Northwest **Power** and
Conservation Council

August 6, 2024

MEMORANDUM

TO: **Council Members**

FROM: **John Ollis, Manager of Planning and Analysis**

SUBJECT: **Wholesale Power Price and Avoided Market Emissions Rate Forecast**

BACKGROUND:

Presenter: John Ollis

Summary: This presentation will review the process used to create the market price forecast and the underlying buildout information for different scenarios. Then, it will discuss how those policies/buildouts are projected to affect prices and avoided market emissions rates in the region over the next 20 years.

Relevance: Wholesale power markets outside the region were highlighted as a key data point to monitor coming out of the 2021 Power Plan in which policy changes throughout the western states impacted not just wholesale power markets in the long term, but also in the short term. This update will revisit some of the Power Plan market study findings and track any major changes in the updated study results.

While not required by the Power Act to be updated regularly, revisiting this price and avoided emissions rate analysis on an annual basis will provide an important data point on the wholesale power markets to inform our Mid-Term Assessment. This study has historically provided high value to stakeholders, who use it for several purposes such as vetting their own

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price forecasts for resource planning or providing avoided market emissions rate guidance for state agencies developing building codes.

Workplan: A.2.3: Update the wholesale electricity price forecast and the related emissions forecast

Background: The Council has periodically updated its wholesale electricity price study using the AURORA model to help inform Council staff and regional stakeholder analysis. The Council relies on the System Analysis Advisory Committee to help provide expert feedback on market fundamentals and power system modeling assumptions related to the market price study.

The Council's forecast is a fundamentals-based forecast that reflects actual power system operation, relationships of supply and demand for, and transmission of electricity. In addition, underlying a wholesale electricity price forecast in this region would be an understanding of the operating characteristics of future and existing supply and demand-side resources, as well as unit commitment, ancillary services, fuel prices, hydro, wind and solar conditions. The AURORA software captures many of these characteristics of the power system well and has a periodically updated WECC database, and thus, AURORA has been the Council's wholesale market electricity price forecasting model.

Due to significant clean and RPS policies and less dependence on new baseload generation to meet growing loads, the market price forecast studies from the 2021 Power Plan scenarios consistently showed extremely large buildouts of new resources, especially solar generation outside the region. These buildouts implied a persistence of market fundamentals that seemed to be just emerging at the time of the plan's development, like significant renewable generation curtailment and negative pricing mid-day. This market update is another look at how the plan work compares to current market behavior and policy implementation and highlights some of the data sources the staff uses to monitor this behavior for reference.

More Info: July 31, 2024 System Analysis Advisory Committee presentation

Wholesale Power Price Forecast from the 2023 Market Study Update

Wholesale Power Price Forecast from the 2021 Plan

2024 Wholesale Market Price and Avoided Emissions Forecast

Council Meeting
August 12, 2024

John Ollis

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Overview

- Process Review
- Discussion of Buildout Results
- Discussion of Wholesale Market Prices and Avoided Emissions Rate
- Identifying market risks to monitor
- Improvements for the future

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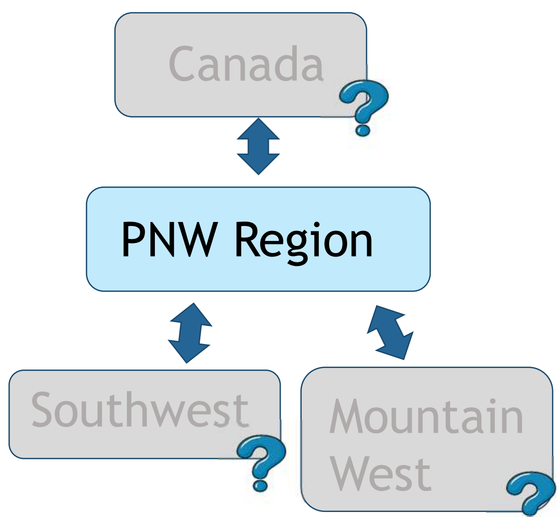
Process Review

Why Do We Look at the Whole West-wide Market?

1. Economics
   - Even though we only plan for the region, the economics of every regional resource decision depends not just on the regional market fundamentals/policies but on the market fundamentals/policies throughout the WECC.
2. Adequacy
   - Even though regional adequacy depends primarily on regional resources, understanding what resources might be available outside the region during stressful times is also important for keeping rates down.



Review: Market Study Use Cases

WECC-wide Resource Buildouts	• Used to build market supply at different price bins in adequacy and plan needs assessments.
Prices and Avoided Emissions Rates Studies	• Used in regional capital expansion in the plan to understand market prices and emissions. • Used by regional stakeholders as input into, or vetting for, their planning processes.

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Buildout Scenario Analysis

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

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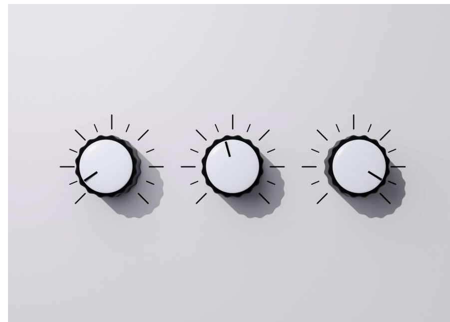
What Assumptions Drive Changes from Previous Studies

- Demand updates
- Gas price updates
- Transmission buildout updates
- Existing policies and resources updates
- New resource options
- Setup and methodology enhancements



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

Notes about setup

- 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
- 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 policies in CA, WA, BC and AB
- Hydro dispatch in NW limited by daily max and min and monthly energy limits informed by GENESYS

Climate Change Informed Weather Risk

Dynamic Capacity Contribution

Policy Interpretation

NW Hydro Flexibility LImits

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
- **Note that regional loads for this study (also hourly) are still 2021 Power Plan vintage**

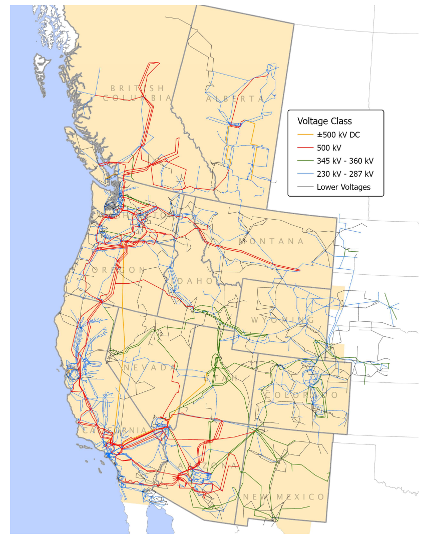


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Image from WECC State of the Interconnection

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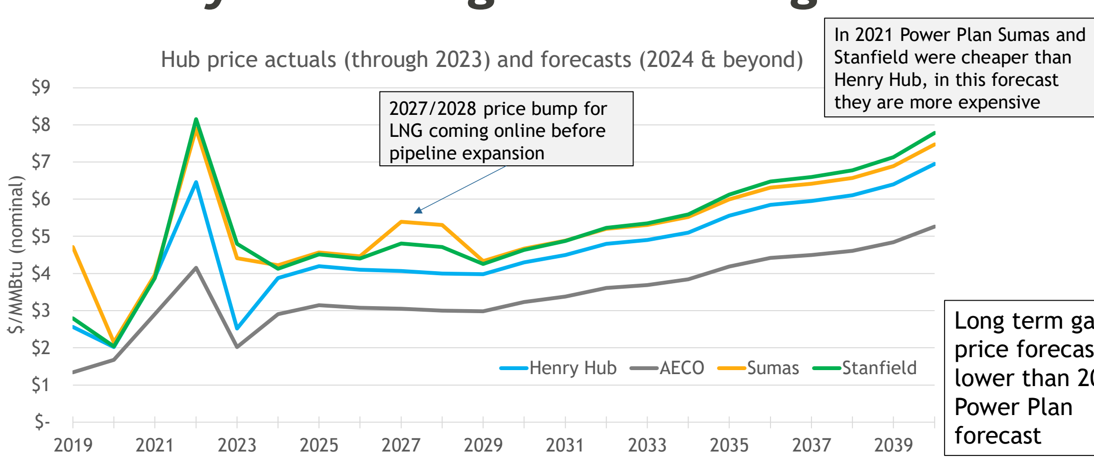
2023 Mid-Case forecast for select Northwest hubs likely influencing Mid-C Pricing



