Draft 2024 Market Study Results

System Analysis Advisory Committee

July 31, 2024

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Northwest Power and Conservation Council

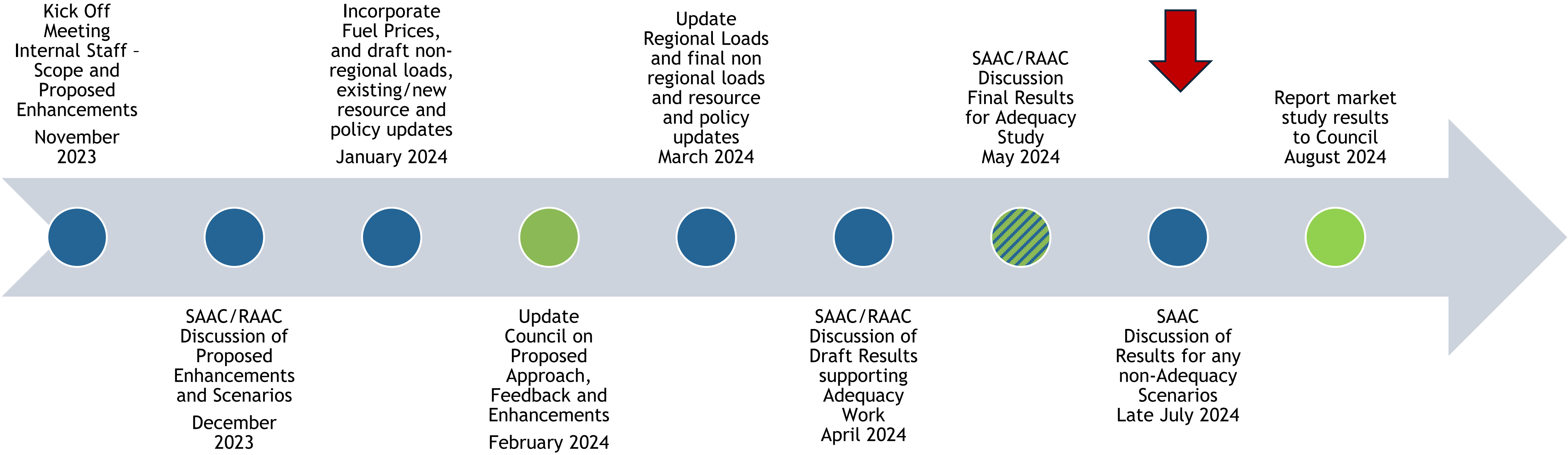
Overview

- Process Review and Timeline
- Review of Inputs for Buildout
- Discussion of Buildout Results
- Review Market Price and Avoided Emissions Rate Methodology

Process Review and Timeline

Annual Assessment Timeline

Updated Proposed Timeline for Market Study



Review: Technical Challenges Required Using Draft Information

Final adequacy results were informed by market fundamentals per outside the region market resources with initial buildout from AURORA

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

2. Draft buildout to inform final adequacy assessment results

Review of Inputs for Buildout

Assumptions for Capital Expansion in AURORA, review of the Council setup

Review: Council AURORA Setup (2021 Power Plan and subsequent studies)

Changes from AURORA default setup

- Ramp in operating pool planning reserve margin (PRM) requirement in first three years
- Use Climate Change inputs for region (temperature, precipitation and wind)
  - Use one climate change hydro dataset for buildout with northwest PRM informed by multiple datasets
  - For price forecast look at all three hydro datasets to get price and avoided emissions rate range.
- Dynamic Peak Credit of 120 hours for variable energy resources
- Limits on gas builds throughout the WECC and onshore wind in CA
- State, Municipal, Local and Utility Policies and Goals are met on a WECC-wide basis
  - RPS and clean resources have negative bid adder to reflect foregone cost of lost generation in case of curtailment
  - Emissions pricing
- Hydro dispatch in NW limited by daily max and min and monthly energy limits informed by GENESYS
- Use Mixed Integer Programming setup to co-optimize between energy and reserves throughout the WECC

Resource Buildout Challenges

Since we last met…

- AURORA Issues completing buildout were resolved.
- Due to timing, most enhancements/data updates not implemented will be pushed until next study/plan

Implemented in 2024 Study	Future Studies
Updated to new version of AURORA (15.0.1008)	Hydro shaping by zone
Add long duration storage resources	Zone alignment in AURORA and GENESYS/SDDP
Update out of region loads	Further storage modeling improvement
Update of policies (IRA, CCA, etc.)	
Update existing generation and transmission	
Update fuel prices	

Update of Out of Region Loads

- Updates are based on planning documents (like IRPs) and historical BA load datasets (EIA 930 and FERC 714)
  - The forecast are mostly annual energy (aMW) and maxes (MW) with hourly shaping from Aurora
- California loads updated to 2022 CEC IEPR Update dataset (from early 2023)
  - Hourly data are used for California IOUs and LADWP
- NW loads for this study (also hourly) were developed as part of the Power Plan

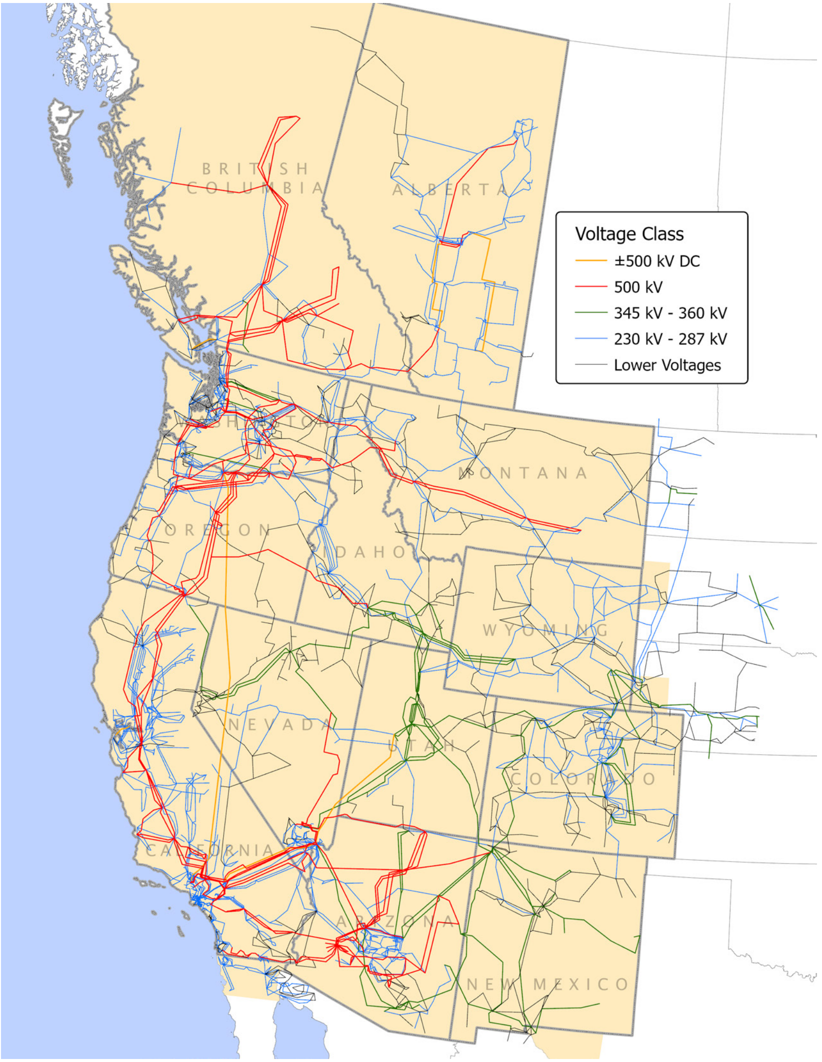
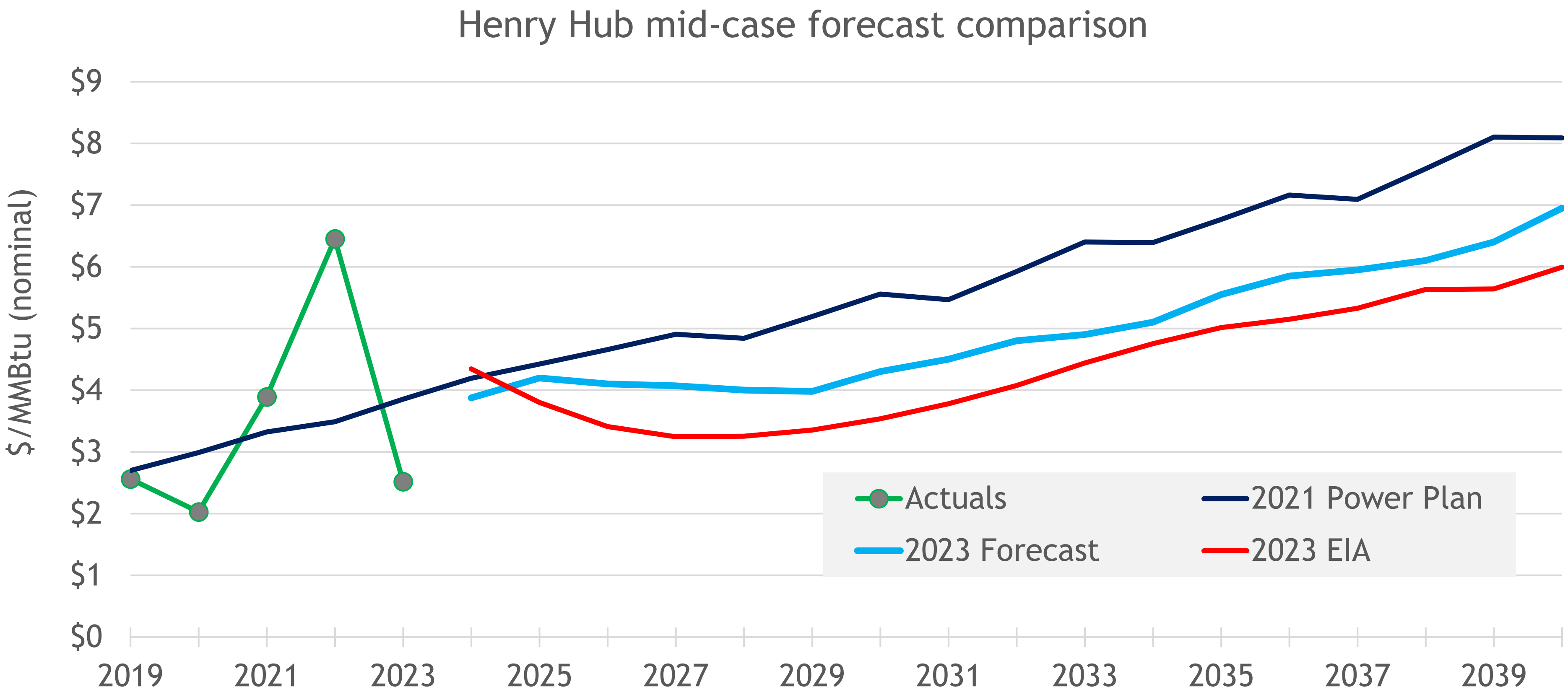
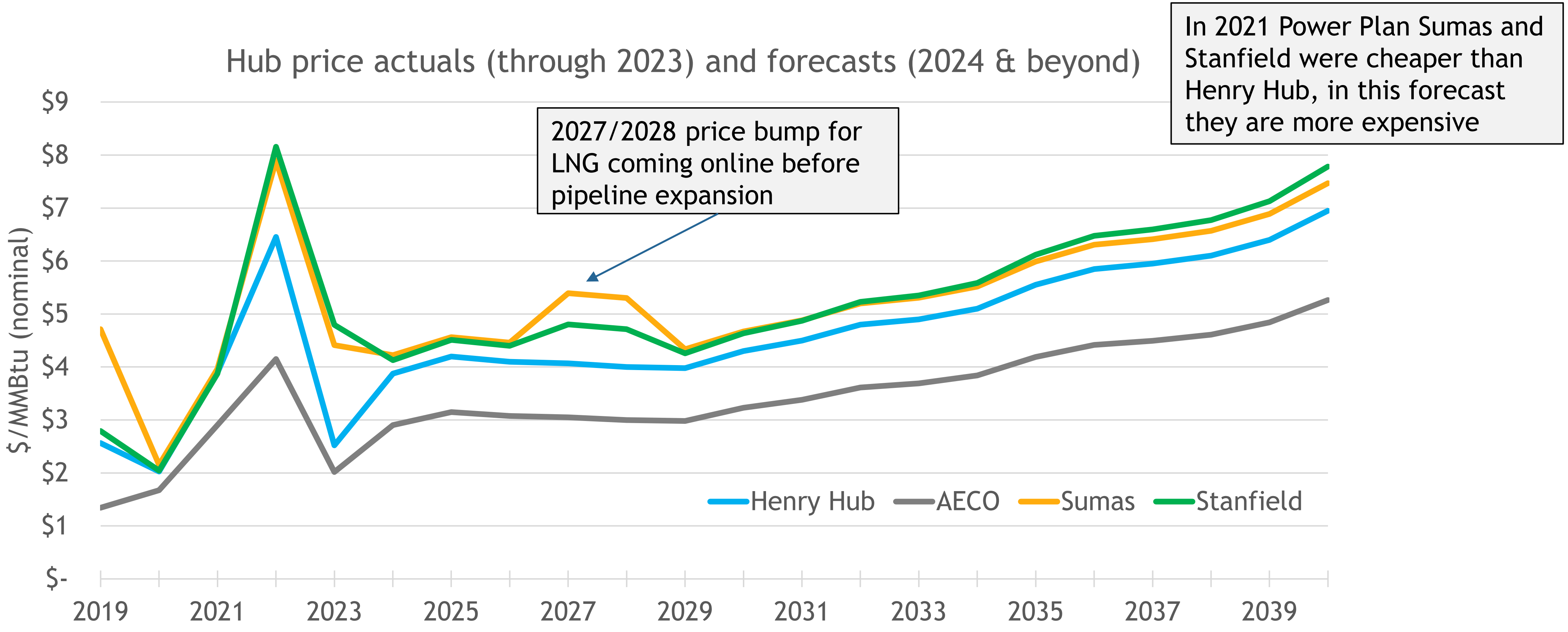


