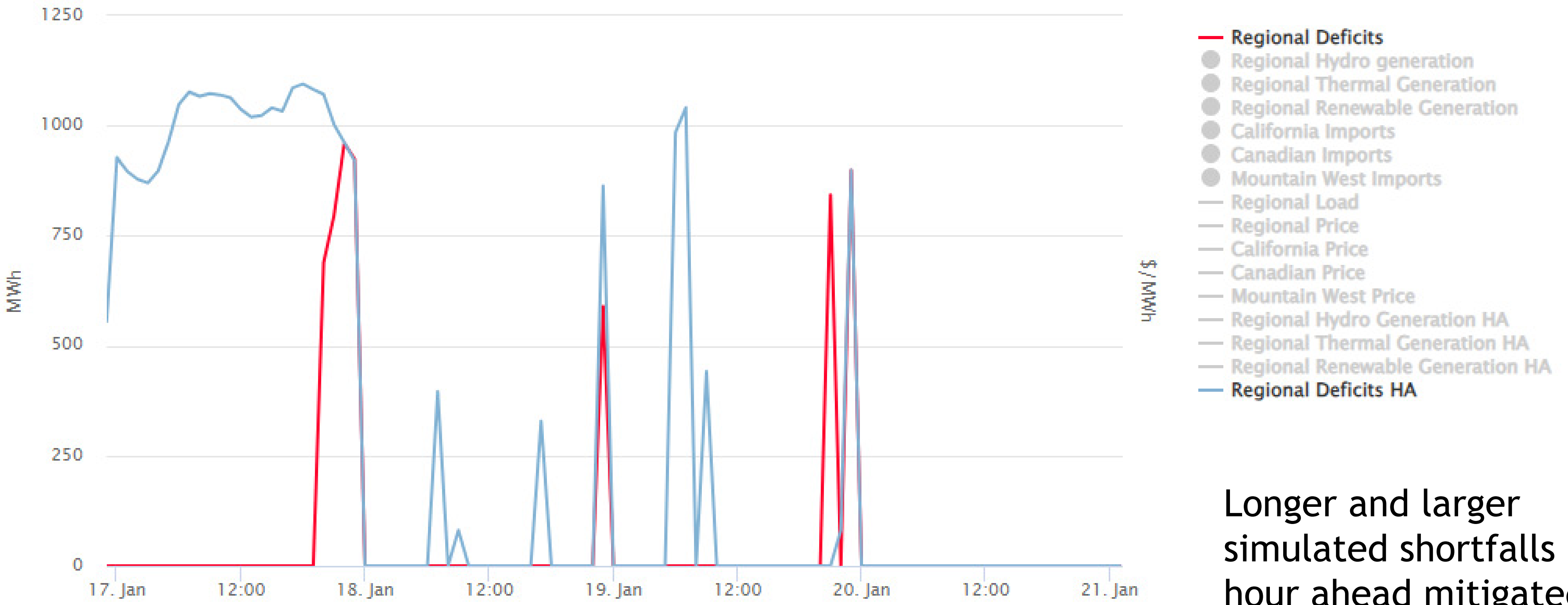
Market reliance limit binding most of the way through event

2029 Adequacy Assessment Reference Case – Scenario 33 Market Reliance



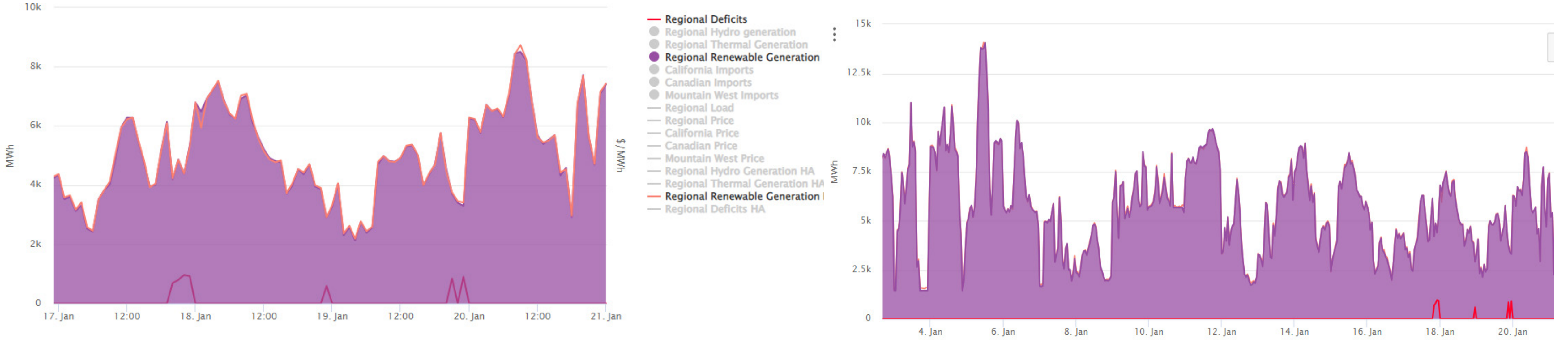
Market prices indicate more market available during the event in SW and Mountain West

2029 Adequacy Assessment Reference Case – Scenario 33 Simulated Shortfalls



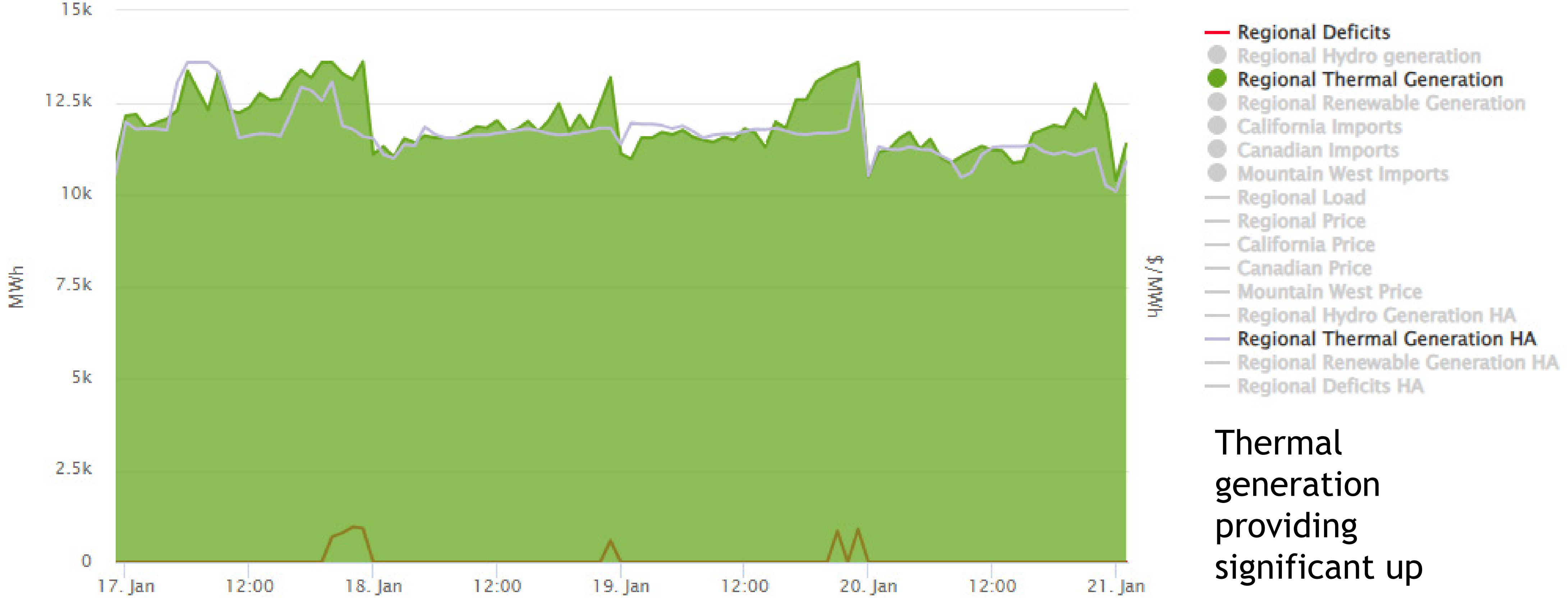
Longer and larger simulated shortfalls in hour ahead mitigated by thermal plant reserves

