Northwest **Power** and
Conservation Council

February 7, 2023

MEMORANDUM

TO: **Council Members**

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

SUBJECT: **Annual Wholesale Electricity Price Forecast**

BACKGROUND:

Presenter: John Ollis, Dor Hirsh Bar Gai

Summary: This presentation will review the process used to create the market price forecast and the underlying buildout information for different policy 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 price forecasts for resource planning or providing avoided market emissions rate guidance for state agencies developing building codes.

851 S.W. Sixth Avenue, Suite 1100
Portland, Oregon 97204-1348
www.nwcouncil.org

Bill Edmonds
Executive Director

503-222-5161
800-452-5161

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 early look at how the plan work compares to current market behavior and highlights some of the data sources the staff uses to monitor this behavior for reference.

More Info: Presentation of draft results relating to buildouts to inform the adequacy assessment work

August 31st SAAC Meeting

August 10th SAAC Meeting

July 27th SAAC/RAAC Meeting

Wholesale Power Price Forecast from the 2021 Plan

Market Price Study, Results and Analysis

Dor Hirsh Bar Gai/John Ollis

February 14, 2023

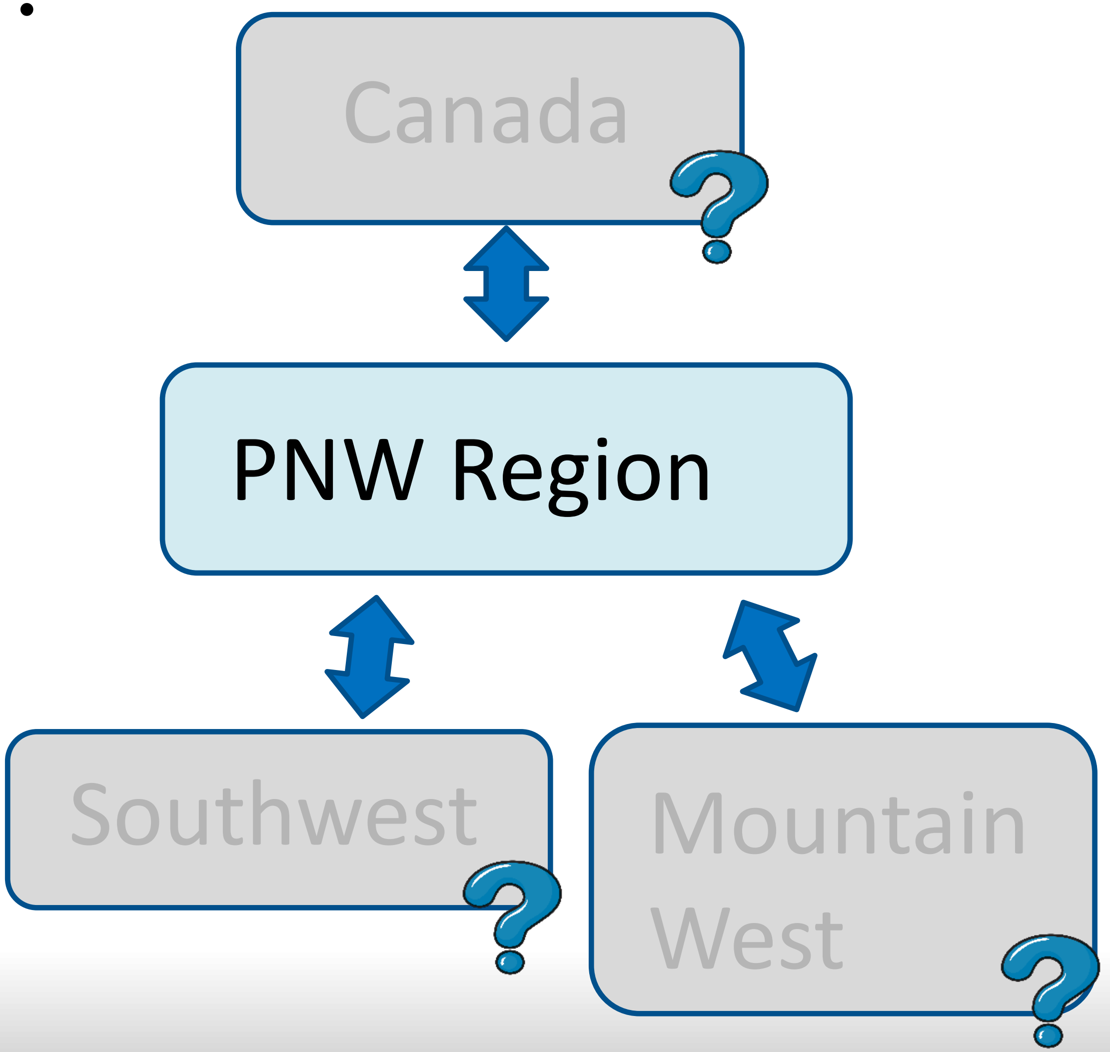
Power Committee

Discussion Today

- WECC buildouts scenario results and analysis review
- Using buildouts to determine wholesale market prices and avoided emissions rates under different scenarios and conditions
- Identifying market risks to monitor
- Improvements for the future

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

1. <u>Economics</u>
   - 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. <u>Adequacy</u>
   - 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.

Market Price Scenarios

Scenarios

Helped RAAC frame market risk in 2027 time period and vetted by SAAC as useful for understanding prices

- Buildout Scenarios:
  - Baseline
  - Limited Markets (no PRMs)
  - High WECC Demand (Increased electrification)
  - Persistent Global Instability (Build limitations and high gas prices)
  - Organized Market (One PRM, wheeling rate)
  - Emissions Price (Universal Carbon Price)
  - No Gas Build Limits (No limits on gas plant builds)