Image from WECC State of the Interconnection

Henry Hub Mid-Case Price Forecast



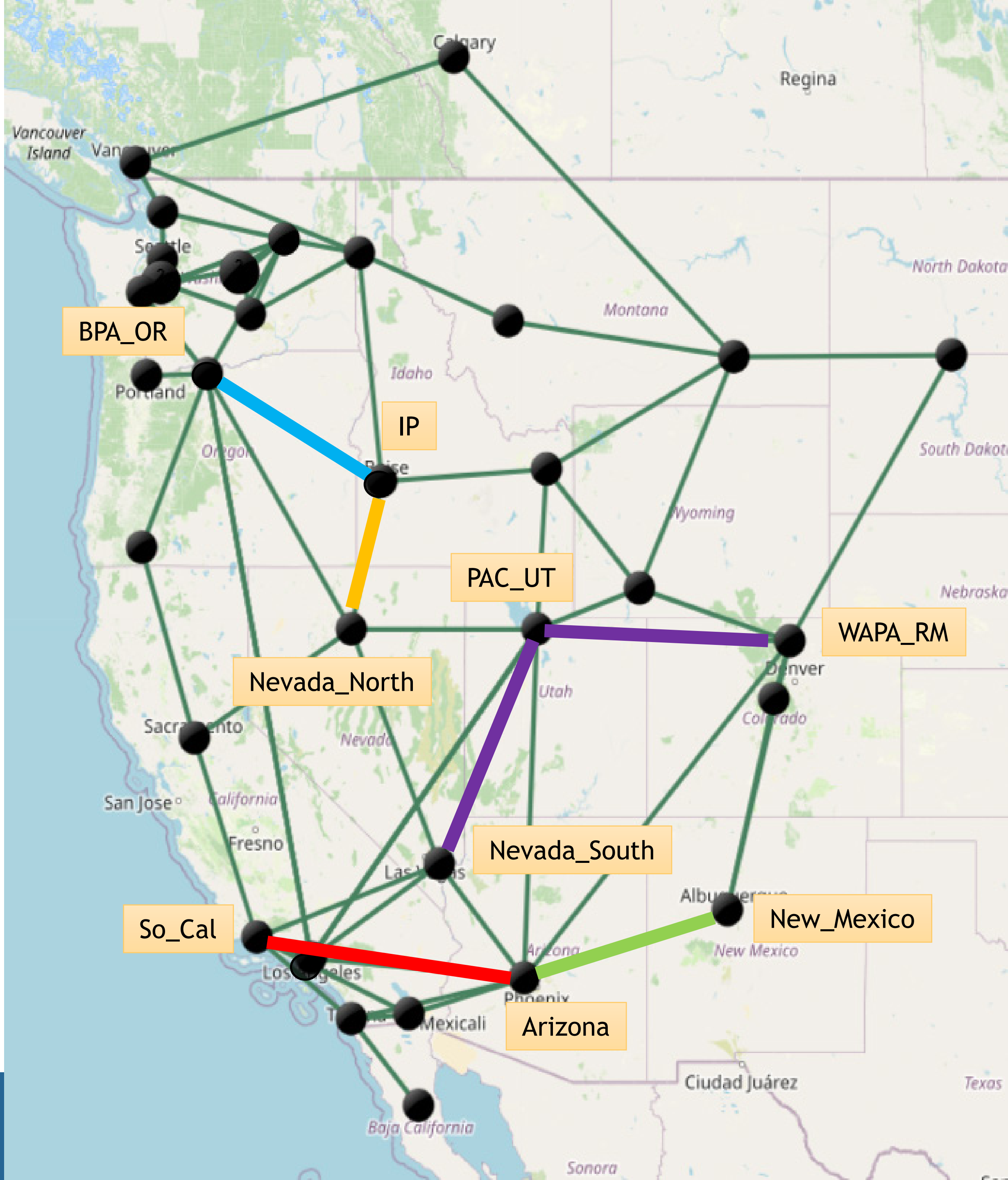
2023 Mid-Case forecast for select Northwest hubs likely influencing Mid-C Pricing



Other Northwest hubs not shown for graphical clarity. The forecast for all hubs is available online.

New Transmission

Planned Transmission	New Capacity (MW)	Path	Online Date	GENESYS Buses	Existing Today (MW)	New 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



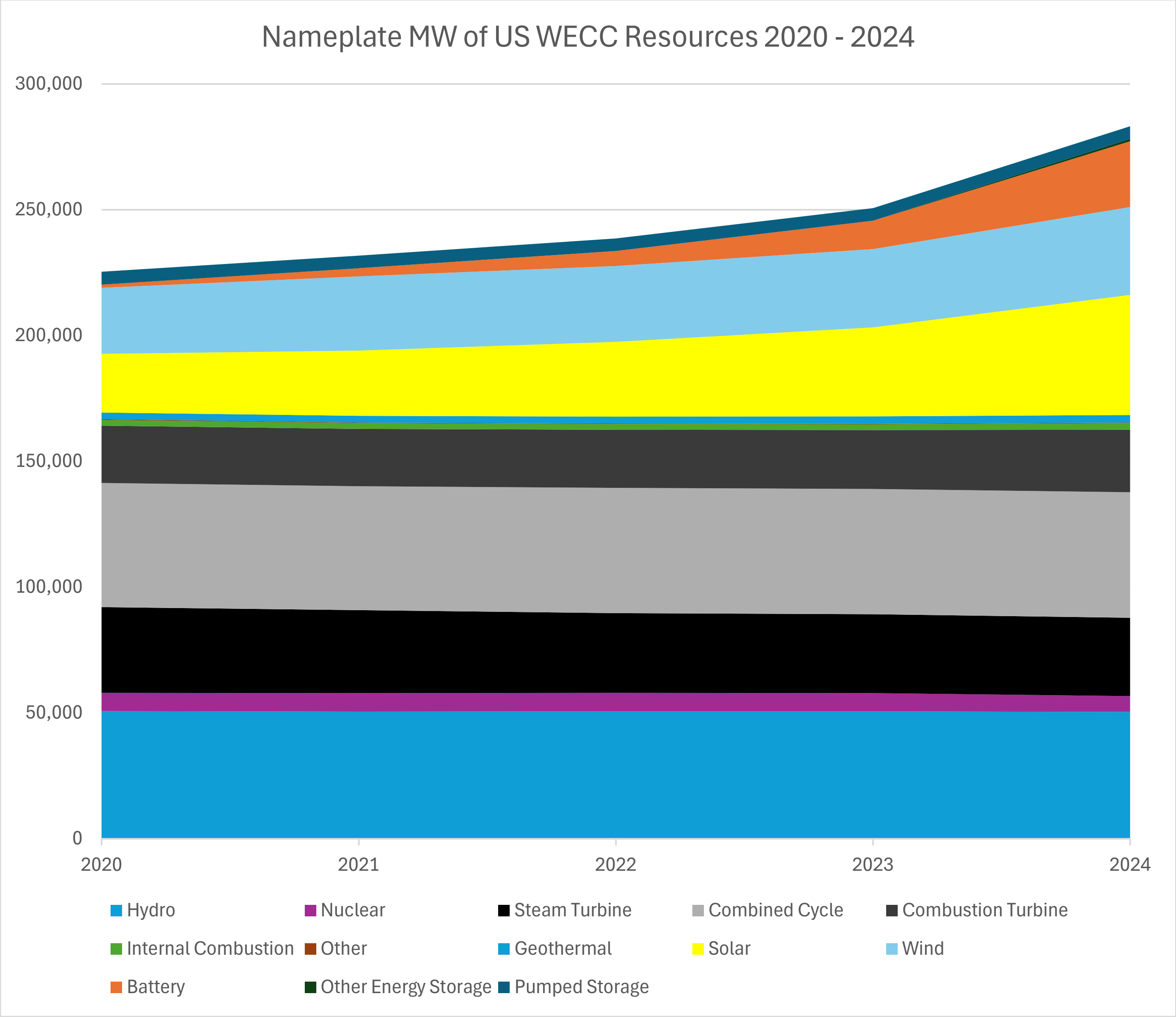
Existing Resources Update

Between 2020 and 2024, the following resource changes have occurred throughout the WECC:

Renewables:
Increase of 24.3 GW of solar, 8.6 GW of wind generation

Thermal:
2.8 GW of coal generation retirements offset by 2.8 GW increase in natural gas generation