2029 Adequacy Assessment Reference Case – Scenario 33 Renewable Generation



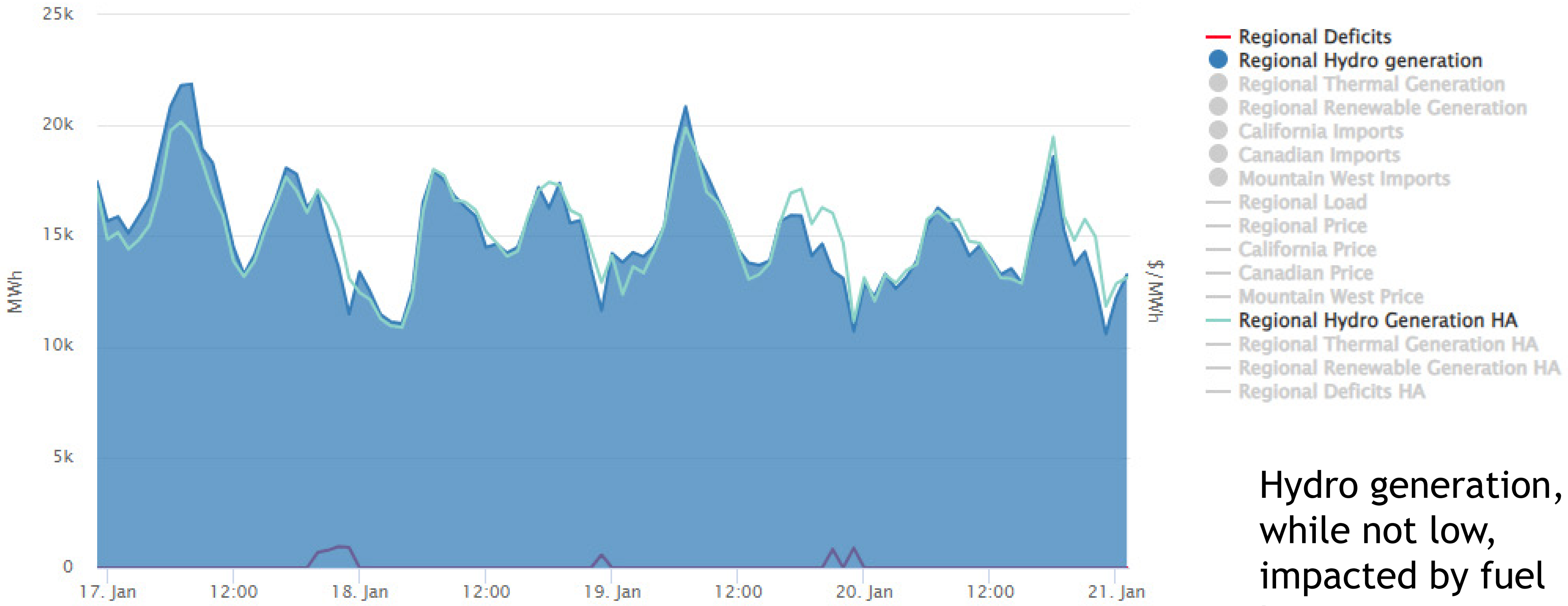
Renewable generation is low during the event but also very low during some of the days leading up to the event.

2029 Adequacy Assessment Reference Case – Scenario 33 Thermal Generation



Thermal generation providing significant up reserves

2029 Adequacy Assessment Reference Case – Scenario 33 Hydro Generation



Hydro generation, while not low, impacted by fuel limitations throughout event

2029 Adequacy Assessment Renewable Generation Risk During High Load Events

Reference Case

- Scenario 33 had an adequacy issue but low wind generation
- Other scenarios that had the same load and hydro but different renewable generation and no adequacy issues.
- The market reliance limit is binding leading up to and throughout the event; however, market fundamentals show more availability outside the region

Next Steps

2029 Adequacy Assessment Timeline

Kickoff
- April 2, 2024
- Interim Multi-metric thresholds
- Scenarios discussion

Technical setup
- April 4, 2024
- Region Loads
- Existing resources
- Review of new hydro operation changes
- GENESYS enhancements
- Scenario discussion

Setup results
- Early May
- Report market scenarios and results
- Preliminary exploration of new hydro operations
- Preliminary exploration of enhancements and assumptions

Interim adequacy results
- May 30, 2024
- Discuss interim adequacy results

Final Adequacy Report
- Late June
- Discuss final adequacy results
- Evaluate multi-metric framework

Council Meeting Update
- July 9-10, 2024
- Report on Assessment
- Discuss recommendation for final multi-metric adequacy thresholds

Next Steps

- Run and analyze low end of EE in Alternative Trajectories
- Prepare final 2029 adequacy assessment report (Late June RAAC)
  - Including evaluation of multi-metric framework
- Present final 2029 adequacy assessment in July Council Meeting

Questions on Draft Results?

			4 event-years 2.2% LOLP Adequate	24 event-years 13.3% LOLP Non-Adequate
	Metric	**Threshold**	**Reference**	**High Data Center**
Frequency	Winter LOLEV	0.1	0.022	1.294
	Summer LOLEV	0.1	0.017	0.3
Duration	Duration VaR 97.5	8	0	20.6
Magnitude	Peak VaR 97.5	1,200	0	3,076
	Energy VaR 97.5	9,600	0	196,324
Reported metrics (non-binding)	Annual LOLEV	0.1	0.05	1.644
	Peak NVaR 97.5	~3%*	0	9%
	Energy NVaR 97.5	~0.0052%*	0	0.09%

* Approximate

Questions?

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John Ollis
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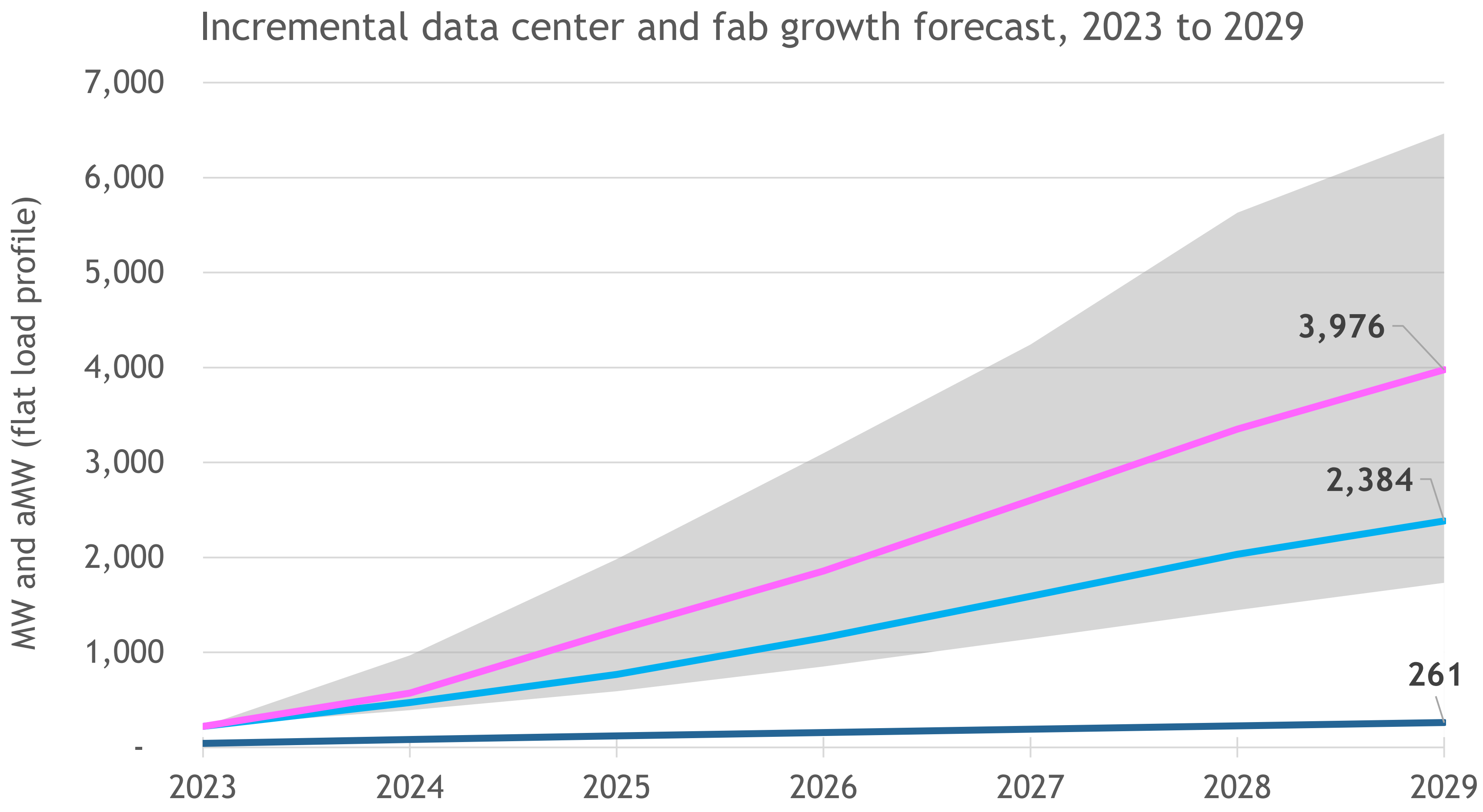
Appendix

Data center & chip fab forecasts



Higher case forecast, trends accelerate, closer to utility projections

Reference case forecast, based on current trends continuing

8th Plan high case forecast (data center only)

Duration (Hours)

Metric	Threshold	Reference	High Data Center
Duration VaR 97.5	8	0	20.6
Max		4	119

Simulation Max Duration Hours:

Ref	High DC
4	119
1	48
1	45
1	22
	22
	19
	18
	16
	3
	2
	2
	2
	1
	1
	1
	1
	1
	1
	1
	1
	1
	1
	1
	1

Peak (MW)

Simulation Max Peak MW:	Ref	High DC
	960	8,863
	525	6,440
	46	6,117
	27	5,500
		4,392
		1,621
		1,217
		1,096
		1,096
		1,096
		788
		551
		537
		485
		455
		454
		436
		351
		331
		296
		199
		93
		38
		34

Metric	Threshold	Reference	High Data Center
Peak VaR 97.5	1,200	0	3,076
Max		960	8,863

Energy (MWh)

Metric	Threshold	Reference	High Data Center
Energy VaR 97.5	9,600	0	196,324
Max		6,281	441,491

Simulation Max Energy MWh:

Ref	High DC
6,281	441,491
525	295,138
46	276,632
27	260,354
	255,857
	130,525
	104,506
	102,367
	2,835
	2,149
	1,217
	1,101
	992
	804
	599
	578
	455
	454
	351
	331
	199
	93
	38
	34

However, if data center load growth will be in the higher range of the forecast, the region will have insufficient resources to maintain adequacy – signaling the importance of analyzing such futures in the 9th Power Plan.