Long term gas price forecast lower than 2021 Power Plan forecast

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

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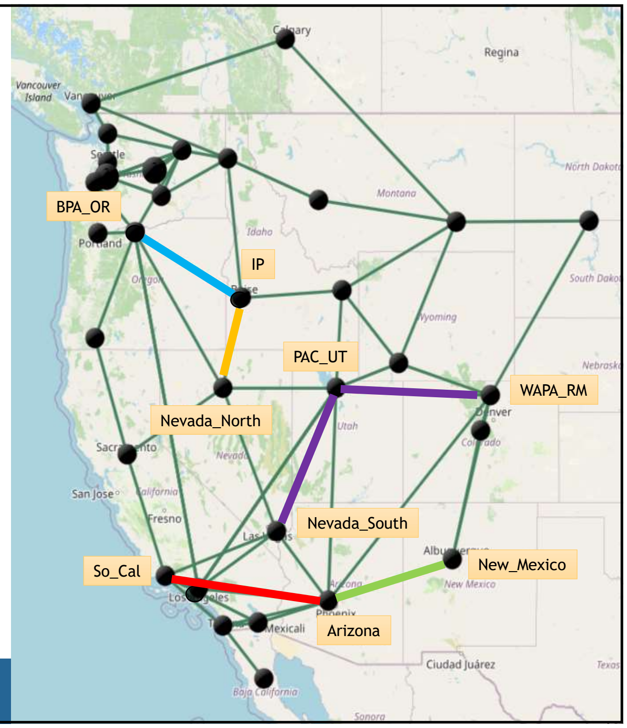
New Transmission

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



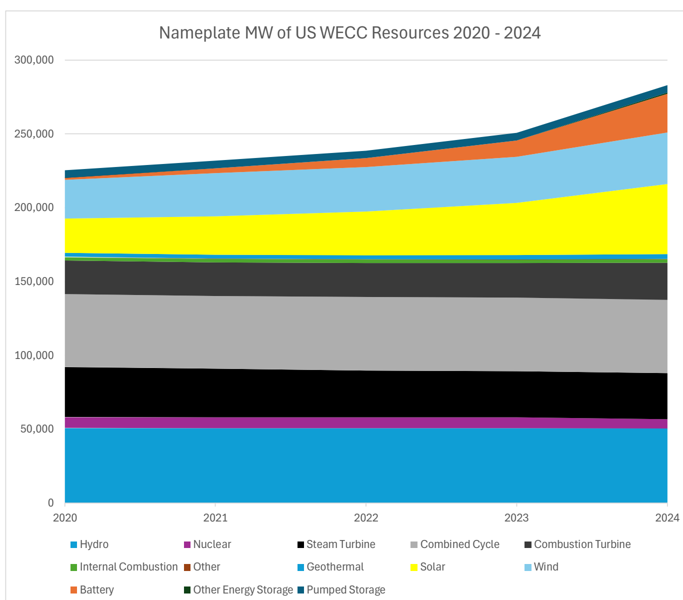
Existing Resources Update

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

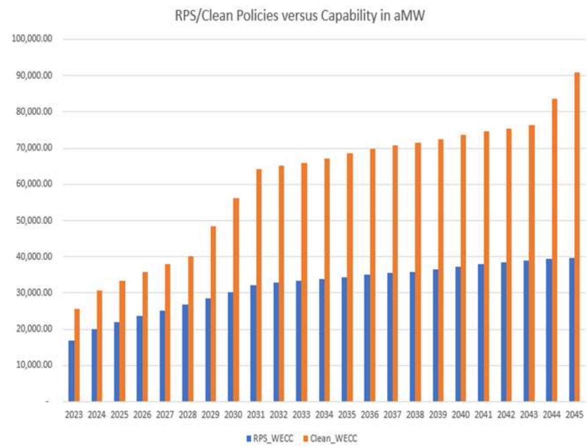
Thermal:
2.8 GW of coal generation retirements offset by 2.8 GW increase in natural gas generation

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



Existing Policy Updates

- Updated fixed costs for all new resources to reflect the provisions of the Inflation Reduction Act.
  - Investment Tax Credit (ITC) of 30% of the fixed costs for all investments placed in service by 2032
  - Production Tax Credit (PTC) of 27.50 $/MWh for all investments placed in service by 2032
  - Applied ITC to fixed costs of all eligible resources: Wind, Solar, Storage, Nuclear
- Attempted to model the implications of the Climate Commitment Act in WA by using a similar carbon pricing scheme as California.
  - With existing carbon pricing policies in California, British Columbia and Alberta the variable costs of serving load with emitting generation is significantly more expensive for almost 60% of the WECC of the WECC demand.
  - 12 to 31 $/MWh depending on emissions rate of the unit
- Updated policy targets for clean energy and RPS for the WECC per the changes in demand.



2024 Resource Buildout Enhancements

- 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
Added long duration storage resources	Zone alignment in AURORA and GENESYS/SDDP
Updated out of region loads	Further storage modeling improvement
Updated of policies (IRA, CCA, etc.)	
Updated existing generation and transmission	
Updated fuel prices	

Draft 2029 Market Study Buildout Scenario Results

Scenario descriptions and results

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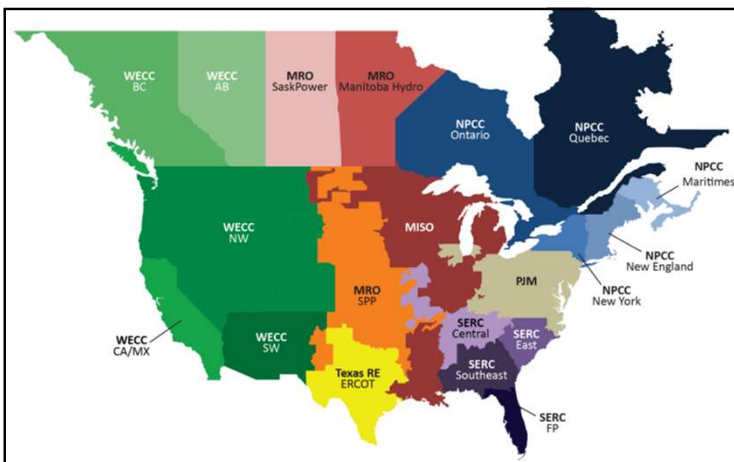

Review: Building out the WECC to Regional Reserve Margins

Before we can calculate prices and associated emissions rates, we need to simulate likely plant buildout in all of the WECC.

- Key reasons to build.