Storage:
25.8 GW of energy storage added with 24.9 GW battery storage



Draft 2029 Market Study Buildout Scenario Results

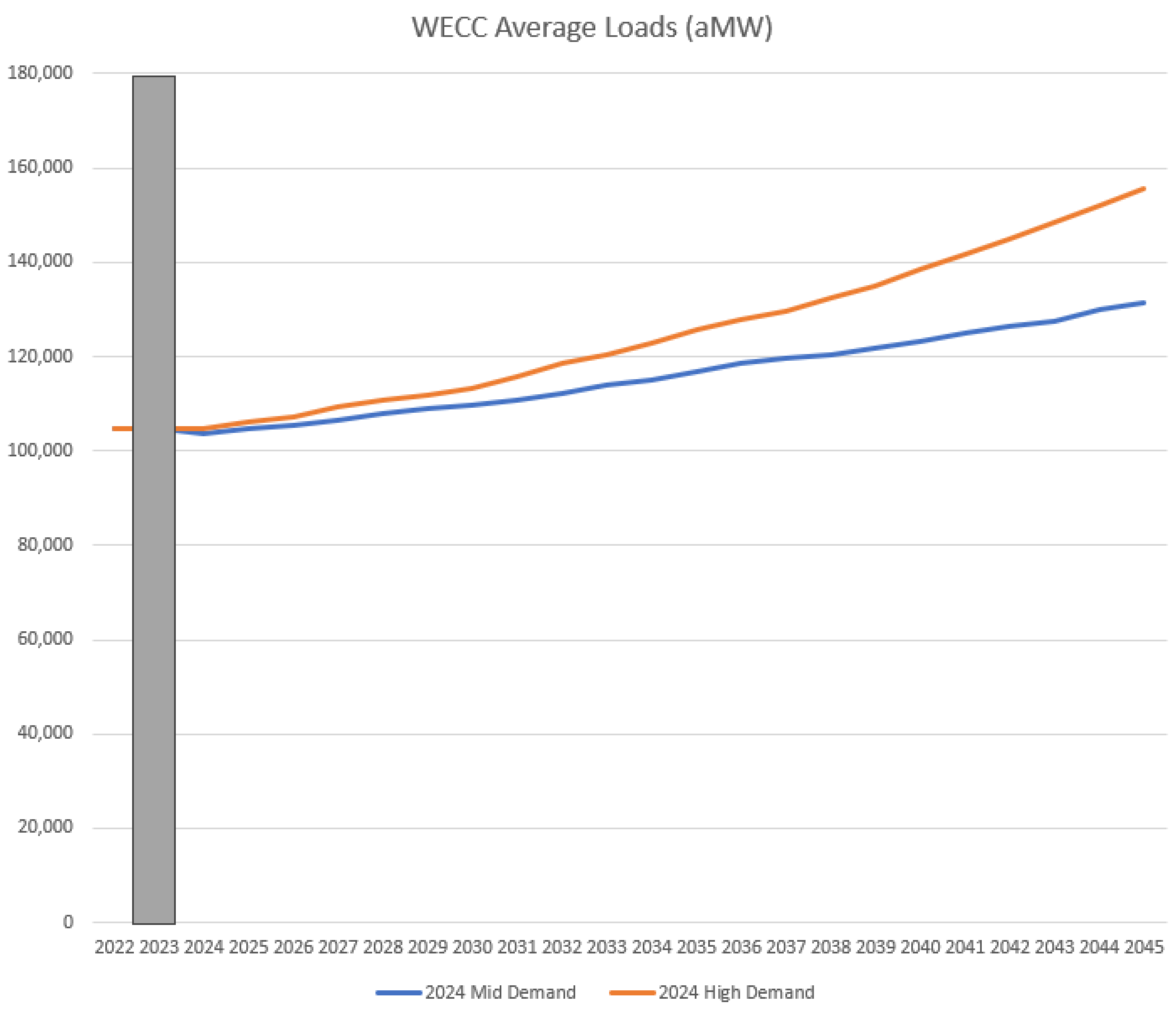
Buildouts

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

Scenario Description Review:
2021 Baseline and High Demand

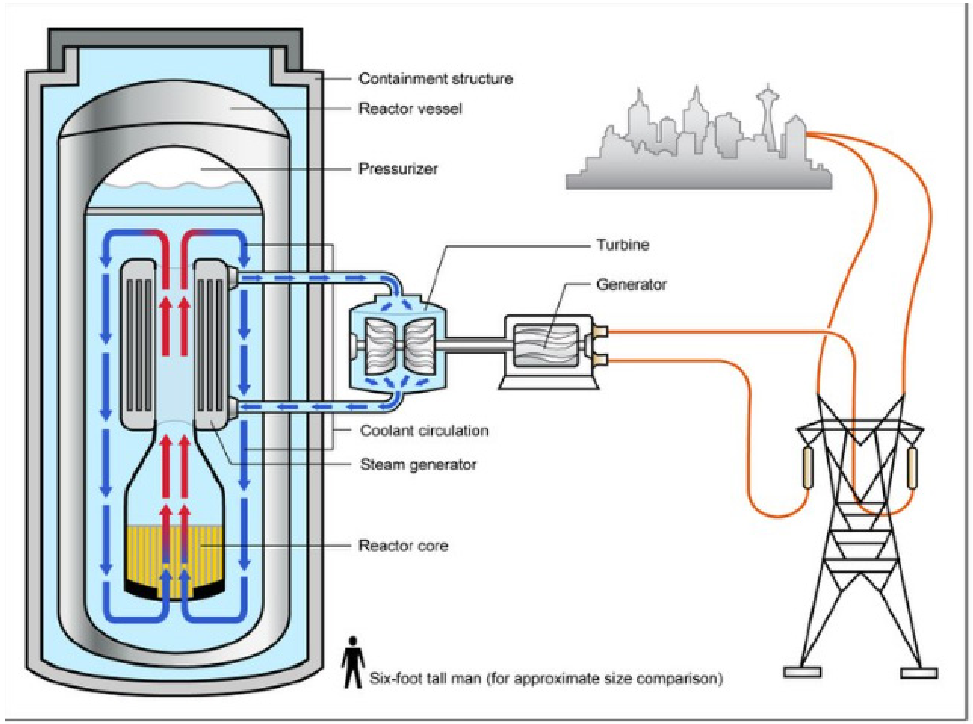
- Demand Update Out of Region
  - High Demand forecast reflects higher demand forecasts in BC, AB, CO and NW
  - Note that CA base forecast is higher and includes electrification

- Demand In Region not updated
  - 2024 Mid Demand reflects 2021 Plan baseline forecast
  - 2024 High Demand reflects 2021 Plan high demand forecast
    - In the short term tends to best track the increase in data center loads…



Scenario Description Review: Delayed Emerging Resources

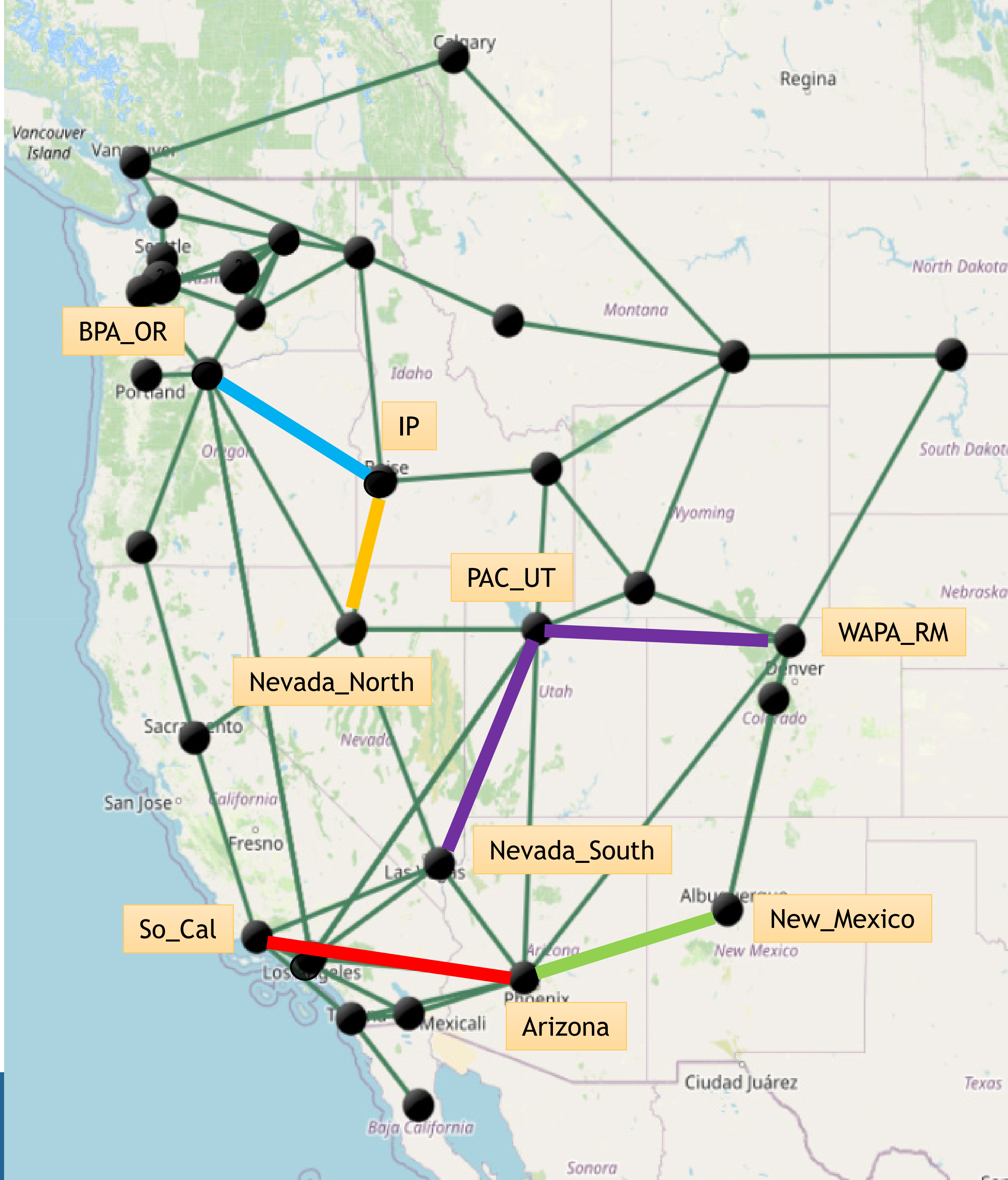
- Significant uncertainty about possible online dates of hydrogen peakers or small modular reactors
  - Delayed online date by 5 years for offshore wind, SMRs and Long Duration Energy Storage
  - All other settings the same as the High Demand