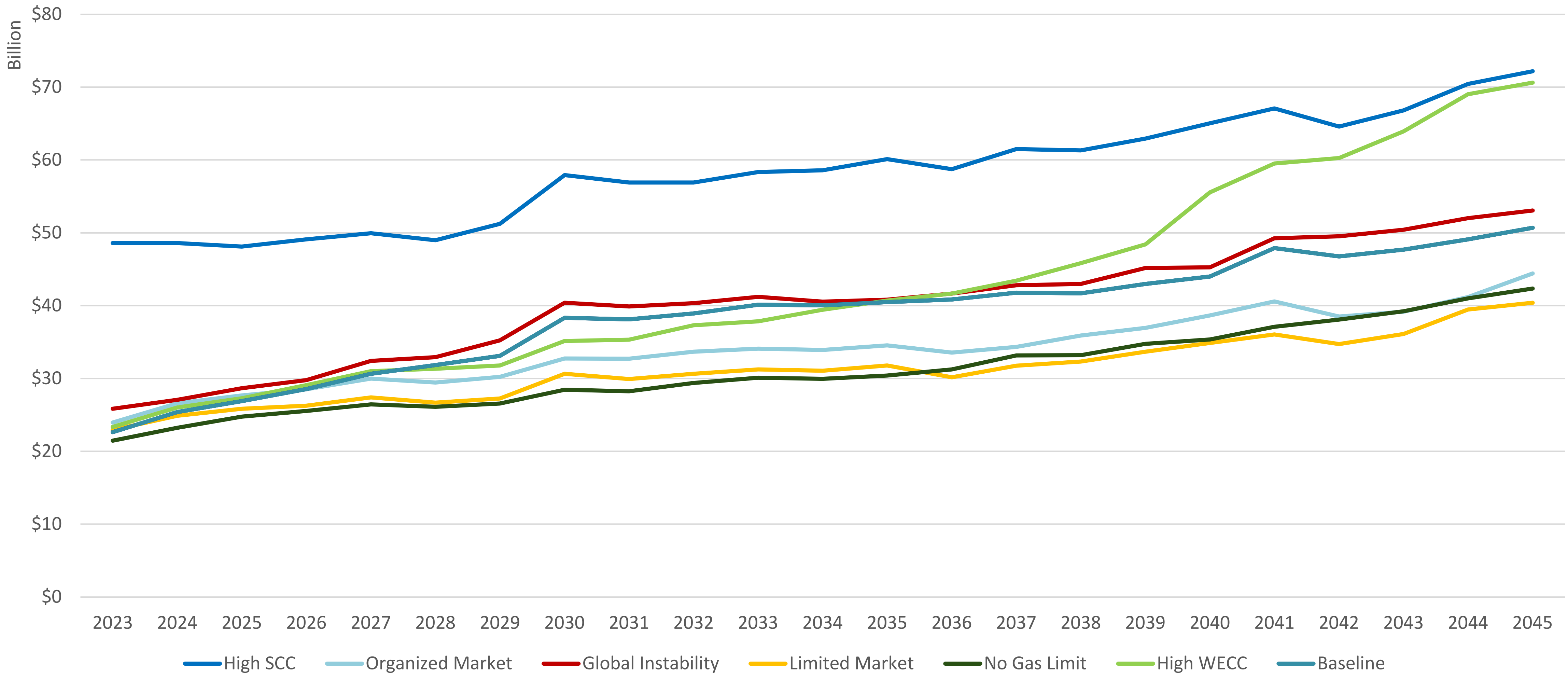
Review Buildouts Information

Scenario	Baseline	Persistent Global Instability	High WECC Demand – West Coast	High Emissions Price	No Gas Build Limits	Limited Markets	Organized Markets
Meets Reserve Margins	Yes	Yes	Yes	Yes*	Yes	No	Borderline**
Meets Policies	Yes	Yes	Yes	Yes	No	No	Borderline
Build Size	**2027: 110 GW** **2045: 252 GW**	2027: 98 GW 2045: 257 GW	2027: 91 GW 2045: 314 GW	2027: 125 GW 2045: 267 GW	2027: 67 GW 2045: 161 GW	2027: 73 GW 2045: 112 GW	2027: 79 GW 2045: 181 GW