1. **Planning Reserve Margins for each reserve sharing group.**
   - Southwest Reserve Sharing Group
   - California ISO (includes part of Baja California)
   - Western Power Pool US
   - Western Power Pool Canada
2. **WECC clean and RPS policy levels.**
3. **Peaking/reserves capability/need timing**

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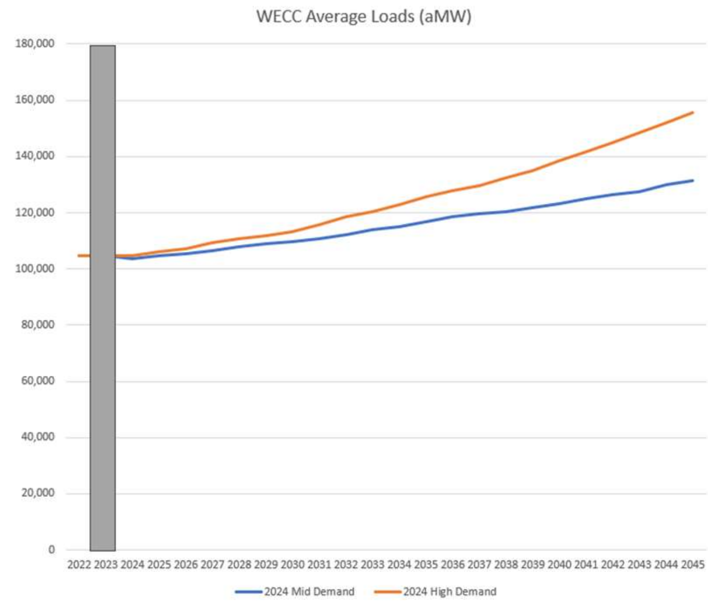
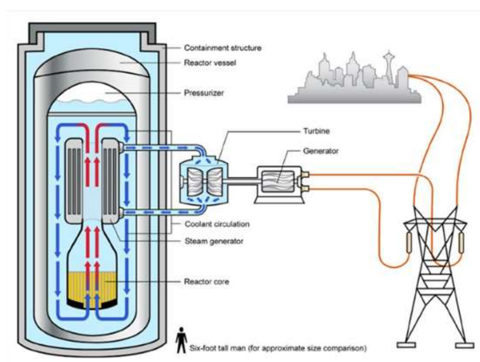
Scenario Description Review: 2021 Baseline and High Demand

- 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 projected regional increase in data center loads…

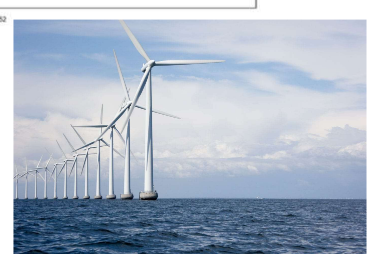


Scenario Description Review: Delayed Emerging Resources

- 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

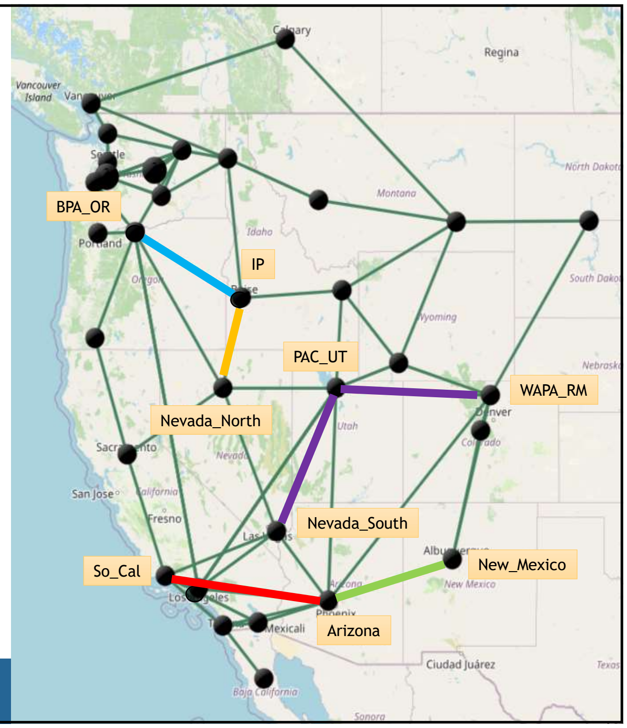


Source: GAO, based on Department of Energy documentation. | GAO-15-652



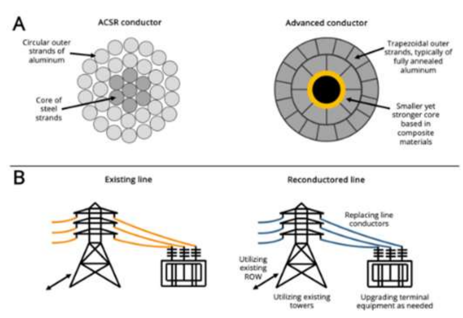
Scenario Description Review: Delay Transmission Build

- 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



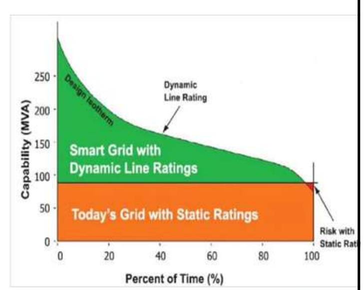
Scenario Description Review: Additional Transmission Build

- 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

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Back of the Envelope Resource Planning

- Through the course of the study, WECC coincident peak forecast goes up by approximately 57 GW and average load goes up by 45 aGW throughout the study
- Note that there are about 17 .6 GW thermal retirements over the course of the study.
- Assume that the WECC will be adequate to a 15% planning reserve margin (PRM)
- Meeting Peak +PRM requires around 85 GW of new capability plus 45 aGW of additional energy of which 28 aGW need to be zero emitting resources to meet policies gives us a set of needs to meet.

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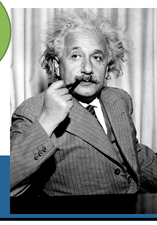
Calculating Nameplate* Need	Solar	Solar Plus Battery	Wind	4-hour Battery/LDES	Gas Peaker/SMR
Peak Contribution*	0-15%	0-40%	5-41%	62%/100%*	95%/95%
Energy	20%	20%	33%	88% efficient/42% Efficient	27%-38%/95%
Peak Load + Retirement MW+ PRM	19 /.075=253 GW	19/.2=95 GW	19 /.18=106 GW	19 /.62=31 GW* 30 /1=30 GW *	24 /.95=25 GW 10 /.95=11 GW
Clean/RPS requirements	18/.2= 90 GW	18 /.25= 92 GW	18 /.33= 54 GW	31/.88/.2 = 176 GW add 30/.42/.25= 286 GW add	N/A 11 *.95=10 aGW

Solving the capacity problem first, at least 97 GW additional buildout would be required to meet peak, assuming all the 25 GW gas, 30 GW LDES and 11 GW SMR are built. An additional 54 GW of wind for policies.



It seems like 151 GW could be the lowest build, but batteries increase average load by 13% to 186% depending on efficiency for every hour you want to shift, most of that new load for economic and policy purposes need to be served with renewables.

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Calculating Nameplate* Need	Solar	Solar Plus Battery	Wind	4-hour Battery/LDES	Gas Peaker/SMR
Peak Contribution*	0-15%	0-40%	5-41%	62%/100%*	95%/95%
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So, the 151 GW would be the lowest build for capacity and policy that is not influenced by the increased load due to storage, but adding the additional energy/policy requirements and economic considerations due to storage will likely add 255 - 462 GW of renewables. Thus, a new total build is likely between 406 - 613 GW.