Staff will work with the Power Committee to finalize the 2029 Adequacy Assessment, including testing an additional scenario to evaluate the adequacy risk if the low end of the energy efficiency target outlined in the 2021 Power Plan is achieved instead.

Relevance: Continuously enhancing modeling and assumptions is key for Council analysis. These new enhancements and assumptions improve the analytical capabilities to better represent system operations and dynamics.

Resource adequacy is a critical component of the Council's mandate to develop a regional power plan that "ensures an adequate, efficient, economic and reliable power supply." To test the efficacy of the plan's resource strategy, the Council – in cooperation with regional stakeholders – annually assesses the adequacy of the power supply with planned resource additions. The annual assessment is based on a multi-metric adequacy approach to categorize the risk of frequency, duration, and magnitude of events that is currently under evaluation by the Council since 2022 and approved in 2023, evolving past the resource adequacy standard of Loss of Load Probability (LOLP) metric used since 2011.

Workplan: B.1.3 Continued Enhancement of GENESYS operations to support periodic studies and next power plan.

A.2.4 Conduct the regional Adequacy Assessment and prepare report detailing the analysis and findings.

Background: An adequate power supply can meet the electric energy requirements of its customers within acceptable limits, considering a reasonable range of uncertainty in resource availability and in demand. Resource uncertainty includes forced outages, early retirements and variations in hydro, wind, solar and market supplies. Demand uncertainty includes variations due to temperature, economic conditions, and other factors. Resource availability and demand are also affected by environmental policies, such as those aimed at reducing greenhouse gas emissions.

In January 2023 the Council approved a transition towards a multi-metric adequacy approach with the completion of the 2027 Adequacy Assessment to 1) prevent overly frequent use of emergency measures, (2) limit the risk of long duration shortfall events, (3) limit the risk of big capacity shortfalls, and (4) limit the risk of big energy shortfalls. Frequency, duration, and magnitude metrics are used in combination of expected and tail-end event statistics, known as value at risk (VaR).

GENESYS Enhancements & Early 2029 Adequacy Assessment Results

Council Meeting
June 11, 2024

Dor Hirsh Bar Gai
John Ollis

Northwest Power and Conservation Council

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Agenda

- Review of GENESYS Enhancements & Assumptions
- Reminder of Adequacy Assessment
- 2029 Market Buildout
- 2029 Assessment Scenarios & Results

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Modeling Updates

Enhancements

Future value of hydro
Fine tuned forecast error
WECC-wide resources

Assumptions

New in-region solar shapes
Hydro reserve allocation
Thermal Startup costs
Interpreting deficits

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Future Value of Hydro

RAAC Requested

Goal

- Enhance representation of hydro uncertainty risk to mitigate over optimization

Status

- Created functionality to isolate risk-informed hydro inventory allotment

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Fine-Tuned Forecast Error

RAAC Requested

Goal

- Improve representation of forecast error by renewable resource type and load to better capture system risk

Status

- Disaggregated forecast error values for wind, solar, and load
- Re-evaluate error parameters as needed towards Plan

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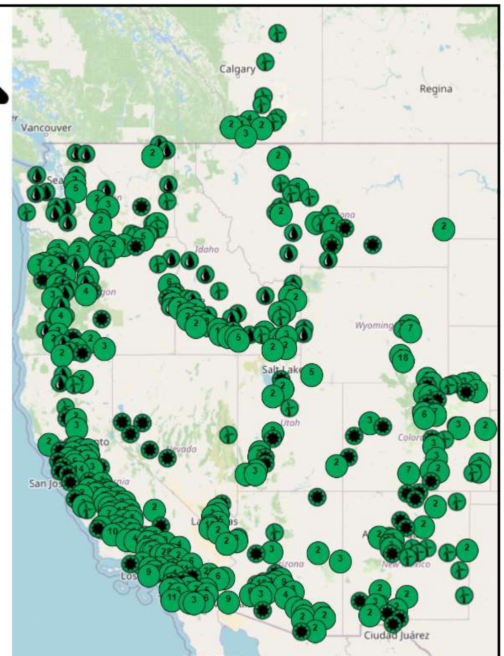
WECC-wide resources

Goal

- Represent market risk of renewable generation across the WECC (due to forecast error)

Status

- Modeled ~2,000 individual renewable resources
- Need to evaluate tradeoff of this assumption (run time vs impact)



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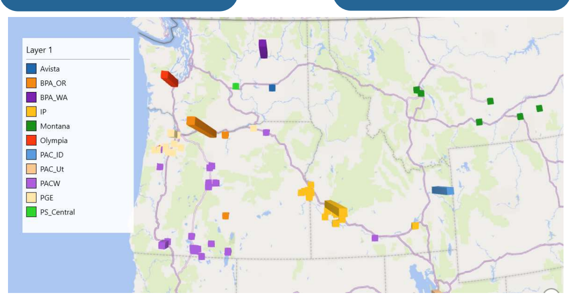
New In-Region Solar Shapes

Goal

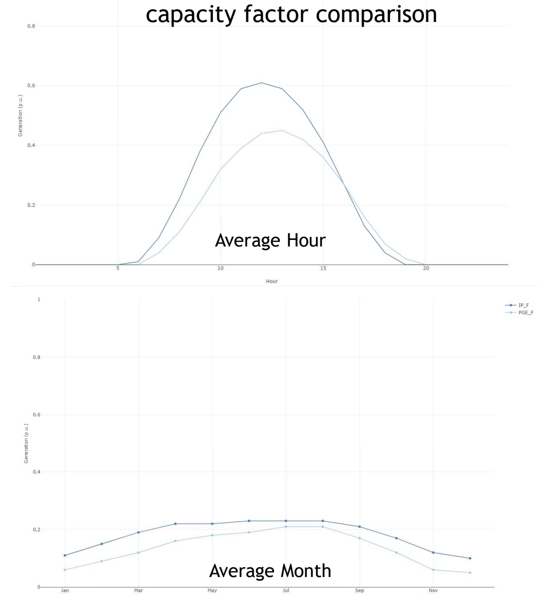
- Improve geographic representation of solar in the PNW

Status

- Created solar capacity factors by Balancing Authority



Example of Idaho Power and PGE solar capacity factor comparison



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Existing Hydro & Thermal System

Goal

- Improve representation of existing hydro and thermal utilization

Status

- Applied limitations on hydro reserve allocation by plant
- Incorporated thermal start up costs

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Interpreting Deficits from the Model

Goal

- Utilize true-up stage for reporting model deficits and calculating adequacy metrics

Status

- Resolved true-up issue

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U.S. Commitments Reminder

Spill operations in Lower Snake and Lower Columbia updated according to Appendix B of US Commitments

Based on follow-up conversations, reviewing and considering improvements we can make to representing these operations, specifically treatment of reserves