Source: GAO, based on Department of Energy documentation. | GAO-15-652

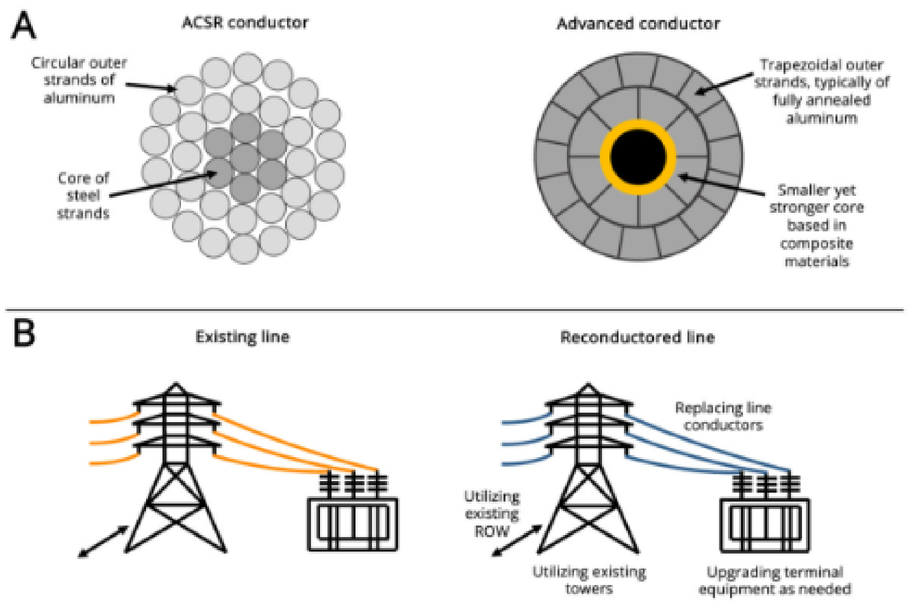
Scenario Description Review: Delay Transmission Build

- Significant uncertainty about possible online dates of scheduled transmission builds
  - Delayed online dates for new transmission projects by 5 years.
  - All other settings the same as the High Demand



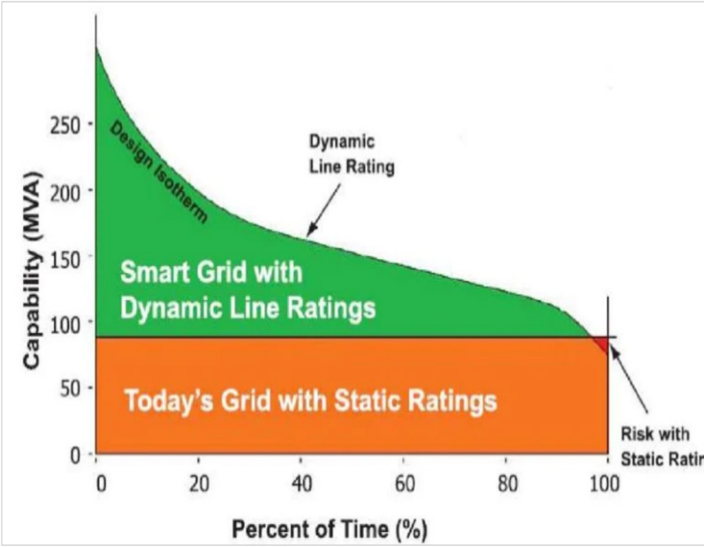
Scenario Description Review: Additional Transmission Build

- Will additional transmission significantly change the resources built?
  - Double the current transmission capacity in the WECC between 2030 and 2040 by 10% a year assuming the utilization of advanced reconductoring, dynamic line ratings and new lines are built
  - All other settings the same as the High Demand



Advanced conductor and ACSR conductor

Image: Energy Institute at the UC Berkeley Haas School of Business



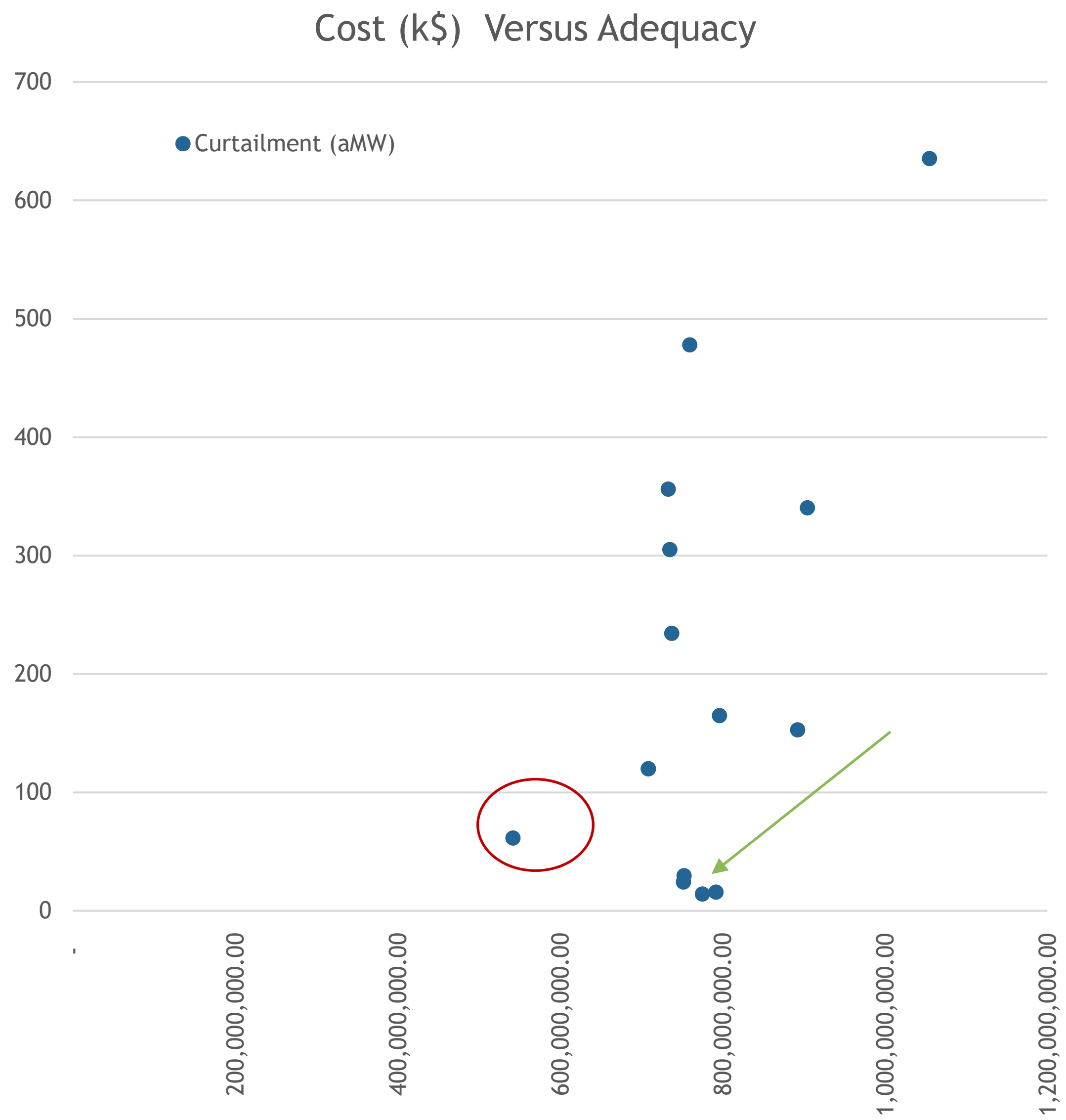
Grids using DLR compared to grids with static ratings. Image used courtesy of DOE

Scenario Description Review: Limited Storage Resources

- Significant uncertainty about availability of storage
  - Cut overall potential for the WECC by half for 4-hour and 100-hour batteries
  - Assuming global competition for materials used to build storage technologies or supply chain challenges limits overall availability
  - All other settings the same as the High Demand

Multiple Buildouts Completed for Each Scenario

- Least Cost Buildout with many load curtailments
  - Current Council parameterization for AURORA optimizes for least cost using reserve margins, static capacity contribution credits for hydro, thermal and storage, and dynamic capacity contribution credit for solar and wind resources.
  - Capacity contribution credit for 4-hour storage likely main driver for adequacy challenges.
- Lowest Cost, Adequate Buildout
  - Selected lowest fixed and variable cost total with 25 aMW or less of load curtailments in any year.



Adequate Buildouts Information

Scenario	**2024 High Demand**	**2024 High Demand, Delay Trans**	**2024 High Demand, Add Trans**	**2024 High Demand, Res Delay**	**2024 High Demand, Storage Limit**	**2024 Baseline Demand**	**2022 High Demand**	**2022 Baseline Demand**
Meets Reserve Margins	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Meets Policies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Build Size	**2030: 114 GW 2045: 551 GW**	2030: 100 GW 2045: 551 GW	2030: 129 GW 2045: 550 GW	2030: 164 GW 2045: 626 GW	2030: 154 GW 2045: 567 GW	2030: 79 GW 2045: 214 GW	2027: 91 GW 2045: 314 GW	2027: 110 GW 2045: 252 GW
Annual System Cost in 2045 (2016 $)	**81 billion** 71% Fixed 29% Variable	**77 billion** 69% Fixed 31% Variable	**75 billion** 73% Fixed 27% Variable	**92 billion** 80% Fixed 20% Variable	**81 billion** 75% Fixed 25% Variable	**47 billion** 56% Fixed 44% Variable	**71 billion** 72% Fixed 28% Variable	**51 billion** 78% Fixed 22% Variable

Solar and Solar Plus Storage Build Comparisons (*installed capacity in megawatts*)

WECC

Solar

Year	2024 High Demand	2024 High Demand, Delay Trans	2024 High Demand, Add Trans	2024 High Demand, Res Delay	2024 High Demand, Storage Limit	2024 Baseline	Draft 2024 Baseline for AA	2022 Baseline	2021 Plan Baseline
2025	9,995	9,101	9,009	19,844	12,782	6,900	2,153	21,528	51,538
2030	34,325	25,615	37,016	44,957	36,953	31,436	14,355	42,206	89,838
2035	46,890	32,880	53,306	80,807	49,158	31,436	15,355	45,141	100,357
2040	49,947	96,612	58,541	141,890	66,353	49,564	17,355	56,494	135,054
2045	55,750	166,315	94,023	159,990	125,164	63,850	19,200	75,890	147,554

Solar Plus Storage

Year	2024 High Demand	2024 High Demand, Delay Trans	2024 High Demand, Add Trans	2024 High Demand, Res Delay	2024 High Demand, Storage Limit	2024 Baseline	Draft 2024 Baseline for AA	2022 Baseline	2021 Plan Baseline
2025	3,000	2,346	5,521	1,000	7,067	9,711	0	23,386	46,600
2030	18,222	9,143	30,336	15,100	44,731	36,753	2,261	60,503	86,600
2035	27,206	14,130	48,529	85,500	65,743	44,763	5,301	60,503	145,500
2040	56,229	37,624	63,243	175,242	91,387	66,937	20,156	63,429	179,800
2045	82,001	65,065	101,343	175,242	114,344	89,471	39,906	63,429	198,000

Wind and Offshore Wind Build Comparisons (*installed capacity in megawatts*)

WECC

Year	2024 High Demand	2024 High Demand, Delay Trans	2024 High Demand, Add Trans	2024 High Demand, Res Delay	2024 High Demand, Storage Limit	2024 Baseline	Draft 2024 Baseline for AA	2022 Baseline	2021 Plan Baseline
2025	4,090	8,989	4,980	7,818	5,388	1,000	2,211	12,155	16,775
2030	14,645	17,177	22,184	54,454	29,455	3,879	16,031	18,634	35,175
2035	31,455	29,504	27,468	73,284	39,872	5,879	16,031	27,906	37,063
2040	112,747	96,486	67,853	96,751	123,417	16,860	30,222	38,221	43,657
2045	169,349	173,556	177,996	147,988	191,311	35,985	36,887	69,769	51,481