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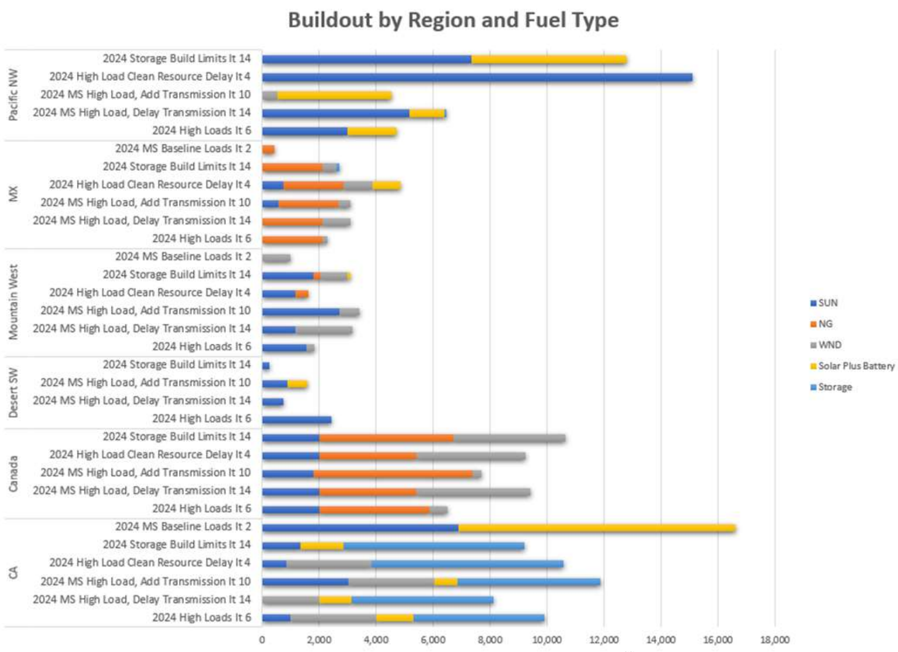
Additional Caveats – Should the Builds be this Big?

- For this forecast, we **do not** model out-of-region EE and DR above what is forecast as expected in out-of-region loads.
  - In region EE and DR increases over time in alignment with the 2021 Power Plan
- Both EE and DR would likely be more efficient at meeting peak needs (especially in summer, when the WECC peaks) than most resources available to select.
- Energy efficiency also offsets policies by reducing average demand
- For example, by the simple math on the previous pages if a little over 13 aGW of EE was available and cost-effective throughout the WECC, it could defer up to 200 GW of build for peaking (storage and supporting energy) and 40 GW for policies.
- Another example, neglecting the effect of policies and the economic risk, if 20 GW of additional gas could be built and likely only operated < 25% of the time for peak it could avoid the 200 GW of build for peaking.

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	**68 billion** 81% Fixed 19% Variable	**50 billion** 83% Fixed 17% Variable



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)

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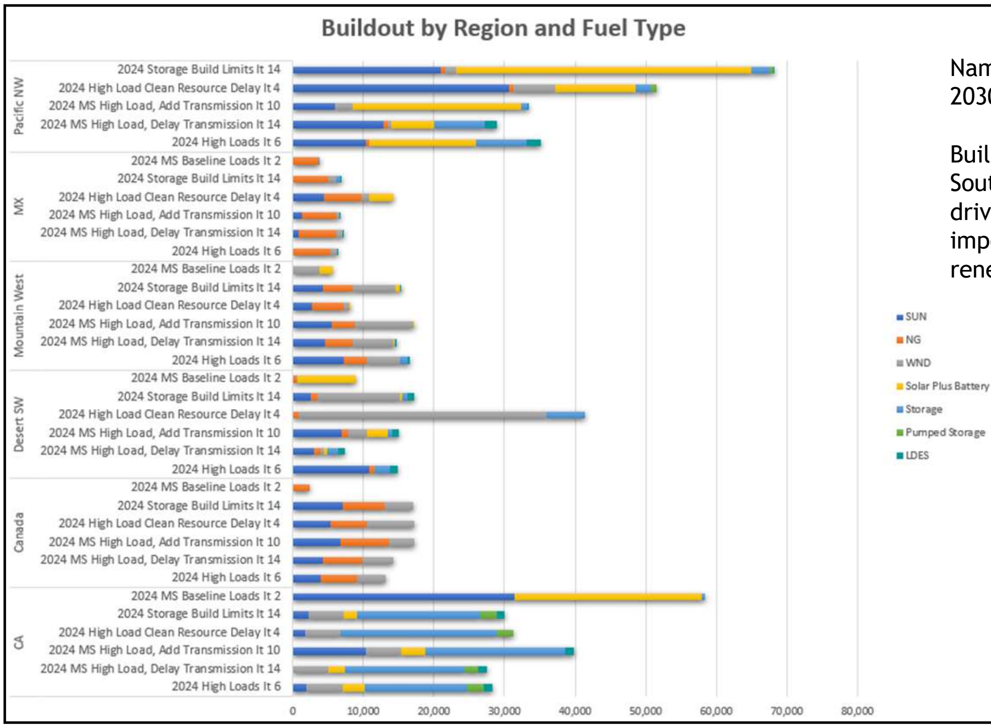

Nameplate Megawatts by 2030

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

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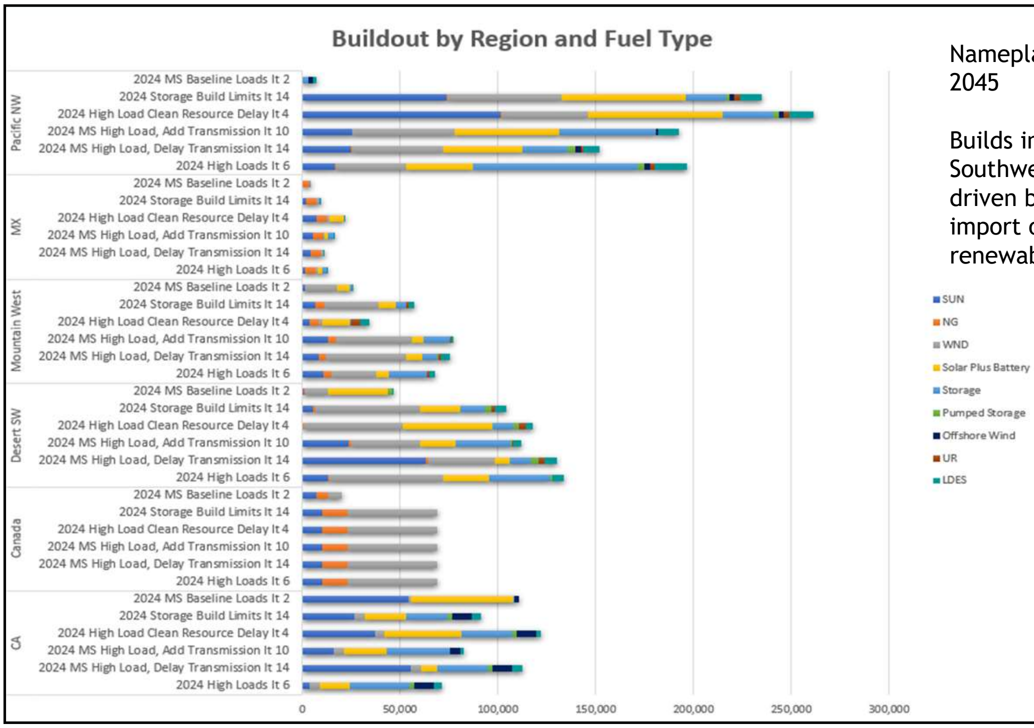