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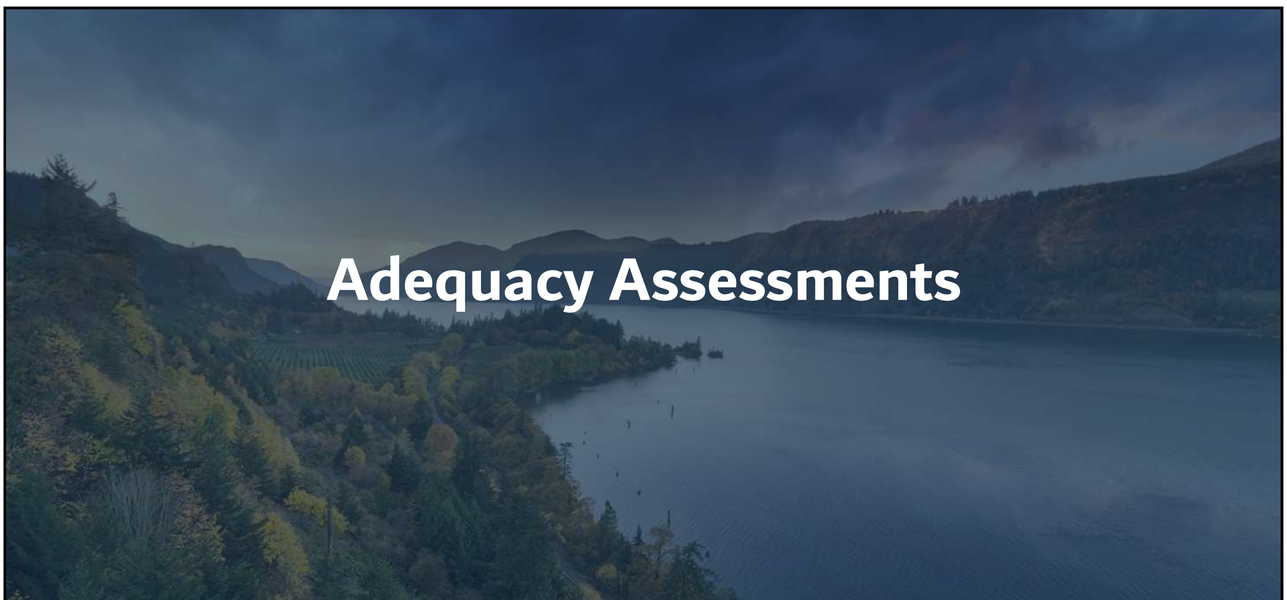

Adequacy Assessments

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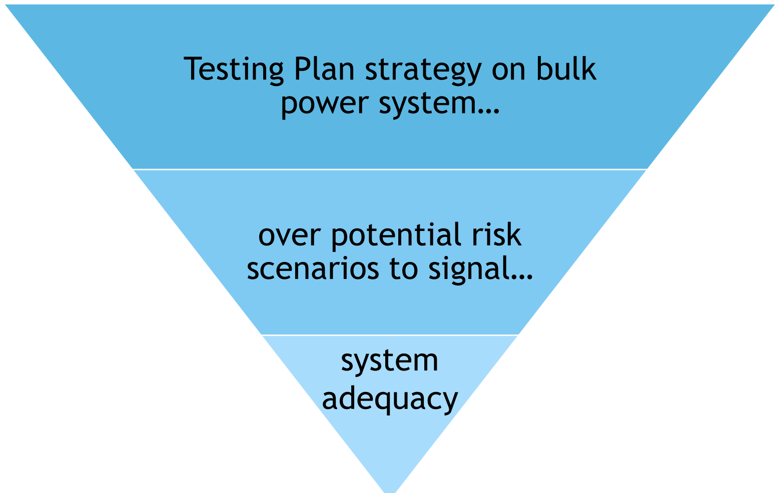
What Are Adequacy Assessments?



Objectives for the 2029 Adequacy Assessment

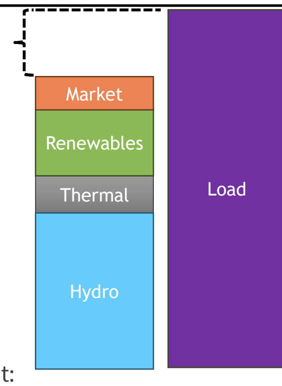
- The two primary <u>objectives</u> for this assessment are as follows:
  1. Provide the 2nd look of whether the 2021 Power Plan continues to provide appropriate direction to ensure an adequate system 5-years out
  2. Test utilization of new multi-metric approach for characterizing system adequacy

To facilitate achieving those objectives:

- **staff will share modeling results** relative to the new metrics
- **Staff is seeking member discussion** on what the results mean relative to the 2021 Power Plan strategy

Adequacy Approach

Model shortfall; no emergency resources are in the model



- Adequacy studies simulate the NW power system to meet NW load
- In each simulation, representing one year, a simulated model shortfall event occurs over a time period when load cannot be served by resources in the model
- However, a shortfall in the model **does not** necessitate an actual curtailment
  - Rather, it signals non-modeled emergency measures are necessary to avoid curtailment:

Type 1: Within utility control

- High operating cost resources not in utility's active portfolio
- High-priced market purchases over max import limits
- Load buy-back provisions
- Industry backup generators

Type 2: Extraordinary measures

- Official's call for conservation
- Reduce less essential public load (e.g., gov't buildings, streetlights, etc.)
- Utility emergency load reduction protocols
- Curtail F&W hydro operations

- Adequacy metrics evaluate shortfalls to inform risk of using emergency measures

The Metrics and Thresholds

Protection against frequent deficits

Protection against tail-end (extreme) deficits

LOLEV	Duration VaR 97.5	Peak VaR 97.5	Energy VaR 97.5
0.1 in summer 0.1 in winter + report annual	8-hour	1,200 MW + report NVaR	9,600 MW + report NVaR

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Out of Region Market Buildout Update

Initial adequacy results are informed by market fundamentals per outside the region market resources with buildout from AURORA

1. Resource buildout challenges (modified timeline and enhancement expectations)

2. Recommend draft buildout to inform adequacy assessment results

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Resource Buildout Challenges

- AURORA Issues completing buildout.
  - Currently working with Energy Exemplar debugging

- Possible draft market buildout could be improved but deemed reasonable by the RAAC for the assessment.

Overview of Input Assumption Change Status

Already Implemented Inputs
- Updated to 2023-2024 vintage out of region load forecast
- Updated gas prices to December 2023 Council Fuel Price forecast

Draft Input Information
- Updated new resource costs to reflect IRA provisions (mostly ITC/PTC changes)
- Updated zonal transfer to reflect updated limits for pricing run (not for buildout)
- Updated new resource information to include Long Duration Energy Storage (LDES)
- Per SAAC suggestion, updated timing on Proxy Clean resource availability from 2035 to 2030

Yet to be Implemented Updates (On Hold waiting for an AURORA fix)
- Existing resources (still 2022 update vintage)
- Any modification of IRA interpretation
- Additional planned increases in transmission capability

Solar, Solar Plus Storage, Battery, LDES and Pumped Storage Build Comparisons (*installed capacity in megawatts*)

WECC

Year	Draft 2024 Baseline	2022 Baseline	2021 Plan Baseline
2025	2,153	21,528	51,538
2030	14,355	42,206	89,838
2035	15,355	45,141	100,357
2040	17,355	56,494	135,054
2045	19,200	75,890	147,554

Year	Draft 2024 Baseline	2022 Baseline	2021 Plan Baseline
2025	27,813	13,634	6,004
2030	35,875	13,940	6,004
2035	46,903	13,965	6,004
2040	104,016	14,861	6,004
2045	129,751	18,390	6,055

Year	Draft 2024 Baseline	2022 Baseline	2021 Plan Baseline
2025	0	23,386	46,600
2030	2,261	60,503	86,600
2035	5,301	60,503	145,500
2040	20,156	63,429	179,800
2045	39,906	63,429	198,000

Year	Draft 2024 Baseline	2022 Baseline	2021 Plan Baseline
2025	0	0	0
2030	1,300	0	4,900
2035	1,300	2,200	5,650
2040	2,840	2,200	6,050
2045	3,840	2,200	9,690

Year	Draft 2024 Baseline
2025	0
2030	5,913
2035	17,943
2040	34,321
2045	46,214

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Wind, Gas, Offshore Wind and Proxy Clean Build Comparisons (*installed capacity in megawatts*)

WECC

Year	Draft 2024 Baseline	2022 Baseline	2021 Plan Baseline
2025	2,211	12,155	16,775
2030	16,031	18,634	35,175
2035	16,031	27,906	37,063
2040	30,222	38,221	43,657
2045	36,887	69,769	51,481

Year	Draft 2024 Baseline	2022 Baseline	2021 Plan Baseline
2025	0	0	0
2030	0	0	6,463
2035	0	0	7,663
2040	10,000	0	10,000
2045	10,000	0	10,000

Year	Draft 2024 Baseline	2022 Baseline	2021 Plan Baseline
2025	4,523	7,305	11,351
2030	11,403	14,332	14,873
2035	14,185	14,806	16,058
2040	14,614	15,235	16,532
2045	16,330	15,235	16,532

Year	Draft 2024 Baseline	2022 Baseline	2021 Plan Baseline
2025	0	0	0
2030	684	1,368	0
2035	684	3,420	0
2040	684	3,420	0
2045	4,104	7,524	0