Year	2024 High Demand	2024 High Demand, Delay Trans	2024 High Demand, Add Trans	2024 High Demand, Res Delay	2024 High Demand, Storage Limit	2024 Baseline	Draft 2024 Baseline for AA	2022 Baseline	2021 Plan Baseline
2025	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	0	0	6,463
2035	0	0	0	0	0	0	0	0	7,663
2040	4,160	2,417	349	12,600	3,285	0	10,000	0	10,000
2045	12,600	12,600	6,748	12,600	12,600	5,100	10,000	0	10,000

Battery and Pumped Storage Build Comparisons (*installed capacity in megawatts*)

WECC

Year	2024 High Demand	2024 High Demand, Delay Trans	2024 High Demand, Add Trans	2024 High Demand, Res Delay	2024 High Demand, Storage Limit	2024 Baseline	Draft 2024 Baseline for AA	2022 Baseline	2021 Plan Baseline
2025	4,607	5,056	5,023	6,742	6,411	0	27,813	13,634	6,004
2030	24,905	25,819	21,284	29,764	21,674	701	35,875	13,940	6,004
2035	66,208	33,150	34,753	39,856	27,842	701	46,903	13,965	6,004
2040	100,273	48,028	81,744	52,449	44,333	701	104,016	14,861	6,004
2045	167,402	66,614	126,513	63,661	60,431	4,596	129,751	18,390	6,055

Year	2024 High Demand	2024 High Demand, Delay Trans	2024 High Demand, Add Trans	2024 High Demand, Res Delay	2024 High Demand, Storage Limit	2024 Baseline	Draft 2024 Baseline for AA	2022 Baseline	2021 Plan Baseline
2025	0	0	0	0	0	0	0	0	0
2030	2,300	1,800	0	3,100	2,700	0	1,300	0	4,900
2035	2,300	4,750	0	5,300	5,400	2,200	1,300	2,200	5,650
2040	4,250	8,240	750	5,300	6,940	2,200	2,840	2,200	6,050
2045	6,950	11,640	750	7,950	7,940	2,200	3,840	2,200	9,690

Long Duration Energy Storage (LDES) Build Comparisons (*installed capacity in megawatts*)

WECC

Year	2024 High Demand	2024 High Demand, Delay Trans	2024 High Demand, Add Trans	2024 High Demand, Res Delay	2024 High Demand, Storage Limit	2024 Baseline	Draft 2024 Baseline for AA
2025	0	0	0	0	0	0	0
2030	4,769	4,138	2,450	0	2,112	0	5,913
2035	13,369	9,733	6,609	6,700	8,045	0	17,943
2040	21,669	17,192	12,437	14,070	15,942	0	34,321
2045	29,821	25,621	17,478	22,840	25,739	2,291	46,214

LDES Charging Energy Availability (MWh of clean energy curtailed)

Year	2024 High Demand	2024 High Demand, Delay Trans	2024 High Demand, Add Trans	2024 High Demand, Res Delay	2024 High Demand, Storage Limit	2024 Baseline	Draft 2024 Baseline for AA
2025	32,362,747	32,505,232	32,765,237	35,021,416	33,418,158	31,818,280	30,960,909
2030	36,155,120	32,939,688	40,386,316	42,896,358	42,198,870	30,400,646	32,755,452
2035	86,737,275	81,977,784	97,707,242	93,459,255	114,129,678	79,669,181	87,666,135
2040	104,249,849	94,996,337	115,867,308	115,820,132	150,742,242	85,720,666	113,676,736
2045	85,598,131	69,786,783	96,583,352	93,469,588	151,777,659	65,220,920	88,177,885

Percent of Hours Full LDES Capability Could be Available with Strategic Charging/Timing of Curtailed Clean Energy (with thermal energy charging all would be 100%)

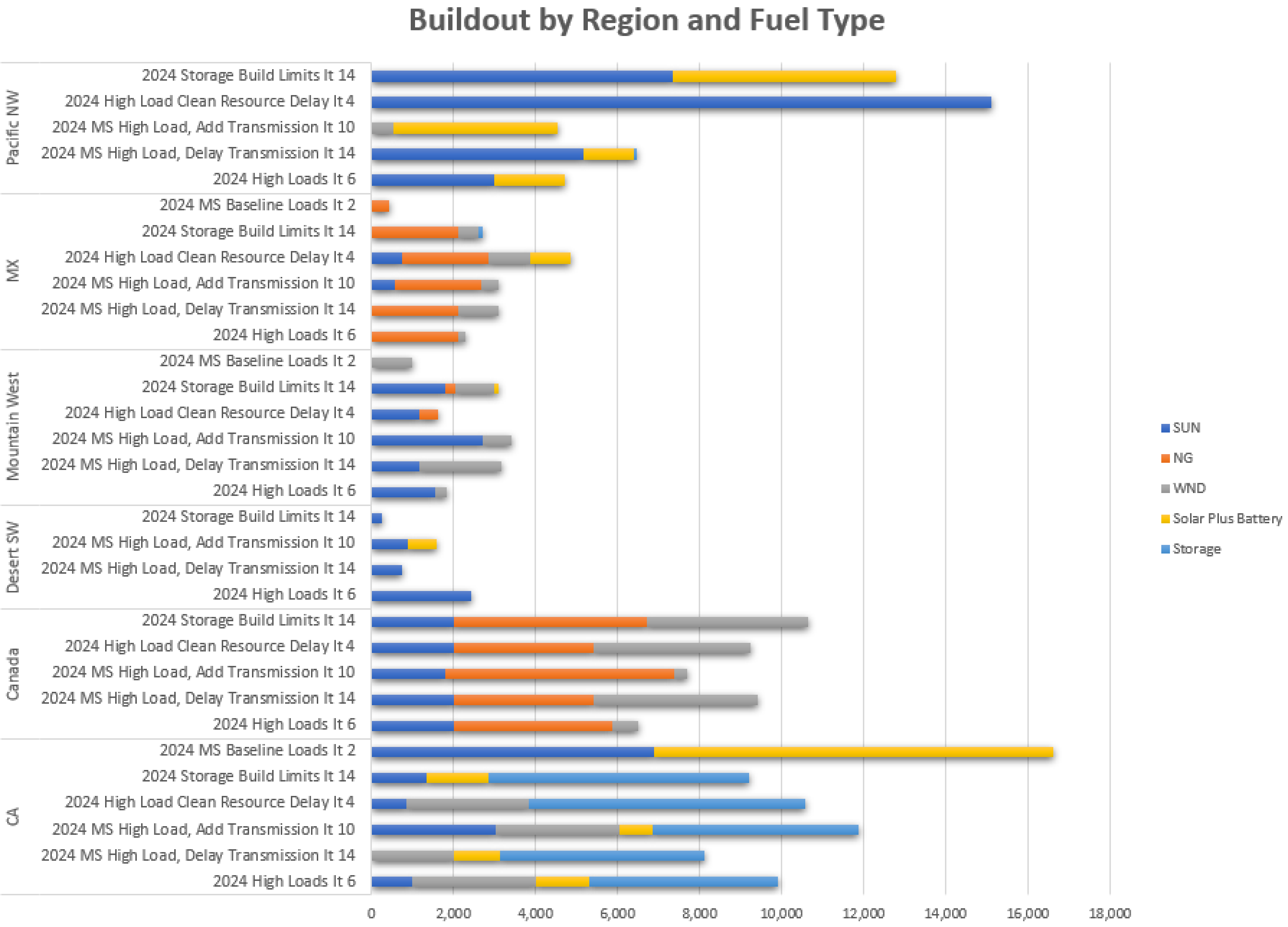
Year	2024 High Demand	2024 High Demand, Delay Trans	2024 High Demand, Add Trans	2024 High Demand, Res Delay	2024 High Demand, Storage Limit	2024 Baseline	Draft 2024 Baseline for AA
2025	0%	0%	0%	0%	0%	0%	0%
2030	36%	38%	79%	0%	96%	0%	27%
2035	31%	40%	71%	67%	68%	0%	23%
2040	23%	26%	45%	39%	45%	0%	16%
2045	14%	13%	26%	20%	28%	136%	9%

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

WECC

Year	2024 High Demand	2024 High Demand, Delay Trans	2024 High Demand, Add Trans	2024 High Demand, Res Delay	2024 High Demand, Storage Limit	2024 Baseline	Draft 2024 Baseline for AA	2022 Baseline	2021 Plan Baseline
2025	5,977	5,548	7,693	6,022	7,072	429	4,523	7,305	11,351
2030	15,202	16,252	15,909	16,534	16,763	6,459	11,403	14,332	14,873
2035	18,724	18,205	20,526	18,250	19,856	7,317	14,185	14,806	16,058
2040	21,004	20,440	22,716	21,535	21,233	8,412	14,614	15,235	16,532
2045	24,007	23,770	23,427	24,481	24,481	10,647	16,330	15,235	16,532

Year	2024 High Demand	2024 High Demand, Delay Trans	2024 High Demand, Add Trans	2024 High Demand, Res Delay	2024 High Demand, Storage Limit	2024 Baseline	Draft 2024 Baseline for AA	2022 Baseline	2021 Plan Baseline
2025	0	0	0	0	0	0	0	0	0
2030	0	0	0	0	0	0	684	1,368	0
2035	0	0	0	0	684	0	684	3,420	0
2040	3,420	1,368	0	6,840	2,736	0	684	3,420	0
2045	3,420	5,472	1,368	10,944	4,788	0	4,104	7,524	0