Nameplate Megawatts by 2045

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

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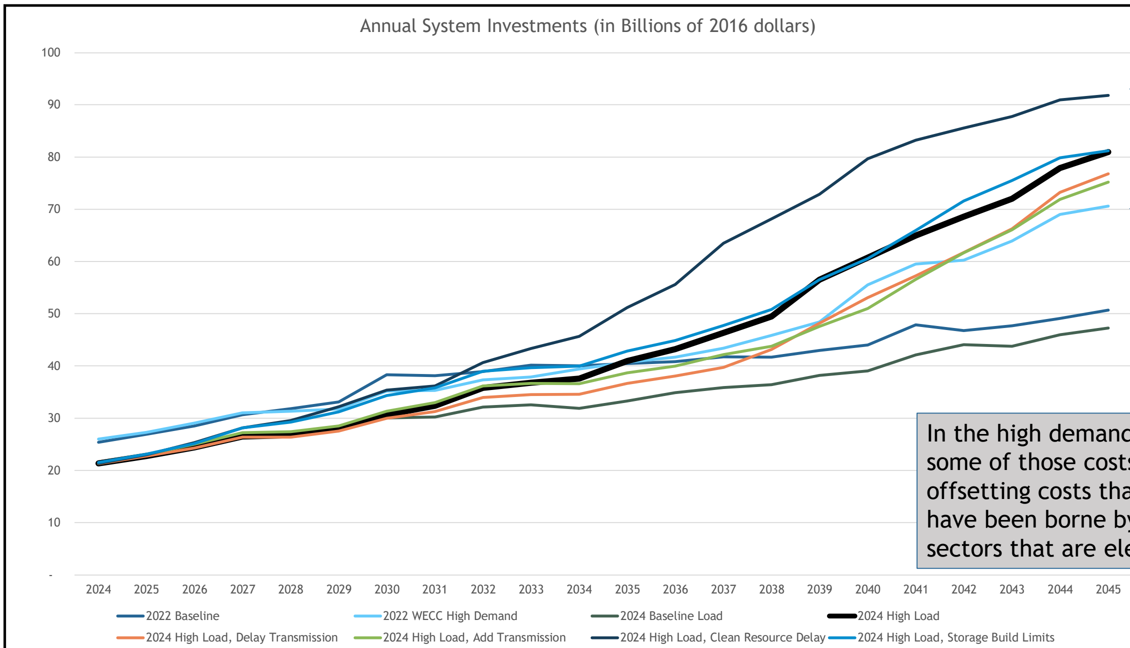

High Demand

Low Demand

In the high demand scenarios, some of those costs are offsetting costs that would have been borne by other sectors that are electrifying.

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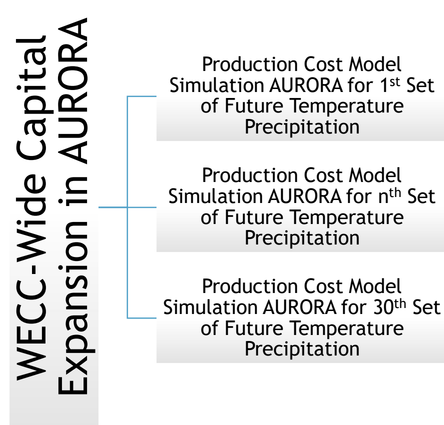
Review of Price Study Methodology

- Simulate hourly market prices and avoided emissions rate forecast in AURORA over 30 regional hydro/load/wind conditions for multiple scenarios
- Mid-Columbia (Mid-C) Prices are the average of GCPUD, CCPUD and DCPUD zonal prices



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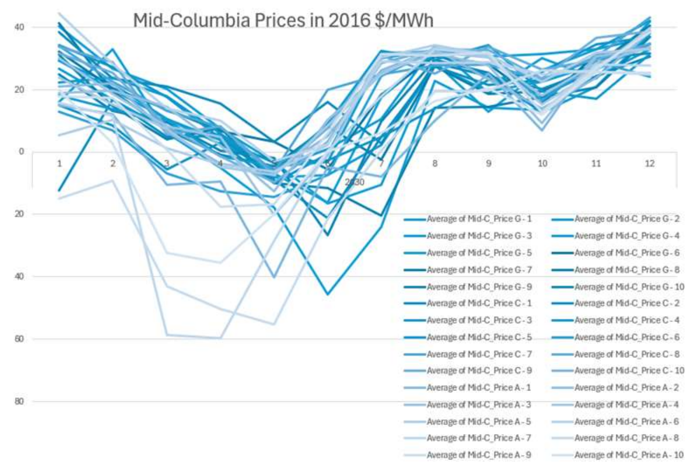
Review: Monthly Variation Will Still Depend Heavily on Hydro Condition

- 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



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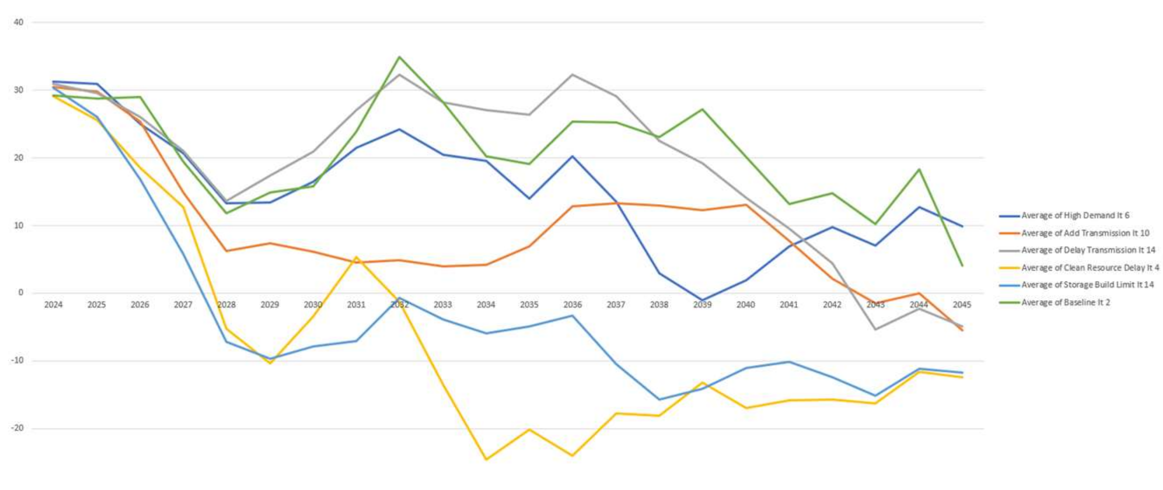
Annual Price Growth By Resource Risk Scenario



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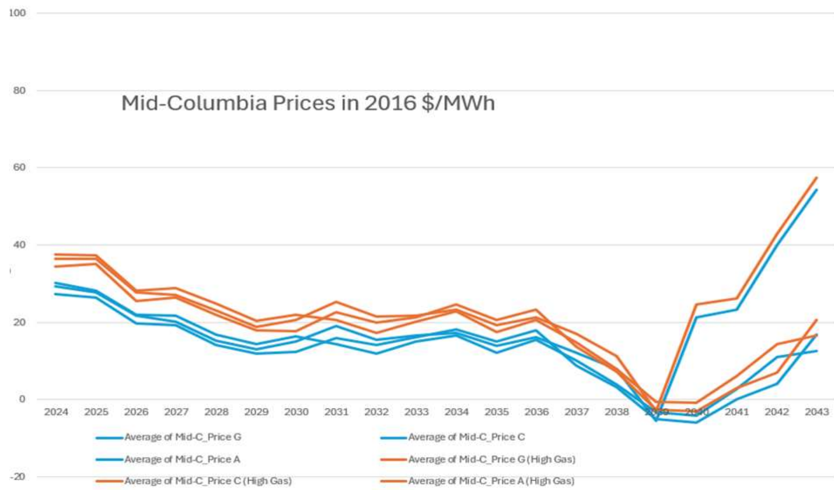
Annual Price Growth by Hydro and Gas Price Risk Sensitivities



Higher Henry Hub index gas prices (on average 1.2 $/MMBtu higher) lead to 5 $/MWh higher pricing.