Annual System Cost in 2045 (2016 $)	**50 billion** 83% Fixed 17% Variable	**53 billion** 75% Fixed 25% Variable	**68 billion** 81% Fixed 19% Variable	**72 billion** 61% Fixed 39% Variable	**42 billion** 46% Fixed 54% Variable	**40 billion** 46% Fixed 54% Variable	**44 billion** 66% Fixed 34% Variable

* This scenario has operational issues and would likely require different policy pricing for more consistency

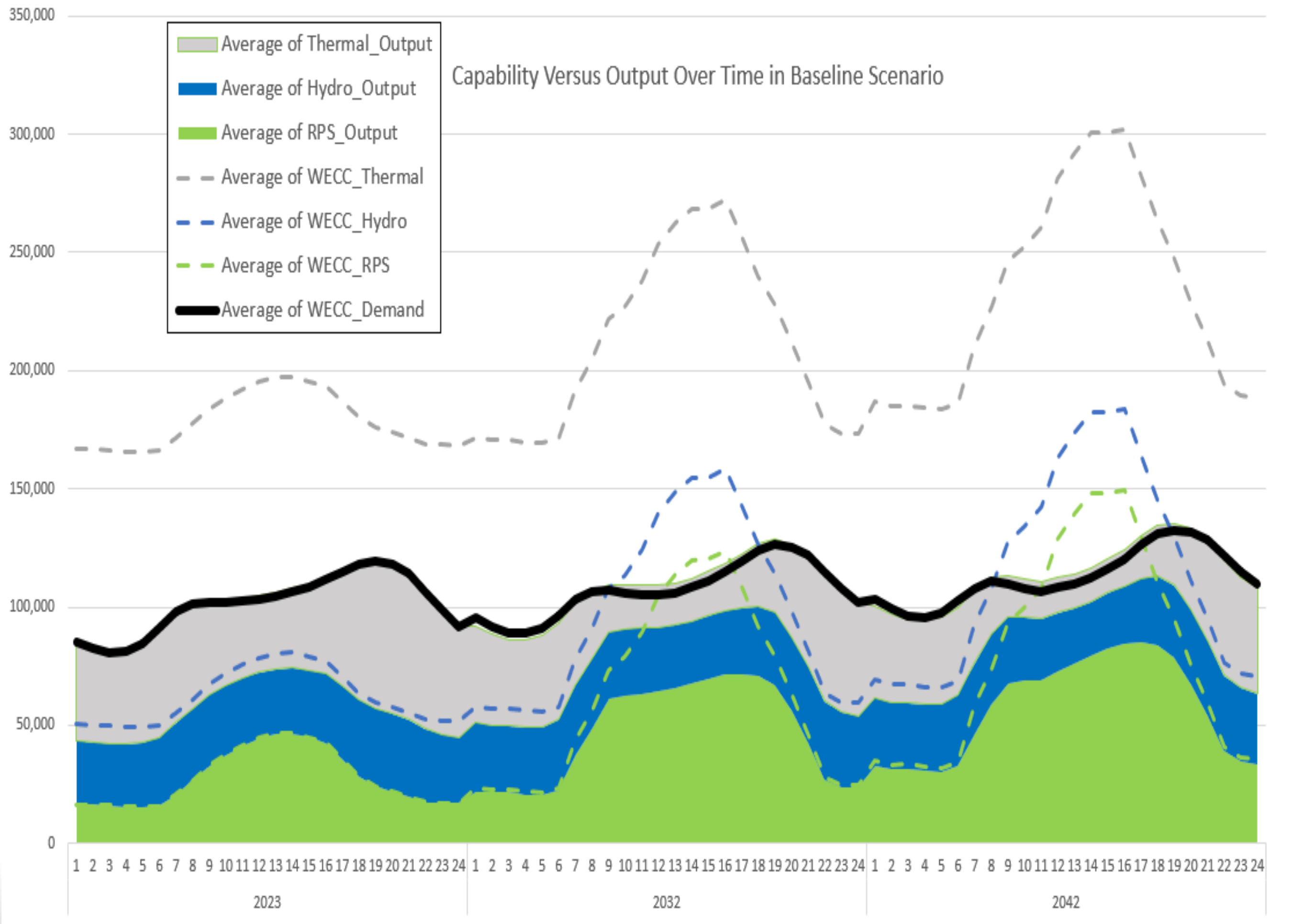
** This scenario relies more heavily on expensive demand side resources. Likely needs larger reserve margin.