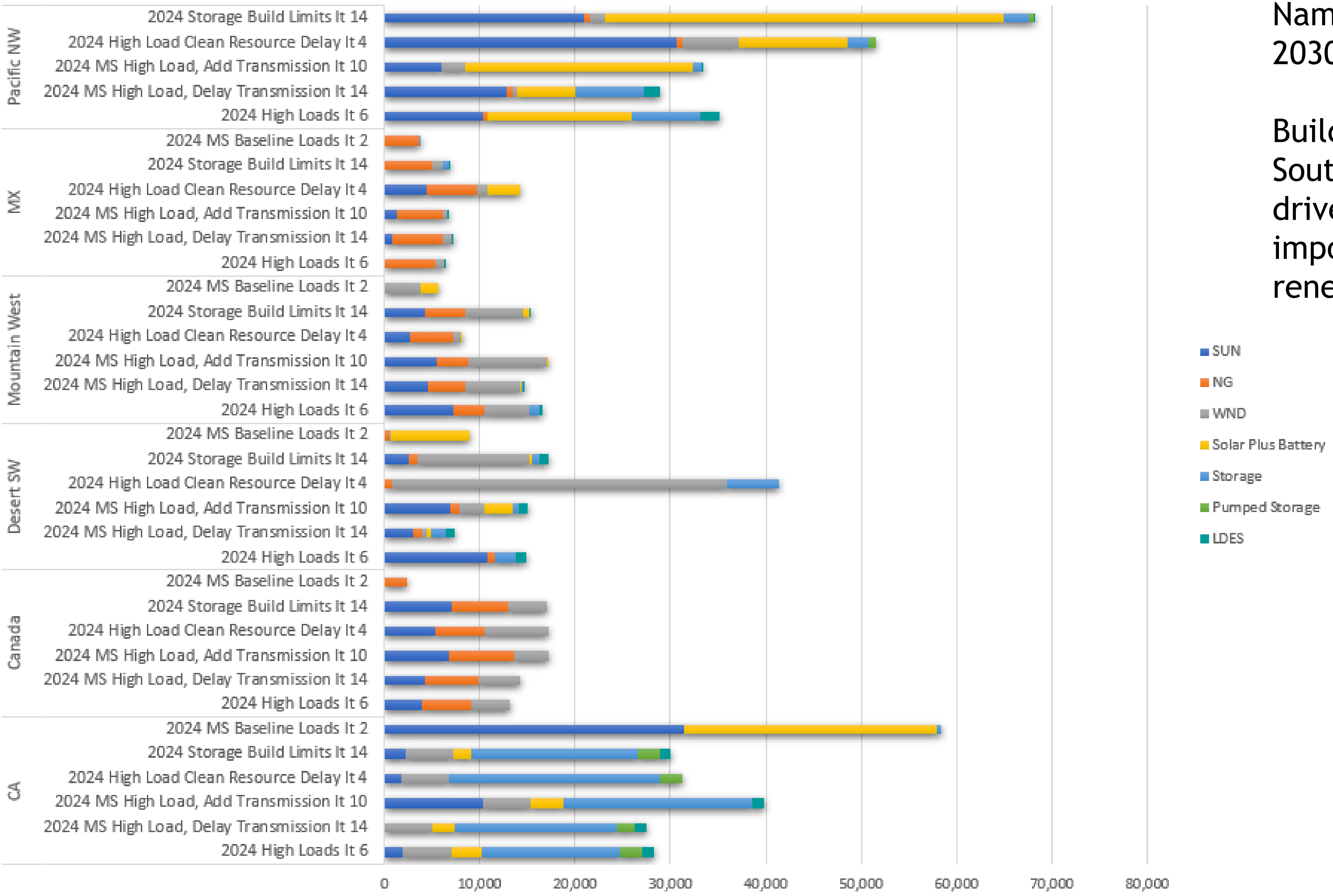


Nameplate Megawatts by 2025

WECC-wide builds since existing resources were frozen at the of 2023 include the following:

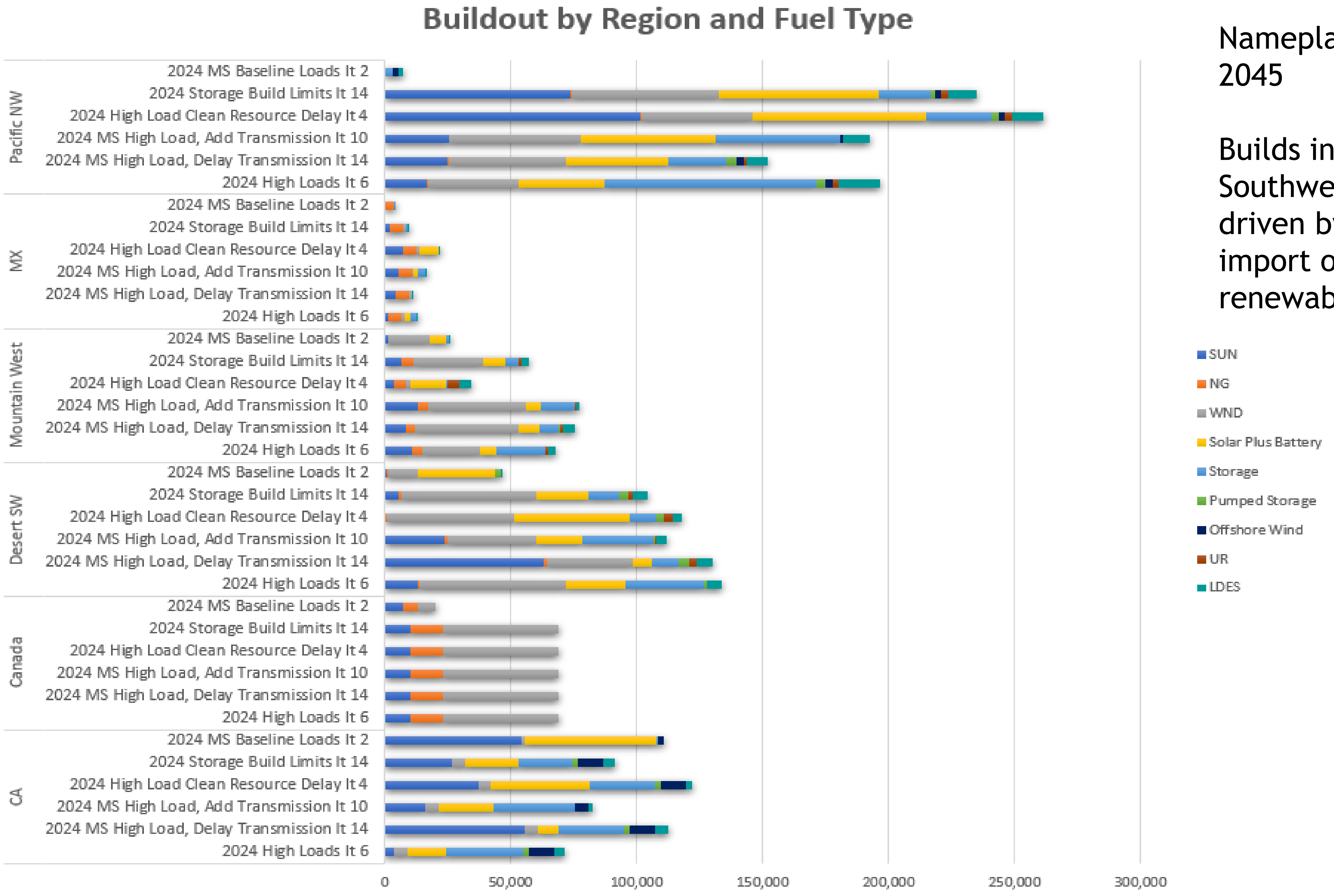
Wind 2.7 GW
Solar 9.9 GW
Storage 12 GW
Thermal 3.3 GW
(mostly coal to gas conversions)

Buildout by Region and Fuel Type



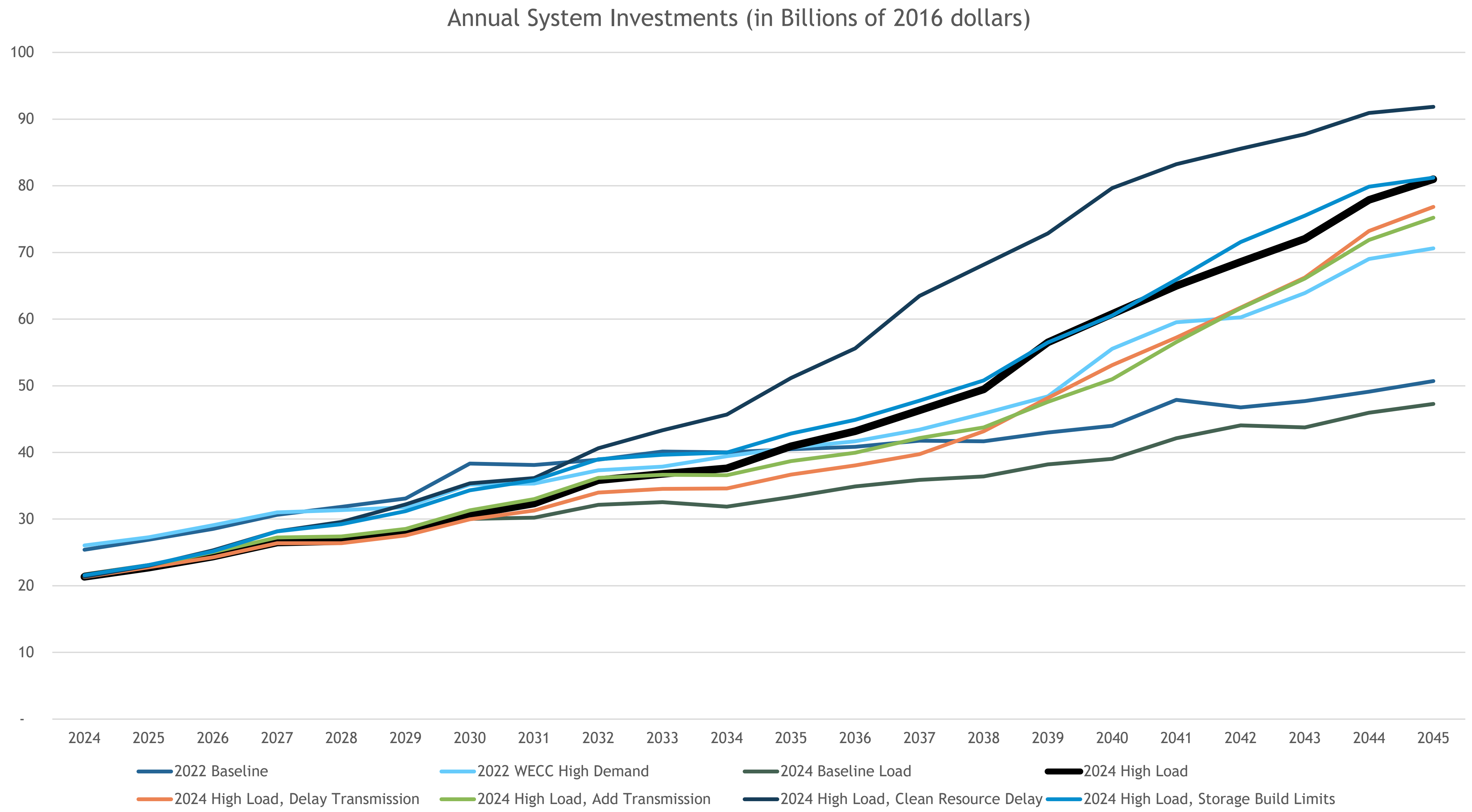
Nameplate Megawatts by 2030

Builds in Northwest, Southwest and Mountain West driven by California plans to import out of state renewables.



Nameplate Megawatts by 2045

Builds in Northwest, Southwest and Mountain West driven by California plans to import out of state renewables.


Annual System Investments (in Billions of 2016 dollars)
100
90
80
70
60
50
40
30
20
10
-
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2022 Baseline
2022 WECC High Demand
2024 Baseline Load
2024 High Load
2024 High Load, Delay Transmission
2024 High Load, Add Transmission
2024 High Load, Clean Resource Delay
2024 High Load, Storage Build Limits

Moving on to Prices and Avoided Emissions Rate Studies

Implications from buildouts, methodology, assumption changes, etc.