NW prices show gas on the margin 60% of the time

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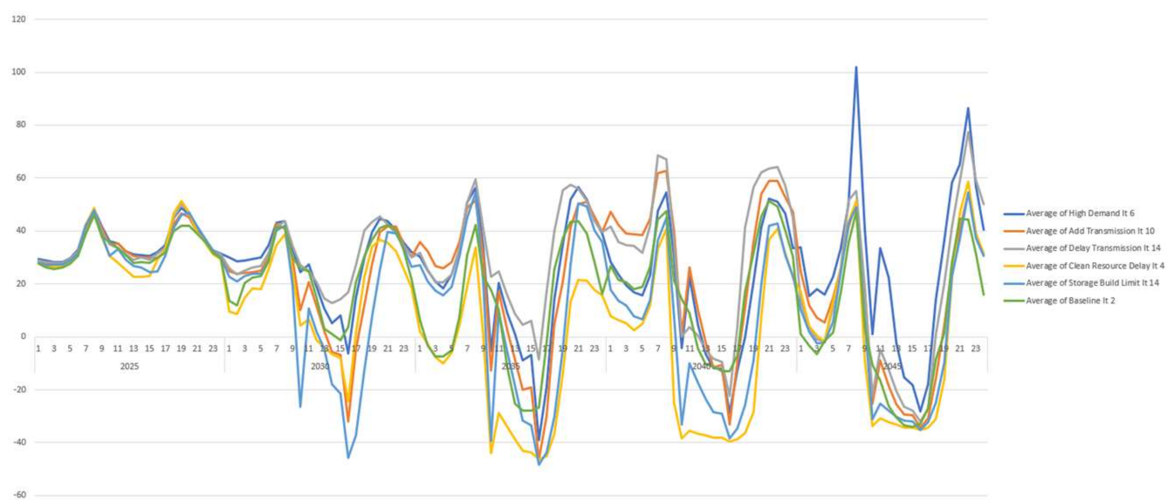
Winter Daily Price Shape By Scenario



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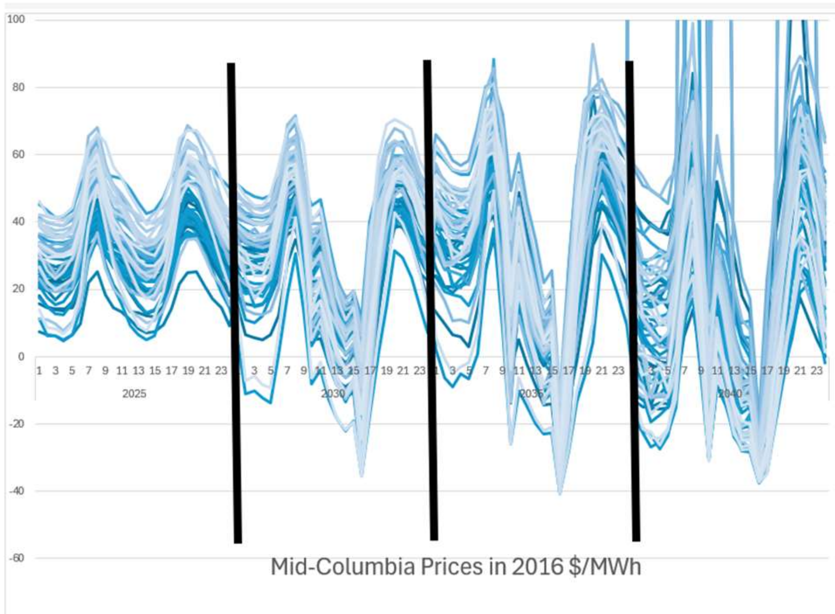
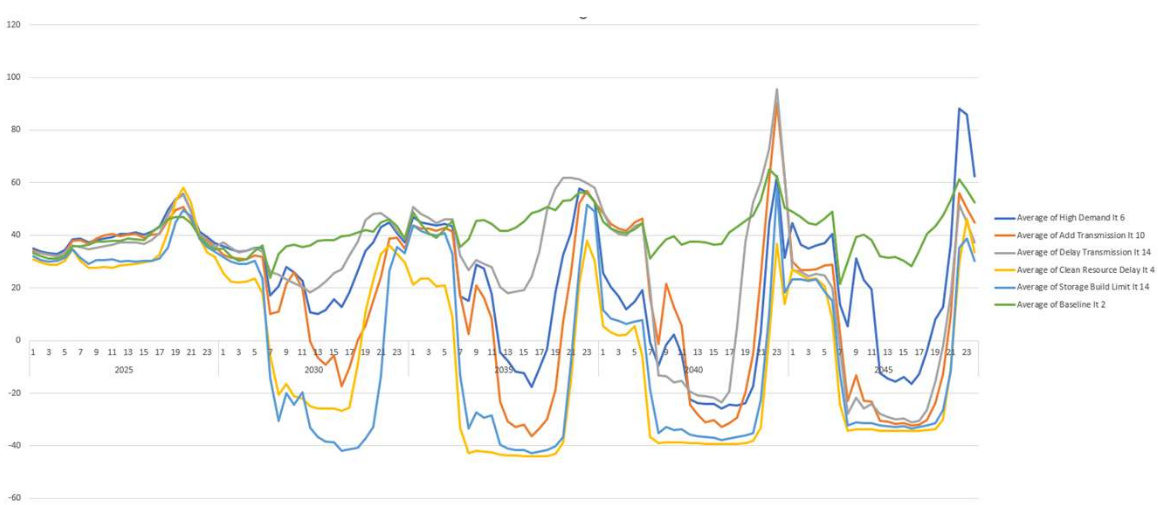
Winter Price Shape by Hydro Condition in 2025, 2030, 2035 and 2040

- Prices continue to trend downward overnight and midday and trend upward during morning and evening ramp periods.
- The price spikes in certain water conditions indicate likely operational challenges in the 2040s

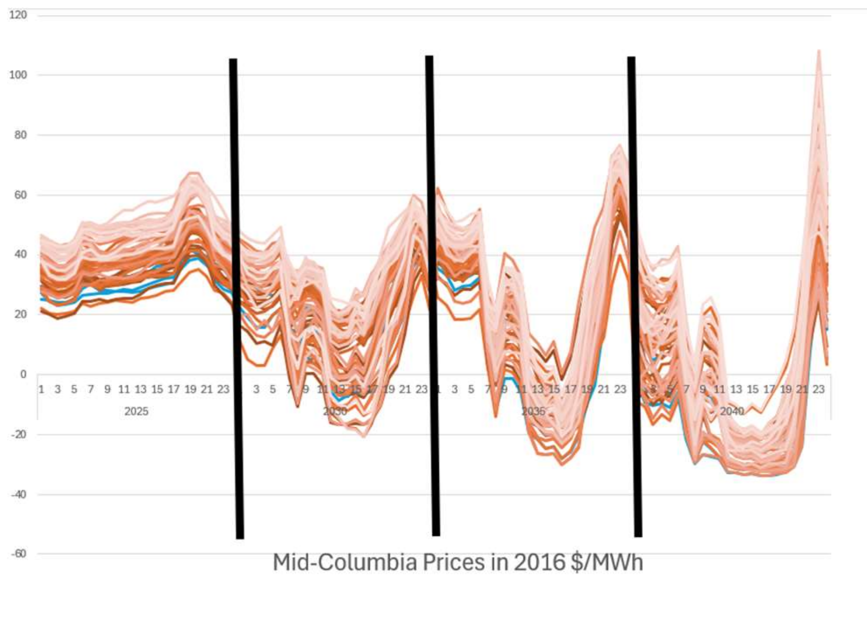


Summer Daily Price Shape By Scenario



Summer Price Shape by Hydro Condition in 2025, 2030, 2035 and 2040

- Prices continue to trend downward midday and trend upward overnight and during morning and evening ramp periods.
- Net coincident peak is pushed later into the evening



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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.