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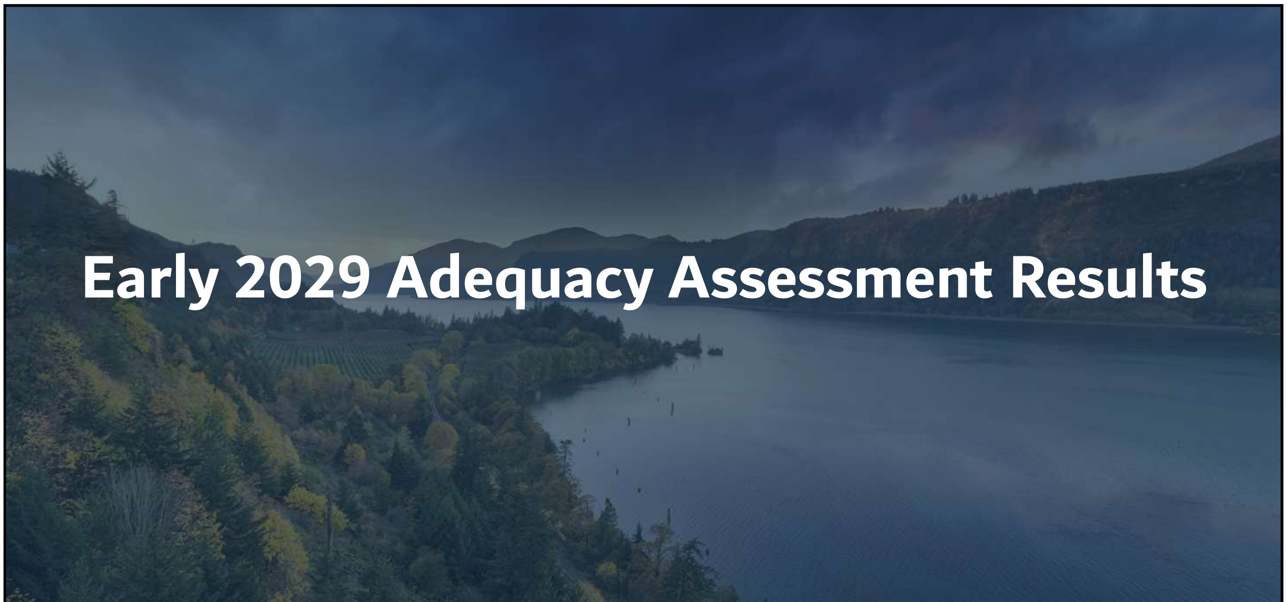
Draft Buildout in 2029 Outside the Region

- Canada
  - Other than Site C in BC, all builds are in Alberta
  - 6 GW of solar, 15.6 GW of wind, 3.4 GW of natural gas
- California
  - 17 GW of 4-hour storage and 1.8 GW of LDES
- Desert Southwest (NV, AZ, NM)
  - 450 MW of solar, 470 MW of natural gas, 5.7 GW of 4-hour storage, 900 MW of LDES
- Baja
  - 2.3 GW of natural gas, 1.5 GW of 4-hour storage, 200 MW LDES
- Mountain West (UT, CO, WY)
  - 1.1 GW of solar, 2.4 GW of gas, 6.9 GW of storage

Observations

- More storage resources than energy resources added in early years.
  - Further modifications to IRA implementation may cause larger VER build early but unclear
- Some coal to gas plant conversions seems to be deferring the needs for builds to maintain planning reserve margins and reducing early need for new gas build
- The buildout will likely change for the market study, but likely to be larger outside the region. A larger buildout would likely only improve adequacy results, so we recommend moving forward with this buildout for the 2029 assessment to stick to the timeline.



Early 2029 Adequacy Assessment Results

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2021 Power Plan Resource Strategy reminder

Existing System: Increase Reserves

To reduce regional needs and support integration of renewables, the region needs to double the assumed reserves. This can most cost-effectively be done through more conservative operation of the existing system (both thermal and hydro units).

Renewables: At least 3,500 MW by 2027

Renewables are recommended due to their low costs, interruptibility, and carbon reduction benefits. Long-term build out will impact the transmission system and should be done mindful of the cumulative impacts of the new resources.

Energy Efficiency: 750-1,000 aMW by 2027

Significantly less acquisition than prior plan due being less cost-competitive, a slower build resource, not inherently dispatchable, and sensitive to market prices. Efficiency that supports system flexibility is most valuable.

Demand Response: Low-Cost Capacity

Highest value products are those that can be regularly deployed at a low-cost and with minimal to no impact on customer. The Council identified demand voltage regulation and time of use rates as two products, estimating 720 MW of potential.

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The 2029 Resource Strategy – the Reference

- Our goal for this assessment was to assume the same trajectory of the strategy used in the reference case for the 2027 Adequacy Assessment

Portfolio	2029 Adequacy Assessment	2027 Adequacy Assessment
Renewables	6,600 MW	5,900 MW
EE	1,300 aMW	1,000 aMW
DR	720 MW	720 MW
Reserves	6,000 MW	6,000 MW

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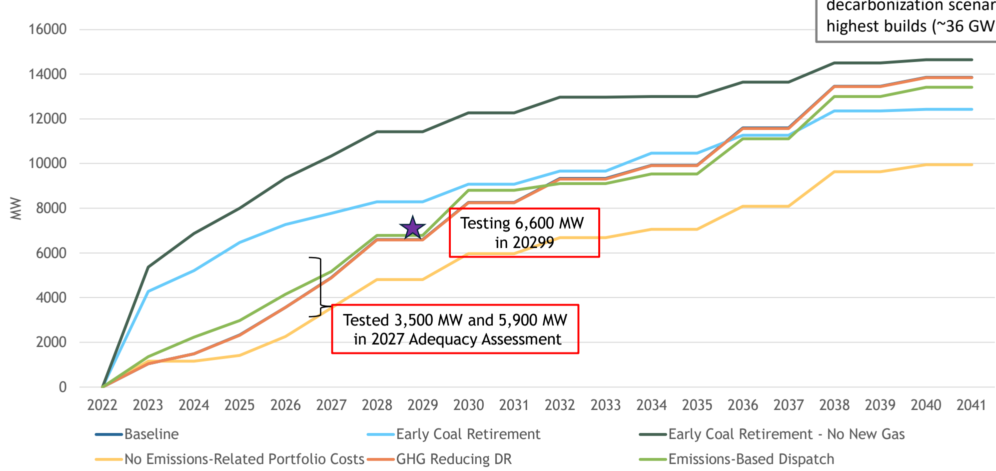
2021 Plan Buildout Trajectories

Not shown here: Early coal retirement, with limits on gas, and the deep decarbonization scenario resulted in the highest builds (~36 GW in 2041)



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Other System Changes Across all Studies

- Announced changes to several thermal plants not retiring (~1,480 MW)
  - Valmy 1 & 2 (138.6 & 134 MW)
  - Bridger 1 & 2 (~1,200 MW)
  - Currently modeled same as before → possible new modeling as gas conversion when new information will be available
- Expanded transmission capacity
  - 12,700 MW of added transmission capacity
  - Only 1,000 MW in region (B2H)

Planned Transmission	New Capacity (MW)	Path	Online Date	GENESYS Buses	Existing Today (MW)	New 2029 capacity (MW)
Ten West Link	3,200	SCE to APS	2024	So_Cal to Arizona	1,400	4,600
SunZia	3,000	PNM to APS	2026	New Mexico to Arizona	1,700	4,700
Transwest Express	3,000	WAPA Wyoming to PACE UT	2027	wapa RM to PAC_UT	650	3,650
	1,500	PACE UT to Nev South	2027	PAC_Ut to Neveda South	250	1,750
SWIP North	1,000	IP to North Nevada	2027	IP to north Nevada	350 | 185	1,350|1,185
B2H	1,000	IP to BPA_OR	2026	IP to BPA_OR	2,000	3,000

Potential Scenarios

- Reference
- Higher data center load (in region)

Developed, simulated, analyzing, discussing today

- In-region gas supply limitations
- Earlier availability of transmission (reconductoring in region)
- Delayed availability of transmission and emerging tech in WECC
- Emission pricing

Pushed to 9th Plan

- Alternative Trajectories within Resource Strategies

In progress

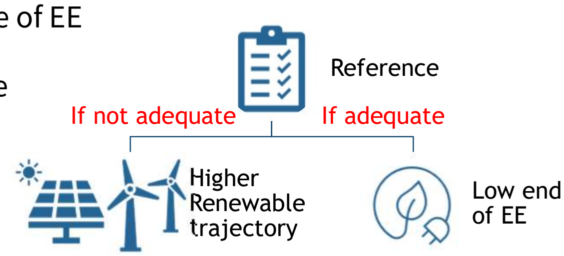
Incremental Load Differences in 2029

	EE Savings aMW	EV Loads aMW	Data Center Loads aMW
2029 Reference scenario	1,300	1,048	2,386
2029 High Data Center scenario	1,300	1,048	3,976

Consideration of Alternative Trajectories within the Resource Strategy

Two alternative trajectories depending on results of the Reference study

- Testing the low end of the cost-effective range of EE
  - ~1,000 aMW of EE by 2029, instead of the 1,300 aMW tested in the reference case



- Testing ~12,000 MW of renewables in 2029 instead of 6,600 MW
  - Planned renewable buildout for 2029 is 11,907 MW (within 2021 Power Plan range)

Draft Results

	Metric	Threshold	Reference 4 event-years 2.2% LOLP Adequate	High Data Center 24 event-years 13.3% LOLP Non-Adequate
Frequency	Winter LOLEV	0.1	0.022	1.294
	Summer LOLEV	0.1	0.017	0.3
Duration	Duration VaR 97.5	8	0	20.6
Magnitude	Peak VaR 97.5	1,200	0	3,076
	Energy VaR 97.5	9,600	0	196,324
Reported metrics (non-binding)	Annual LOLEV	0.1	0.05	1.644
	Peak NVaR 97.5	~3%*	0	9%
	Energy NVaR 97.5	~0.0052%*	0	0.09%

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* Approximate

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LOLEV

Total events:

Metric	Months	Threshold	Reference 9 events	High Data Center 296 events
Winter LOLEV	Dec-Feb	0.1	0.022	1.294
Summer LOLEV	Jun-Aug	0.1	0.017	0.3
Annual LOLEV	All	0.1	0.05	1.644
Spring LOLEV	Mar-May	0.1?	0.011	0.039
Fall LOLEV	Sep-Nov	0.1?	0.000	0.011

Food for thought:
as discussed, relying on winter and summer without an annual perspective overlooks potential spring and fall deficits.