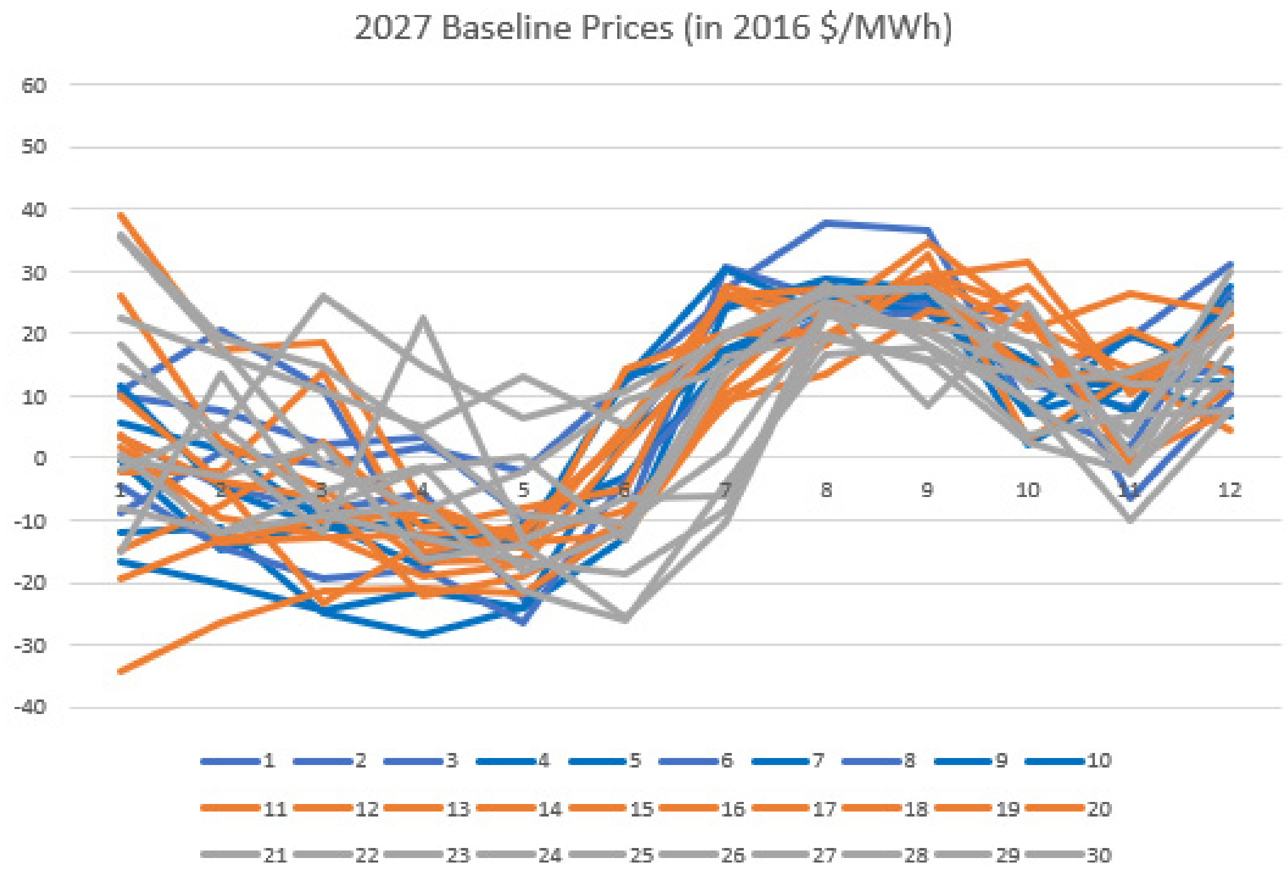
Quick Reminder on Climate Studies

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*

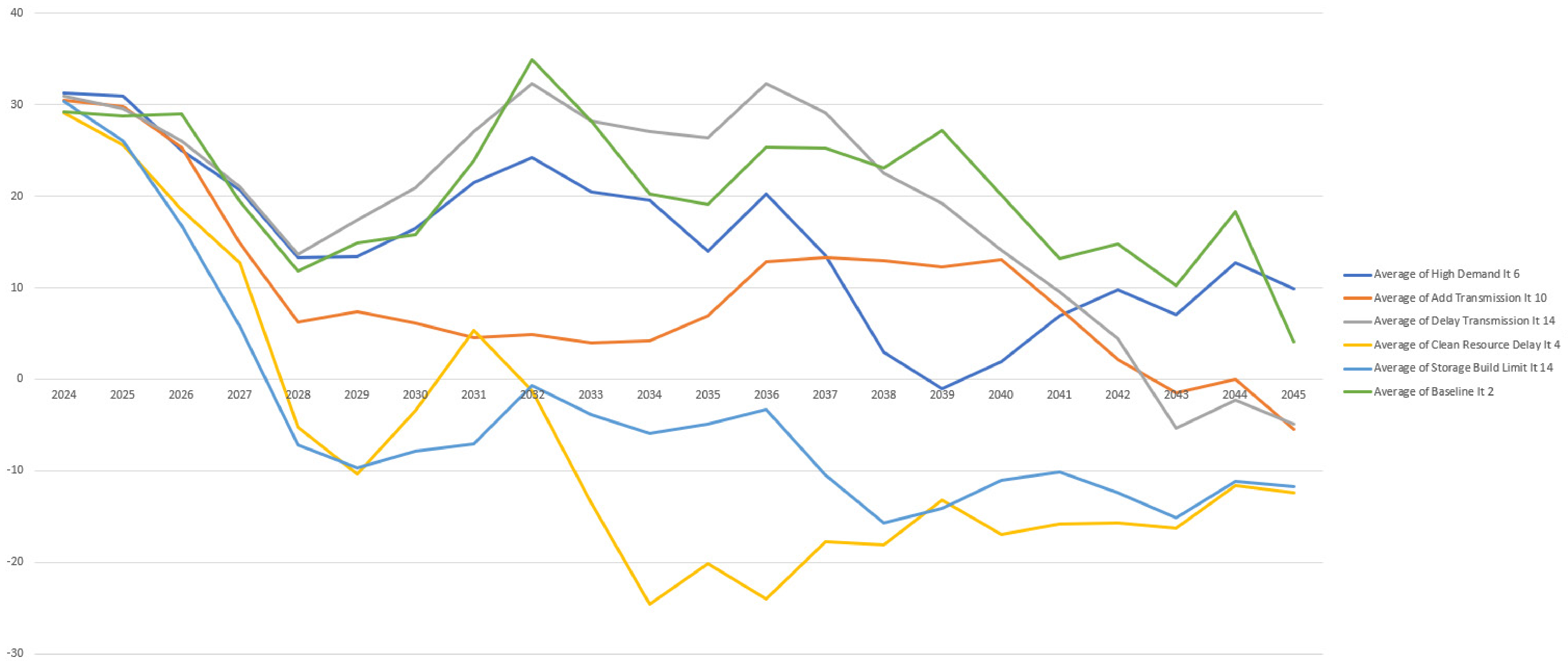
(Circled:) High loads and low water conditions might cause adequacy events

Review: Monthly Variation Will Still Depend Heavily on Hydro Condition

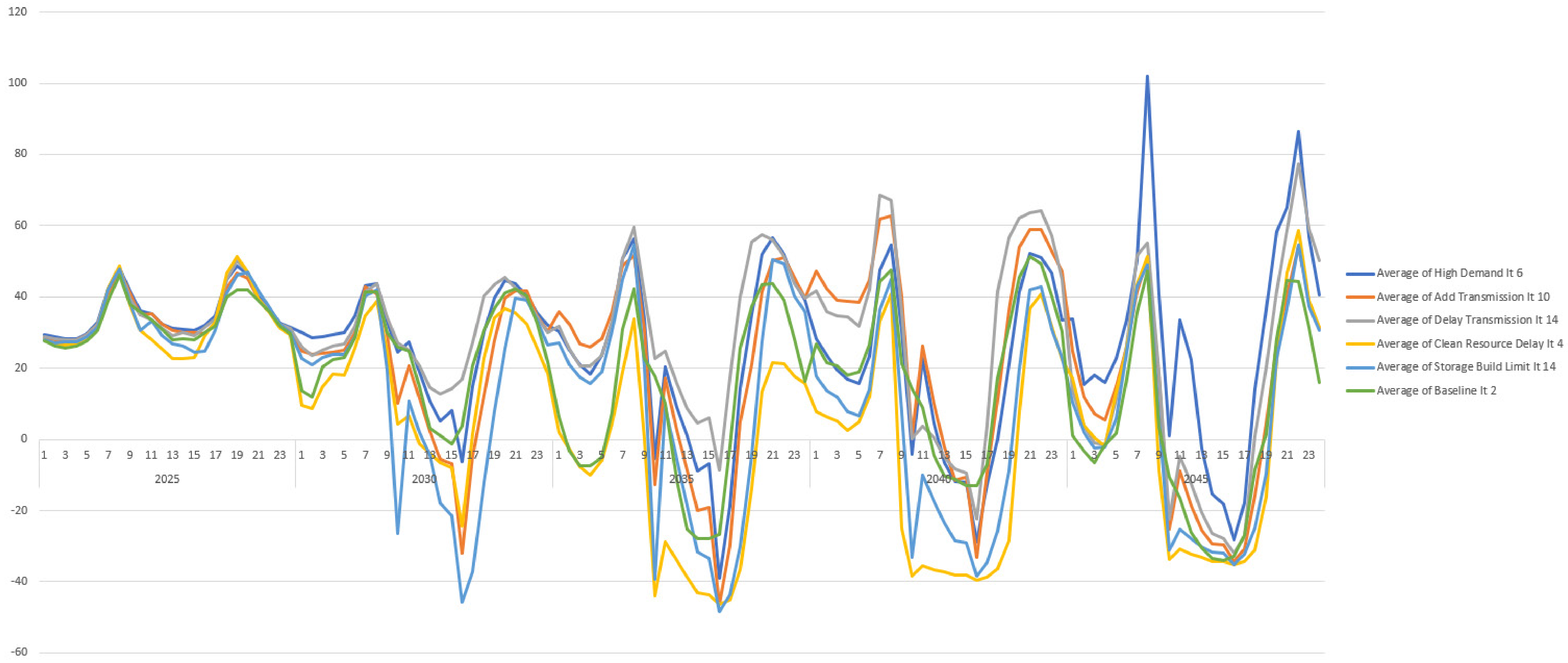
- Consistent with previous studies, Mid-C prices will likely show greater dependency on hydro condition during the winter, spring and early summer depending on runoff.
- This means we should likely simulate the prices over many hydro conditions for each scenario