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Avoided Emissions Rate Methodology

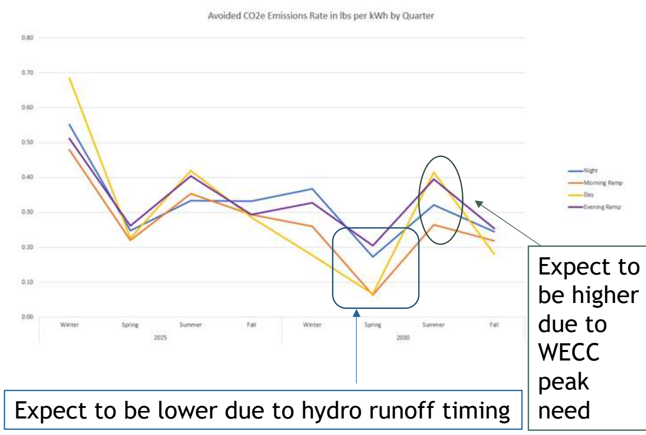
The *avoided emissions rate* over the output changed in the WECC from the flat drop of 1000 MW is

$$\frac{Emissions_{100} \;\; - Emissions_0}{Output_{1000} - Output_0} = X\ lbs/kWh$$

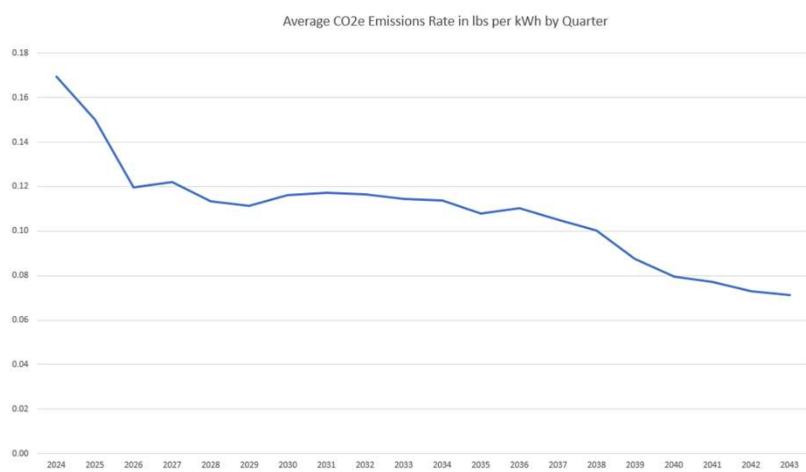
Variable Definition:

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

High Demand Scenario

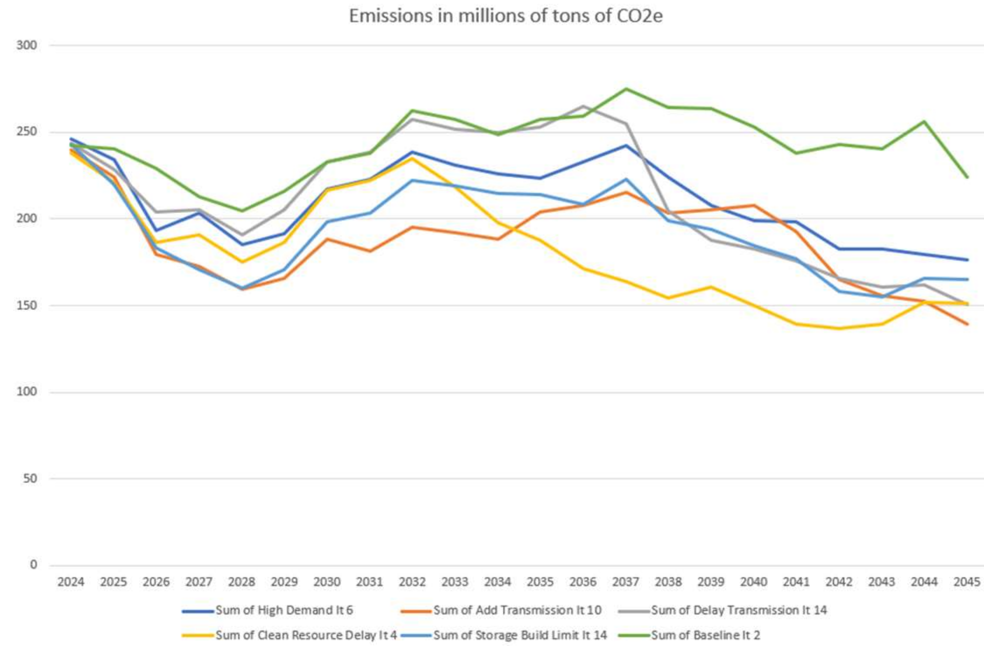


Average Emissions Rate Decreases Over Time, Between 25% and 33% of Marginal Rate



High Demand Scenario

Annual Emissions in tons of CO2e by Buildout Scenario



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Prices and Emissions Summary

- In general, prices and emissions trend down over the course of the study due to investment in lower emitting resources.
- On a daily basis, price and emissions variability increasingly follow the availability of wind and especially, solar generation.
  - Midday when solar generation is peaking prices are consistently low.
  - During the sunrise and sunset periods, prices and emissions are volatile reflecting increasing utilization of emitting, high variable cost resources (like gas plants)
- Some of the variability in prices should be mitigated further by improving storage unit operation

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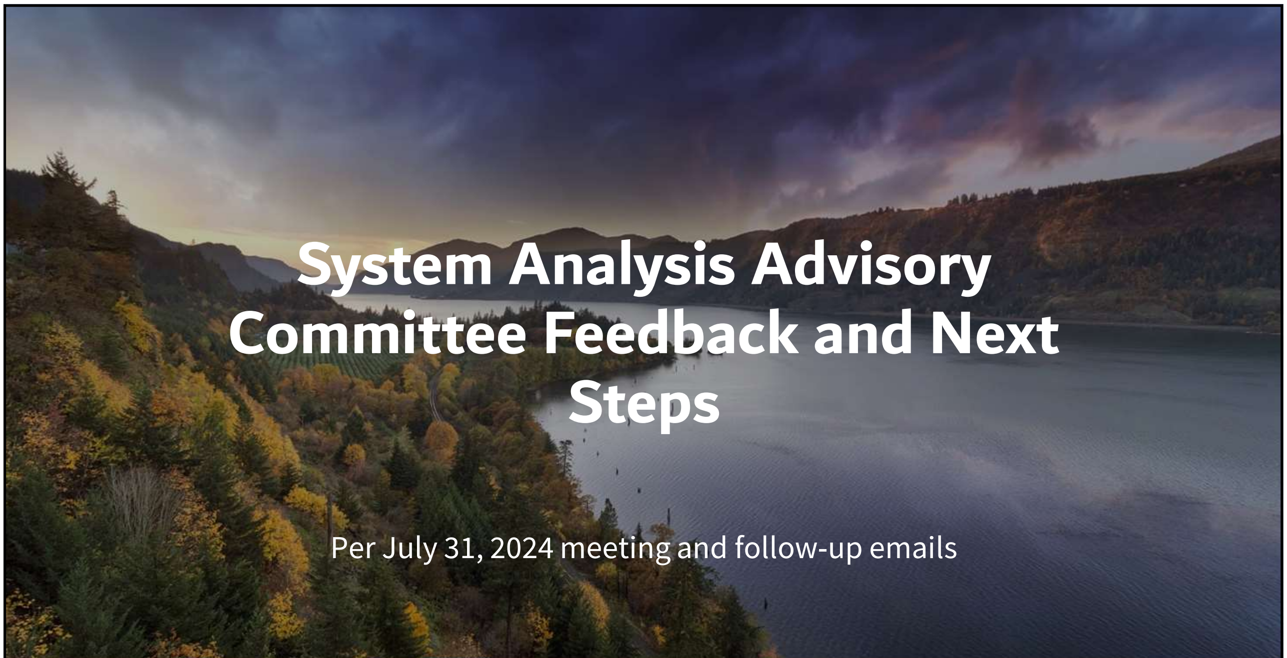

System Analysis Advisory Committee Feedback and Next Steps

Per July 31, 2024 meeting and follow-up emails

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Feedback

- There were concerns about reflecting wildfire risk and effect of gas prices by LNG export facilities
  - Staff signaled we would be looking in further detail on both in the upcoming power plan.
- There was concern about not modeling above expected utility demand response outside the region
  - Staff requested recommendations on data sourcing that would support such modeling in the future.
- There were a number of questions related to long duration storage modeling
  - Staff signaled we would be investigating methods to better do this in the upcoming plan work.