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Quick Reminder on Climate Studies

Study Simulations = 180 years → 60 for each climate scenario → 10 water-load years * 6 regional wind profiles

In other words: 10 water-load combinations that repeat 6 times, once for each different regional wind profile

Scenario	Winter Hydro Generation	Summer Hydro Generation	Winter HDDs	Summer CDDs
CanESM (A)		*low*	*low*	*high*
CCSM (C)	*high*	*low*		
CNRM (G)	*low*	*high*	*high*	*low*

(Red circle) High loads and low water conditions might cause adequacy events

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Recall that a VaR 97.5 value of 0 does not mean no shortfalls;
rather it is a probabilistic representation signaling the shortfall risk 39 out of 40 years

Events in Reference Scenario

Maximum event duration and peak

event_index	Scenario	scenario_event _index	Month	Day	event_ duration (hour)	event_max (MW)	event_sum (MWh)
1	A_40	1	7	13	1	525	525
2	C_31	1	3	30	1	46	46
3	G_5	1	7	18	1	27	27
4	G_33	1	1	17	4	960	3,368
5	G_33	2	1	18	1	589	589
6	G_33	3	1	19	1	844	844
7	G_33	4	1	19	1	899	899
8	G_33	5	5	27	1	359	359
9	G_33	6	7	23	1	222	222

Maximum annual energy 6,281 MWh

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Main challenge is one simulation:
climate scenario G_33

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Major Shortfall Events in High DC Scenario

	event_index	Scenario	scenario_ event_index	Month	Day	event_ duration (hour)	event_ max (MW)	event_ sum (MWh)	Max energy rank
Longest Duration Events	286	G_53	7	1	16	119	1,096	105,349	1st
	265	G_43	3	1	16	48	1,096	46,151	
	242	G_33	4	1	16	45	1,096	41,667	
Highest Peak Events	191	A_56	14	12	27	19	8,863	61,763	2nd
	192	A_56	15	12	28	9	8,407	38,898	
	189	A_56	12	12	26	17	6,688	61,604	3rd

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Events in High Data Center

Scenario A:
More events (226),
greater peaks and energy

Scenario G:
Longest events,
single greatest energy deficit

Scenario	Event frequency	Event Duration		Event Peak		Event Energy	
		Average	Max	Average	Max	Average	Max
A_16	25	6.4	18	1,796	6,117	10,414	51,440
A_26	51	4.0	16	1,193	4,392	5,017	32,118
A_29	1	1.0	1	38	38	38	38
A_31	1	1.0	1	93	93	93	93
A_36	45	3.9	22	1,576	6,440	6,147	51,200
A_37	1	1.0	1	455	455	455	455
A_48	2	1.0	1	496	788	496	788
A_56	48	4.9	19	2,164	8,863	9,198	61,763
A_6	51	5.0	22	1,234	5,500	5,787	38,044
A_60	1	1.0	1	454	454	454	454
C_12	1	1.0	1	1,217	1,217	1,217	1,217
C_19	1	1.0	1	199	199	199	199
C_34	2	1.0	1	289	296	289	296
C_56	4	1.5	3	270	537	537	1,606
G_16	1	2.0	2	551	551	1,101	1,101
G_33	23	5.8	45	730	1,096	4,544	41,667
G_40	1	2.0	2	436	436	804	804
G_43	14	9.4	48	826	1,096	7,312	46,151
G_48	2	1.5	2	1,209	1,621	1,417	1,621
G_49	1	1.0	1	331	331	331	331
G_53	15	10.5	119	698	1,096	8,702	105,349
G_55	1	1.0	1	34	34	34	34
G_60	1	1.0	1	351	351	351	351
G_8	3	1.0	1	200	485	200	485

G challenging years - 33, 43, and 53

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A challenging years - 16, 36 , and 56 (6, 26)
6th climate year - low water throughout the year

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High Data Center Monthly Events

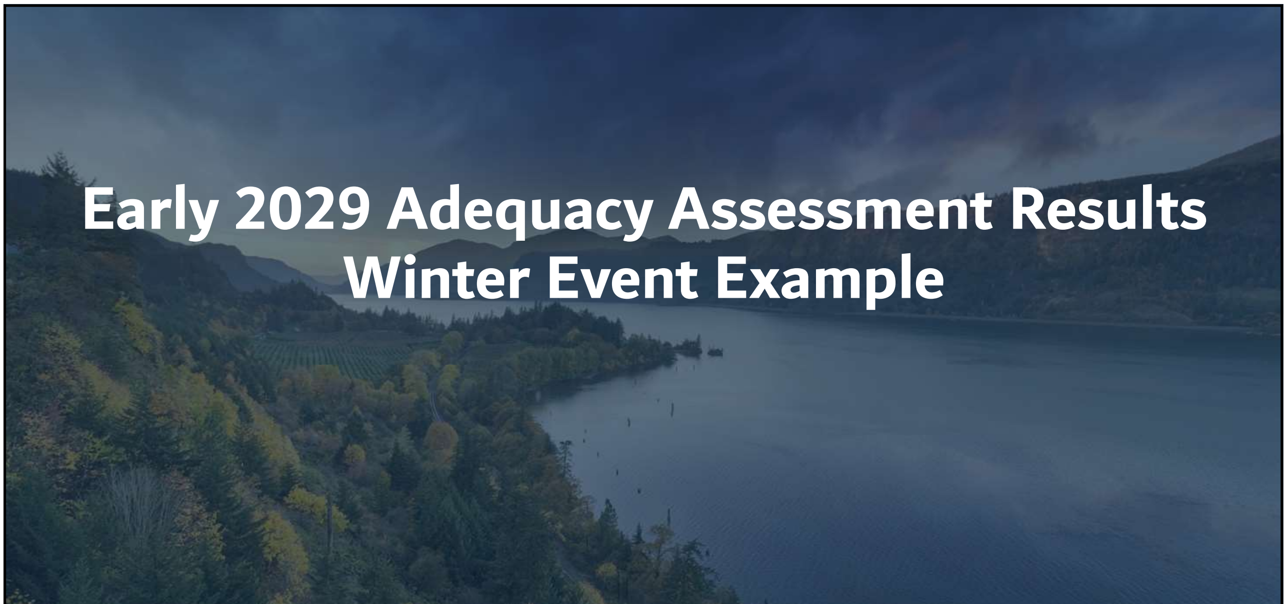
More summer and winter challenges

Scenario	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Dec
A_16	13	1						5		6
A_26	11	8				1		8		23
A_29				1						
A_31					1					
A_36	13	12					1	12		7
A_37								1		
A_48								1	1	
A_56	22	6			1			4		15
A_6	16	11						8		16
A_60							1			
C_12			1							
C_19					1					
C_34						1	1			
C_56						4				
G_16						1				
G_33	23									
G_40							1			
G_43	14									
G_48	1							1		
G_49									1	
G_53	15									
G_55							1			
G_60								1		
G_8			1		1			1		

Discussion Points

- Assuming the reference case is the trajectory:
  - Another two years of energy efficiency and renewables, not retiring thermal plants, and expanded transmission capacity offset the adequacy challenge of increased loads of anticipated data centers and EV electrification
- If the higher data center case is more likely:
  - The ~1,600 MW of increased load associated with **additional** data center load growth above the reference case causes adequacy challenges
  - The plan is to study the impact and resource strategy associated with increased load uncertainty in the upcoming Power Plan.