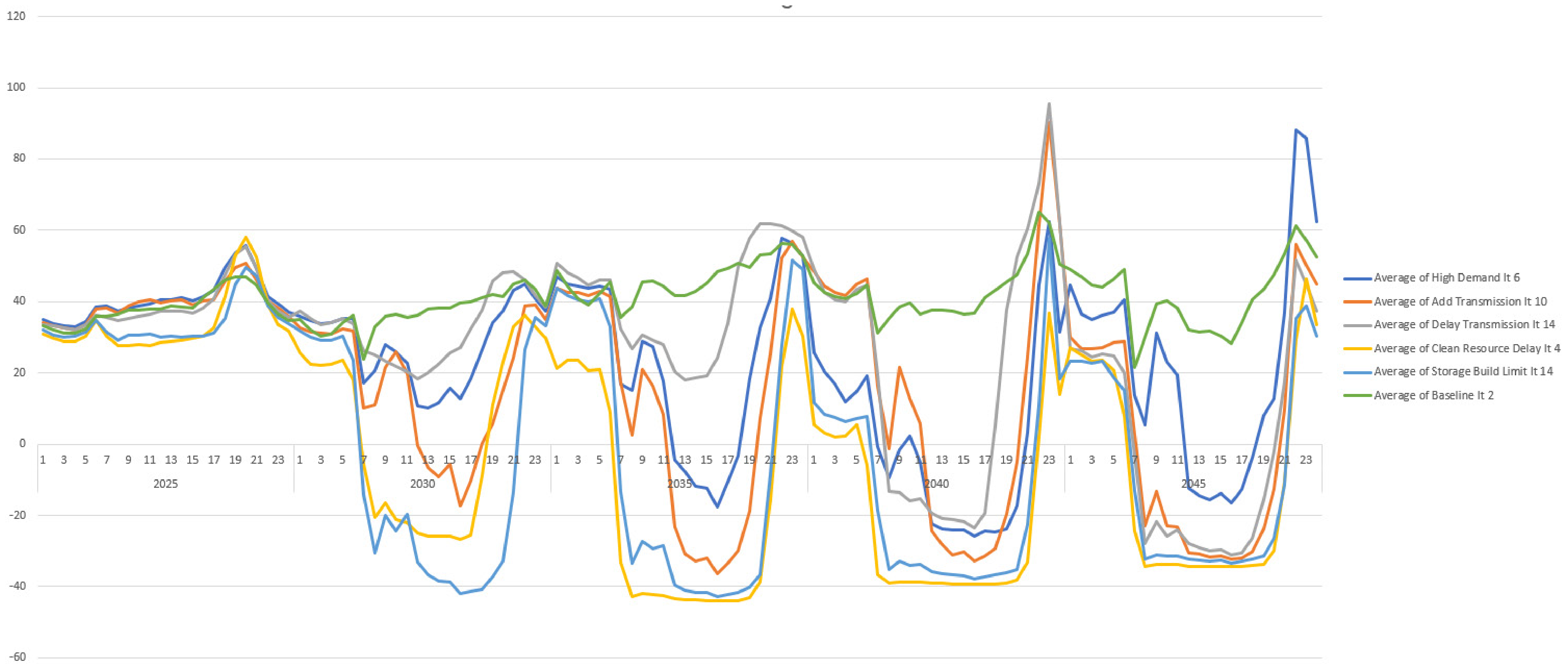
Preview: Annual Price Growth By Scenario



Preview: Winter Daily Price Shape By Scenario



Preview: Summer Daily Price Shape By Scenario



What is the Avoided Emissions Rate?

- The goal is to develop the amount of emissions that are avoided by reducing 1 kWh of load in the NW at any time.
  - In the recent past, this could be determined by the most expensive unit online (almost always coal or gas) assuming it was serving the last kWh of load in any hour.
  - Since many of the expensive generators are now being used for reserves or grid services, the methodology identifying the most expensive unit serving the last kWh is less accurate than before.
- In the past 5 or 6 years, staff and the System Analysis Advisory Committee have developed a different technique for estimating the "market" or "marginal" emission rate.

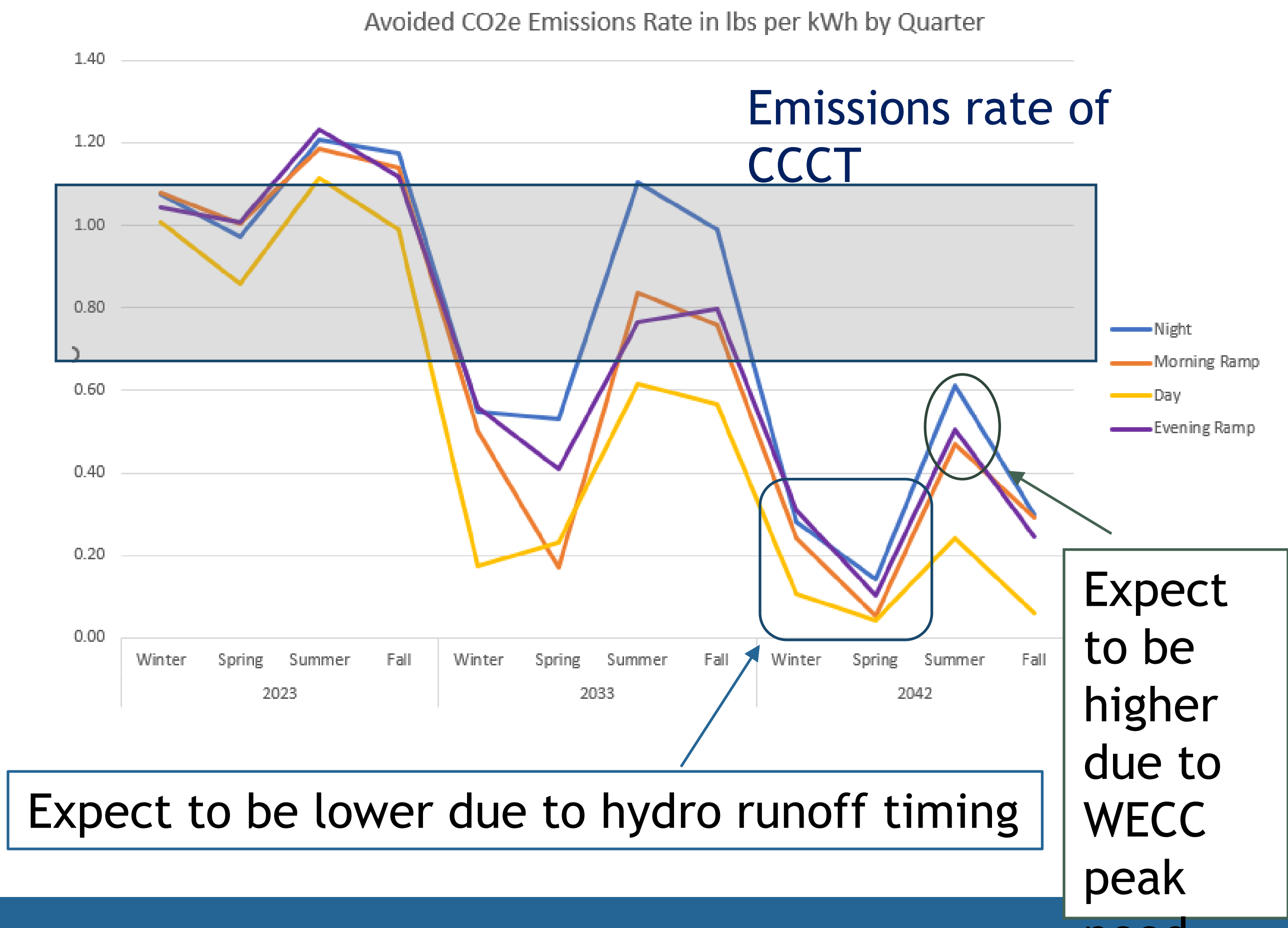
Avoided Emissions Rate Methodology

The *avoided emissions rate* over the output changed in the WECC from the flat drop of 1000 MW is

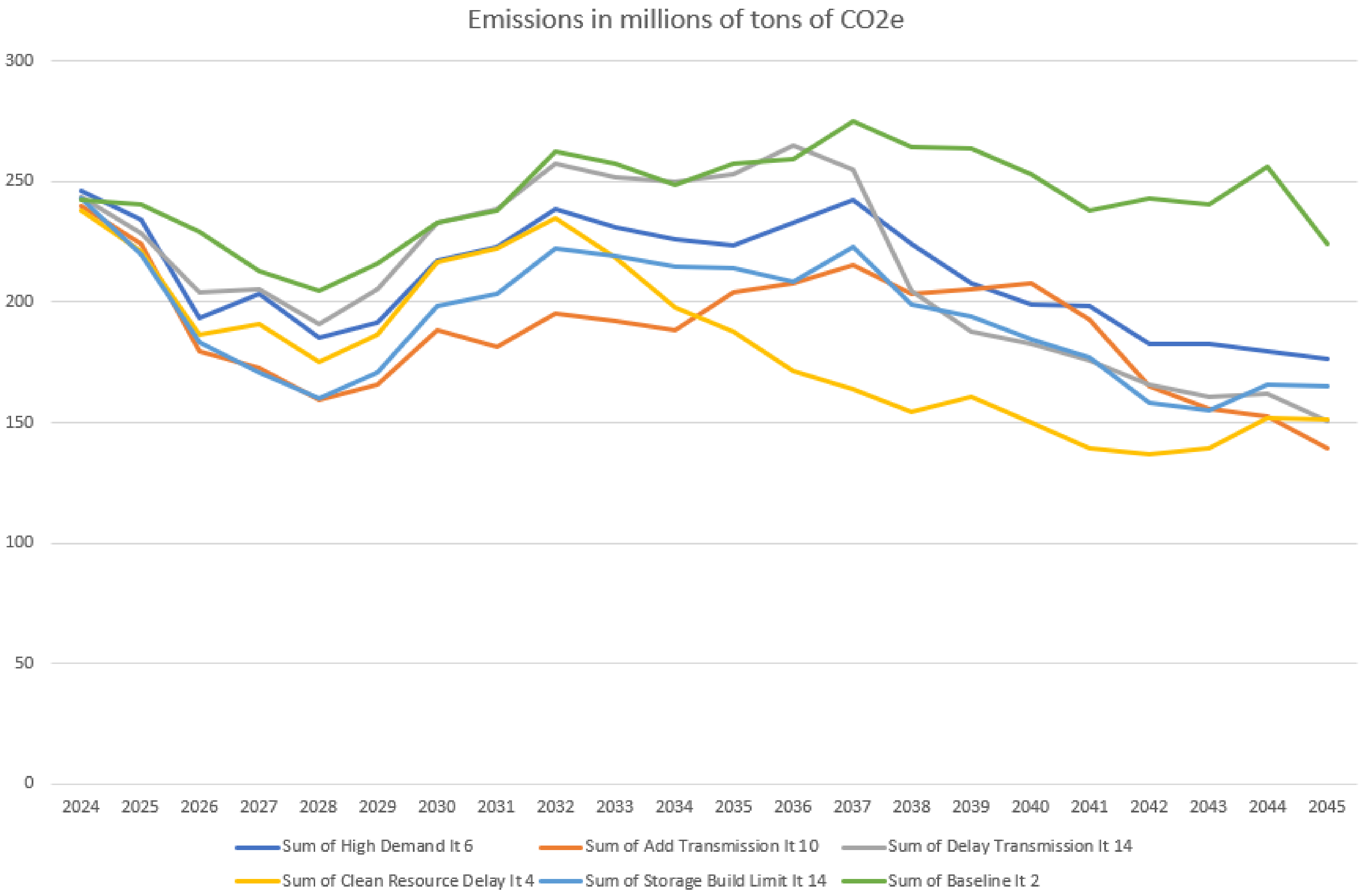
$$\frac{Emissions_{1000} - Emissions_{0}}{Output_{1000} - Output_{0}} = X\ lbs/kWh$$

Variable Definition:

1. $Emissions_{1000}$ is the emissions in the WECC with 1000 MW less load in PNW run
2. $Emissions_{0}$ is the emissions in the WECC in the base run
3. $Output_{1000}$ is the output in the WECC with 1000 MW less load in PNW run
4. $Output_{0}$ is the emissions in the WECC in the base run



<u>Preview:</u> Annual Emissions in tons of CO2e



Questions for the Committee

Before prices and avoided emissions rate simulations

We Need Your Feedback!

1. Is going forward with not perfectly optimized but adequate buildouts OK if more work is done to improve long duration storage modeling effect on prices?
2. Is running a typical day per month OK for prices and avoided emissions rates sufficient?
3. Moving forward for the next plan, what suggestions do you have to improve the forecast?

Questions?

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Appendix

Data center & chip fab forecasts