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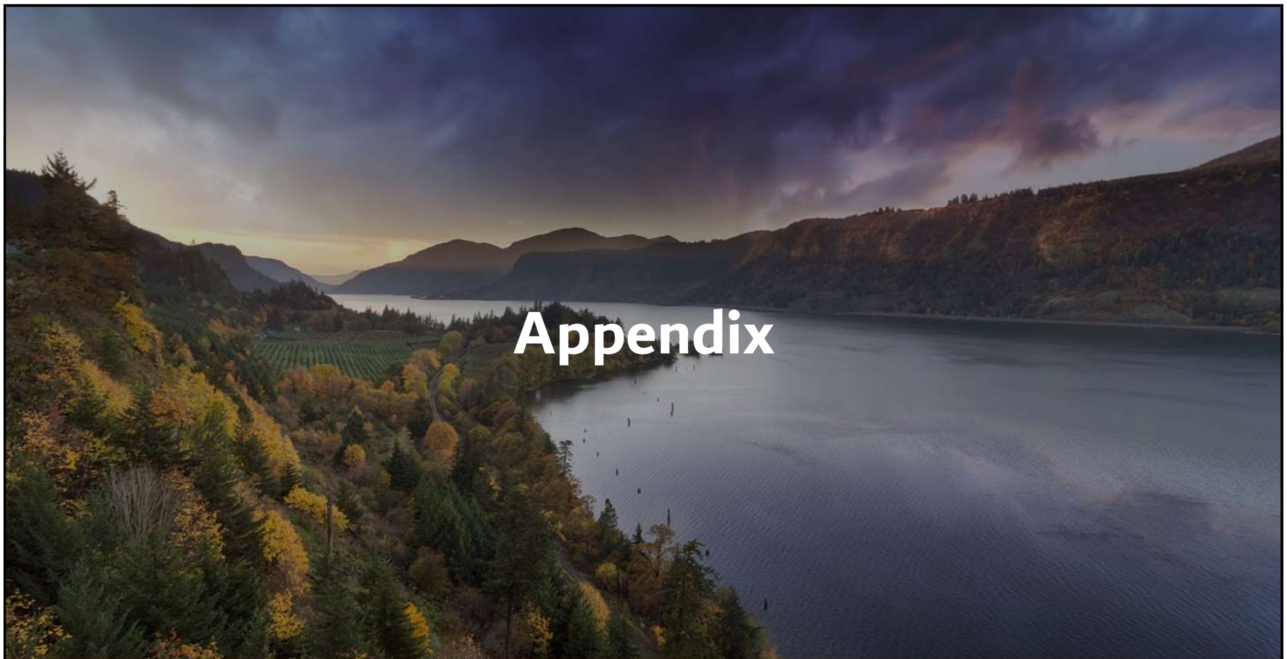
Next Steps

- Staff will report detailed buildout, price and avoided emissions rate results on the website for stakeholder access.
- Work will continue to hone the interpretation of the Inflation Reduction Act and improve hydro and long duration storage modeling in AURORA for the plan market buildout support.

Questions?

John Ollis
jollis@nwcouncil.org



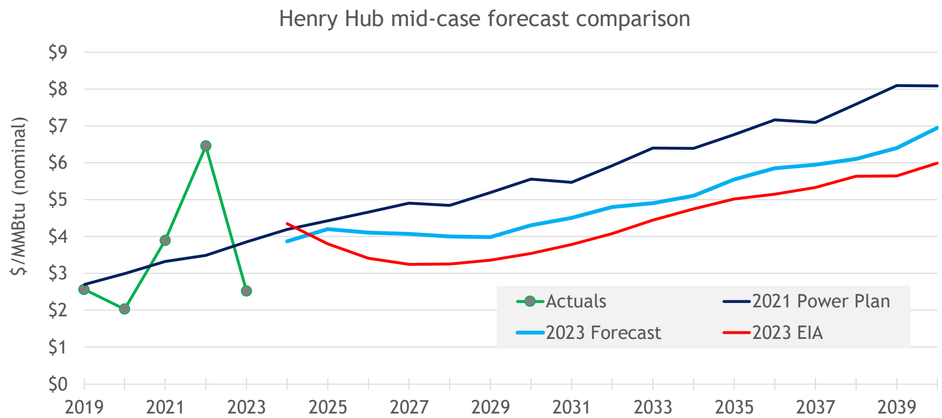
Recall Technical Challenges Required Using Draft Information for Adequacy Assessment

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 informed final adequacy assessment results
   – WECC buildout outside the NW (and in general) was significantly smaller

Henry Hub Mid-Case Price Forecast



Long term price forecast are lower than 2021 Power Plan forecast

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Solar and Solar Plus 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	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

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

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

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

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

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

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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

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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%

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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

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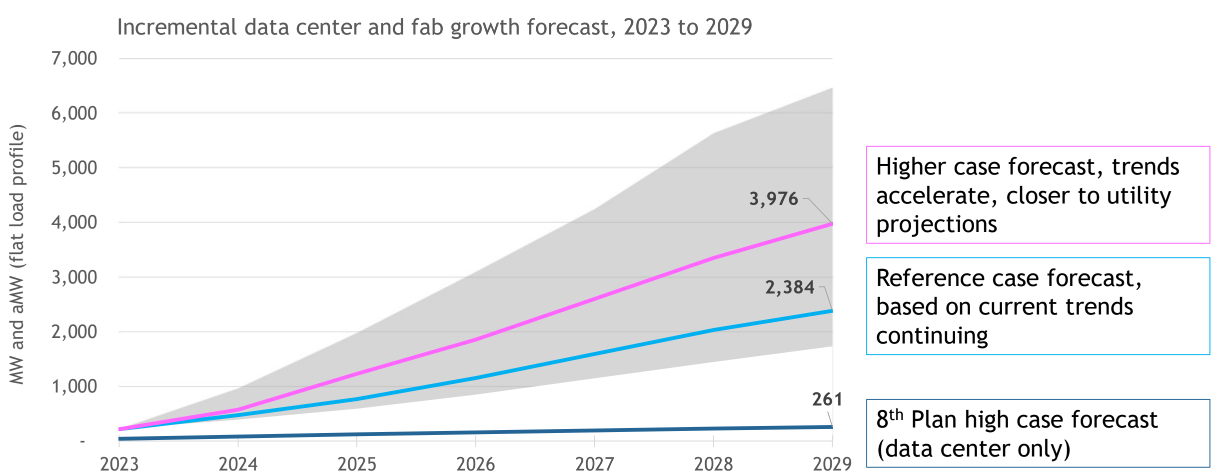
Data center & chip fab forecasts



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