Early 2029 Adequacy Assessment Results Winter Event Example



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2029 Adequacy Assessment Reference Case – Scenario 33 Simulated Shortfalls in January

Simulated shortfalls in the evening, during a period of very high peak loads

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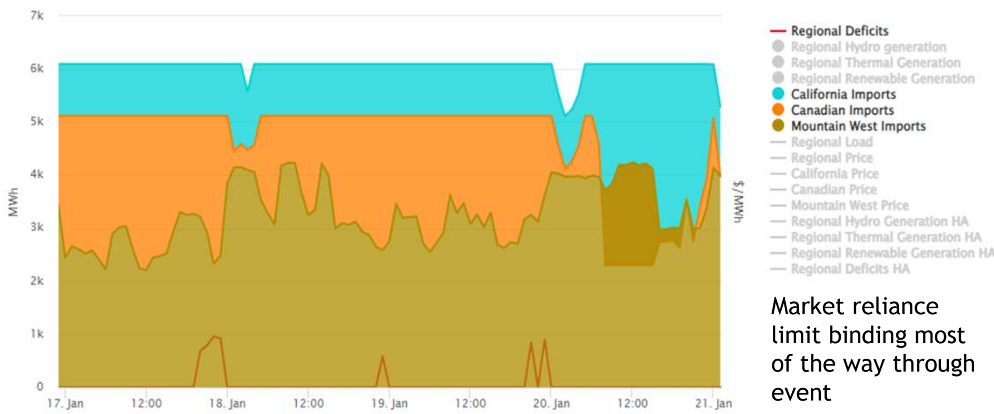
2029 Adequacy Assessment Reference Case – Scenario 33 Load Resource Balance

Multiple days with high peak loads in morning and evening. Why are the simulated shortfalls during the lower evening peak?

2029 Adequacy Assessment Reference Case – Scenario 33 Market Reliance



Market reliance limit binding most of the way through event

2029 Adequacy Assessment Reference Case – Scenario 33 Market Reliance

Market prices indicate more market available during the event in SW and Mountain West

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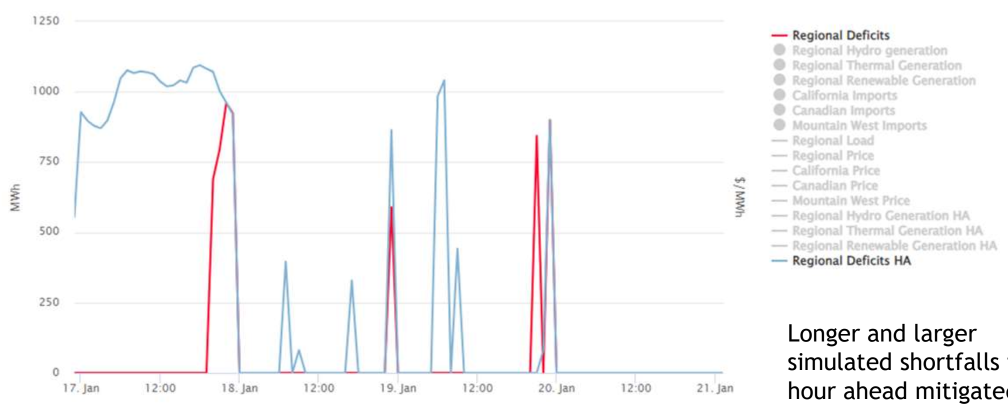
2029 Adequacy Assessment Reference Case – Scenario 33 Simulated Shortfalls



Longer and larger simulated shortfalls in hour ahead mitigated by thermal plant reserves

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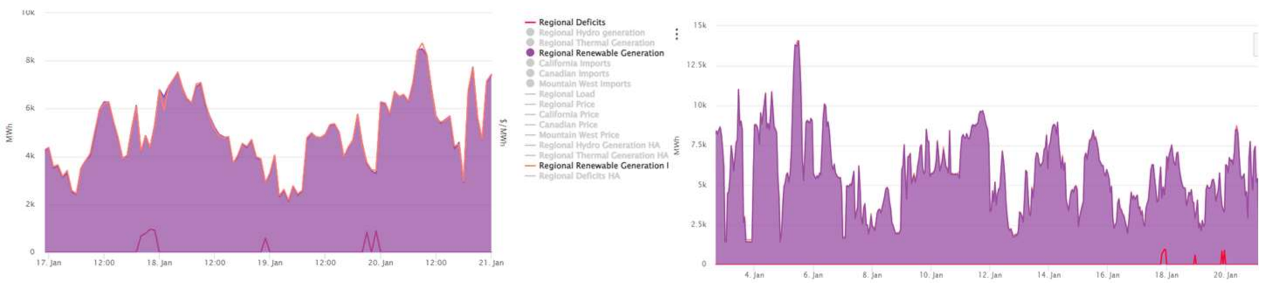
2029 Adequacy Assessment Reference Case – Scenario 33 Renewable Generation



Renewable generation is low during the event but also very low during some of the days leading up to the event.

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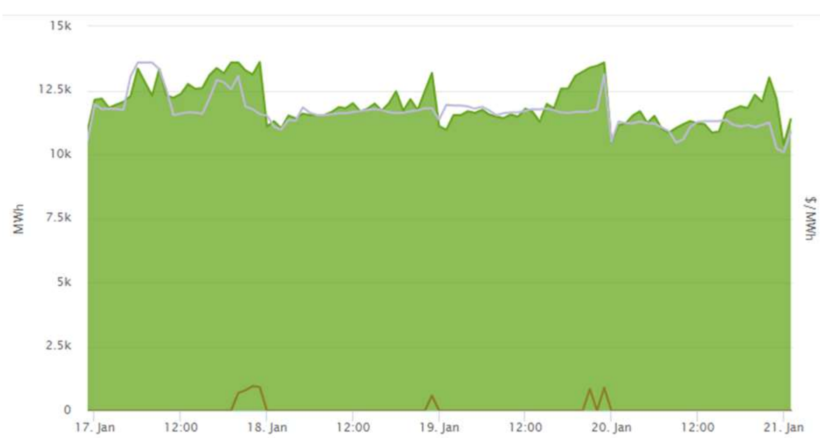
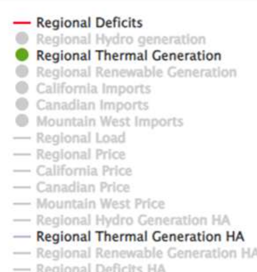
2029 Adequacy Assessment Reference Case – Scenario 33 Thermal Generation





Thermal generation providing significant up reserves

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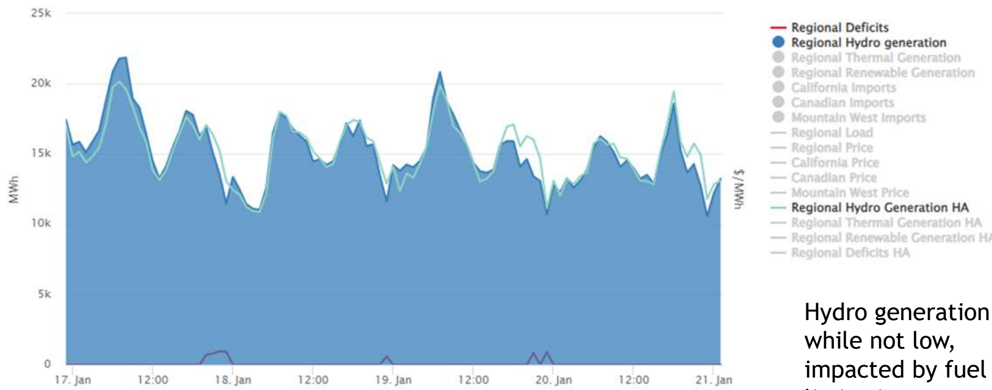
2029 Adequacy Assessment Reference Case – Scenario 33 Hydro Generation



Hydro generation, while not low, impacted by fuel limitations throughout event

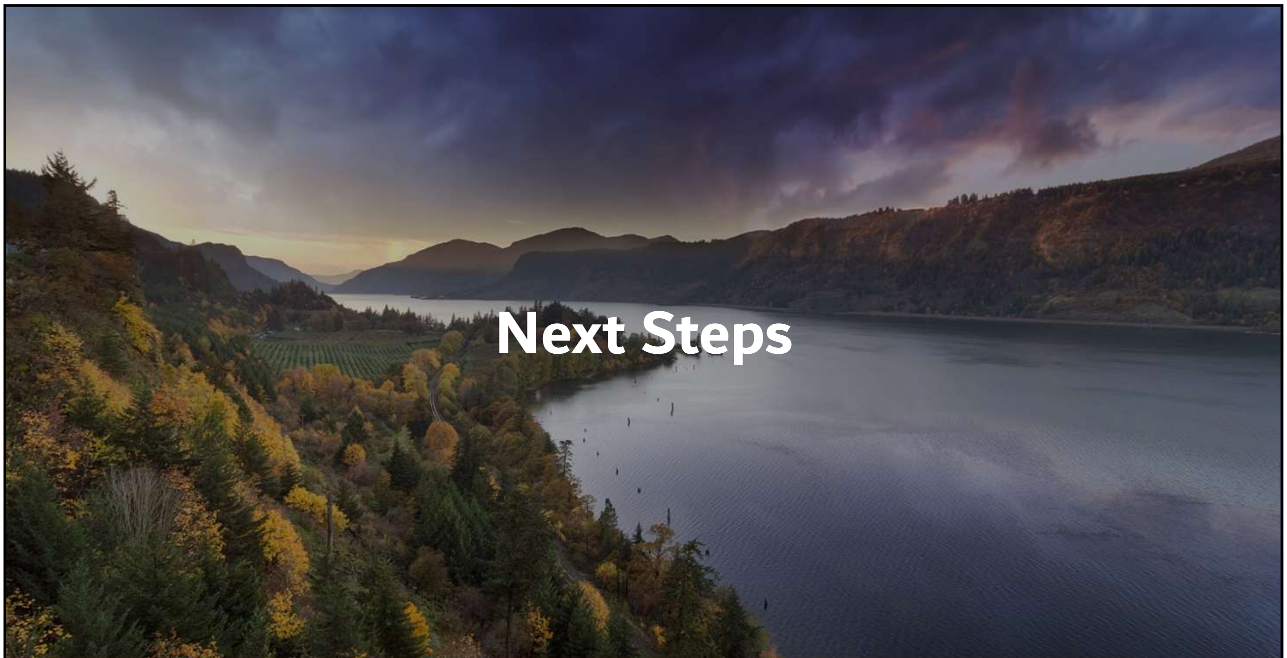
2029 Adequacy Assessment Renewable Generation Risk During High Load Events

Reference Case

- Scenario 33 had an adequacy issue but low wind generation
- Scenarios 3, 13, 23, 43, 53 all had the same load and hydro but different renewable generation and no adequacy issues.

Higher DC Load Case

- G Scenario 33, 43 and 53 had an adequacy issues
- Scenarios 3, 13, 23 all had the same load and hydro but different renewable generation and no adequacy issues.



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2029 Adequacy Assessment Timeline

Kickoff
- April 2, 2024
- Interim Multi-metric thresholds
- Scenarios discussion

Technical setup
- April 4, 2024
- Region Loads
- Existing resources
- Review of new hydro operation changes
- GENESYS enhancements
- Scenario discussion

Setup results
- Early May
- Report market scenarios and results
- Preliminary exploration of new hydro operations
- Preliminary exploration of enhancements and assumptions

Interim adequacy results
- May 30, 2024
- Discuss interim adequacy results

Final Adequacy Report
- Late June
- Discuss final adequacy results
- Evaluate multi-metric framework

Council Meeting Update
- July 9-10, 2024
- Report on Assessment
- Discuss recommendation for final multi-metric adequacy thresholds

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Next Steps

- Run and analyze low end of EE in Alternative Trajectories
- Prepare final 2029 adequacy assessment report (Late June RAAC)
  - Including evaluation of multi-metric framework
- Present final 2029 adequacy assessment in July Council Meeting

Questions on Draft Results?

	Metric	Threshold	Reference (4 event-years, 2.2% LOLP — Adequate)	High Data Center (24 event-years, 13.3% LOLP — Non-Adequate)
Frequency	Winter LOLEV	0.1	0.022	1.294
	Summer LOLEV	0.1	0.017	0.3
Duration	Duration VaR 97.5	8	0	20.6
Magnitude	Peak VaR 97.5	1,200	0	3,076
	Energy VaR 97.5	9,600	0	196,324
Reported metrics (non-binding)	Annual LOLEV	0.1	0.05	1.644
	Peak NVaR 97.5	~3%*	0	9%
	Energy NVaR 97.5	~0.0052%*	0	0.09%

* Approximate

Questions?

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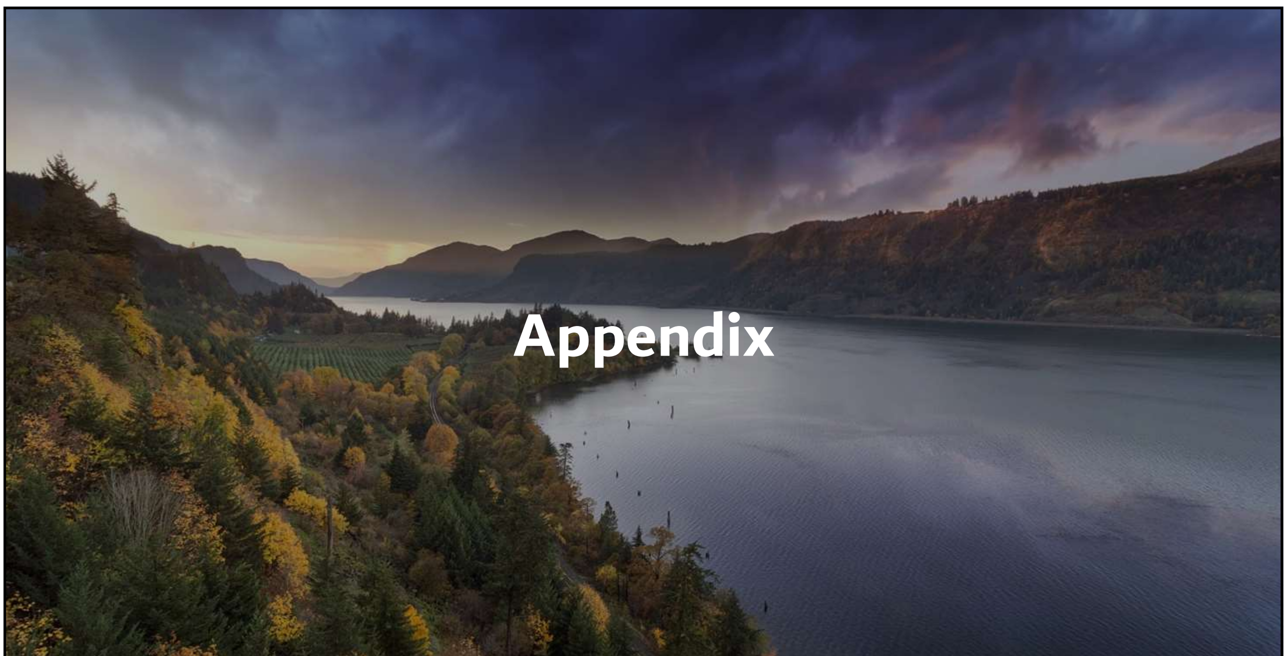

Appendix

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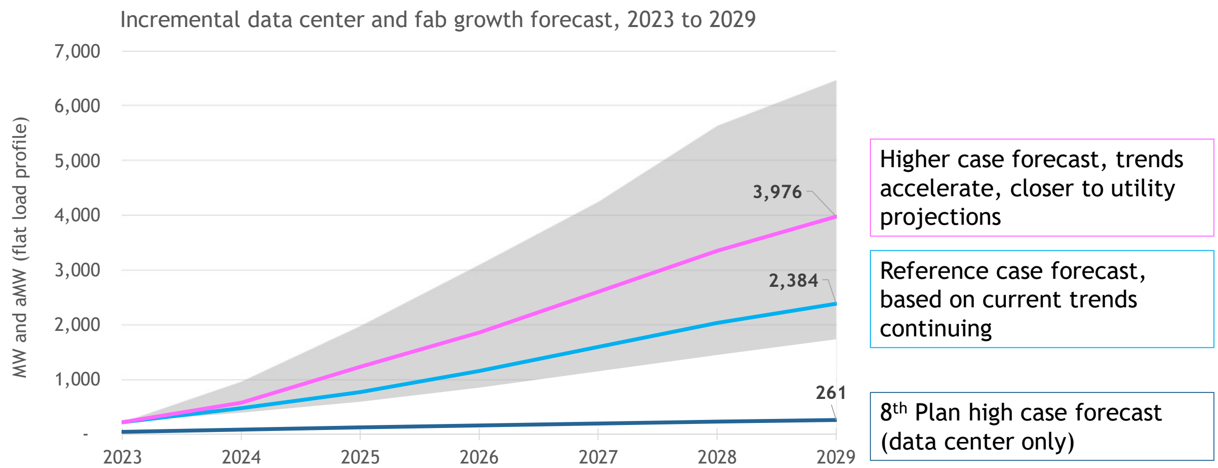
Data center & chip fab forecasts



Duration (Hours)

Simulation Max Duration Hours:

Ref	High DC
4	119
1	48
1	45
1	22
	22
	19
	18
	16
	3
	2
	2
	2
	1
	1
	1
	1
	1
	1
	1
	1
	1
	1
	1
	1

Metric	Threshold	Reference	High Data Center
Duration VaR 97.5	8	0	20.6
Max		4	119

Peak (MW)

Simulation Max Peak MW:

Ref	High DC
960	8,863
525	6,440
46	6,117
27	5,500
	4,392
	1,621
	1,217
	1,096
	1,096
	1,096
	788
	551
	537
	485
	455
	454
	436
	351
	331
	296
	199
	93
	38
	34

Metric	Threshold	Reference	High Data Center
Peak VaR 97.5	1,200	0	3,076
Max		960	8,863

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Energy (MWh)

Simulation Max Energy MWh:

Ref	High DC
6,281	441,491
525	295,138
46	276,632
27	260,354
	255,857
	130,525
	104,506
	102,367
	2,835
	2,149
	1,217
	1,101
	992
	804
	599
	578
	455
	454
	351
	331
	199
	93
	38
	34

Metric	Threshold	Reference	High Data Center
Energy VaR 97.5	9,600	0	196,324
Max		6,281	441,491

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