Annual System Investments (in 2016 dollars)



High-Level Observations

- Policies are pushing towards lower variable cost, higher fixed cost system investments.
- These investments create a natural hedge against fuel price volatility
- Existing thermal plant use shifts from baseload to assisting in grid services and ramping
- Existing hydro and renewable plant use maximized for meeting policies



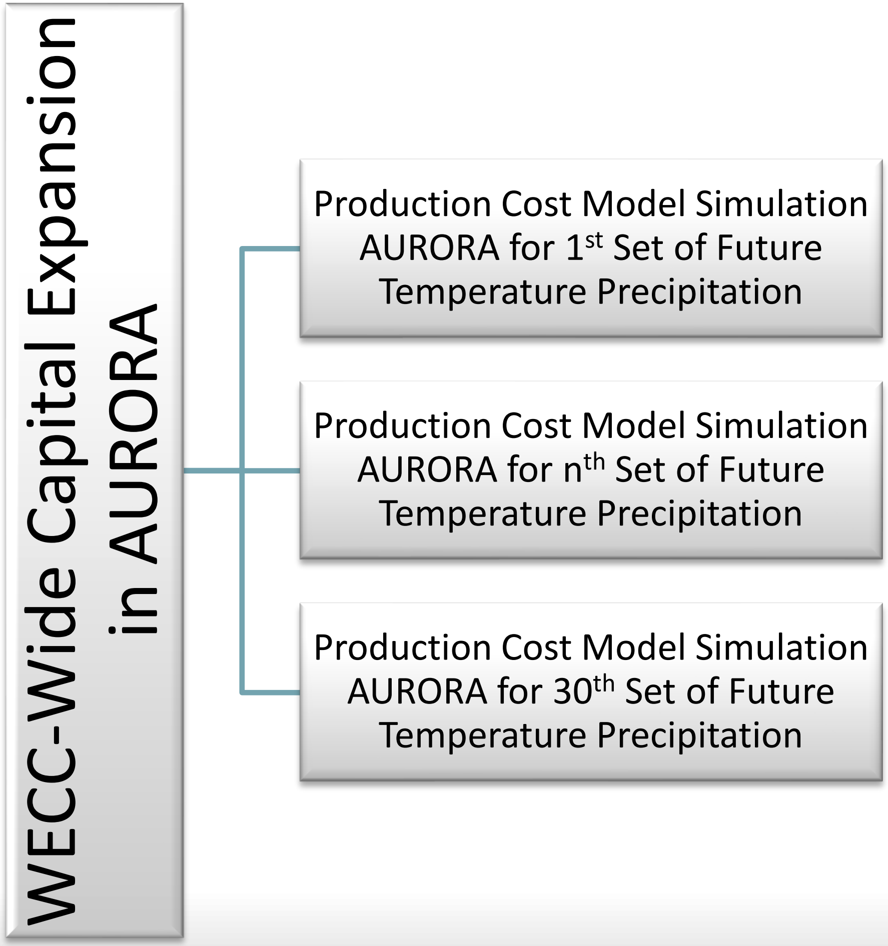
Wholesale Power Prices

Annual, Monthly, Hourly Price Results

Used in Council and stakeholder power planning

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

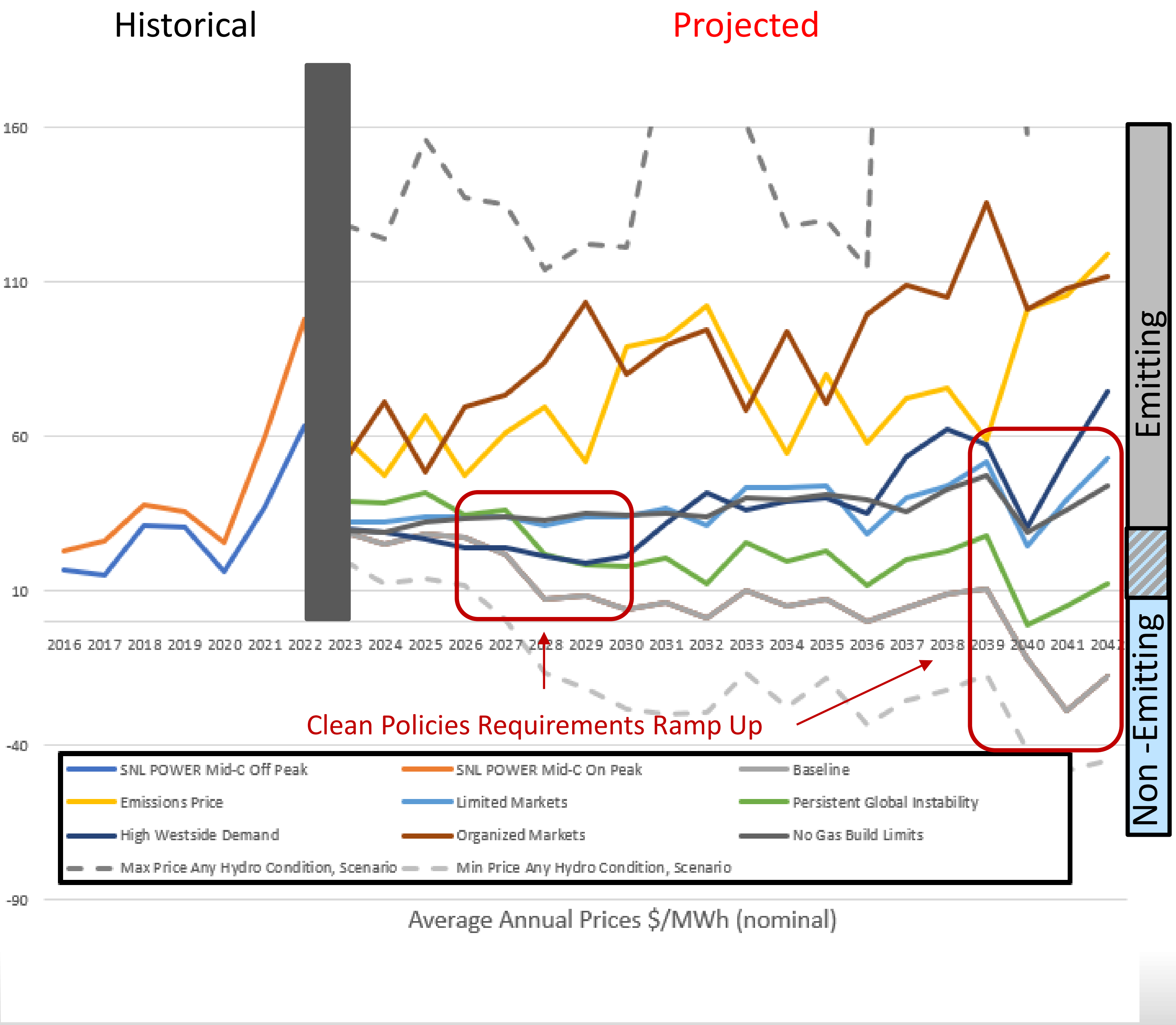


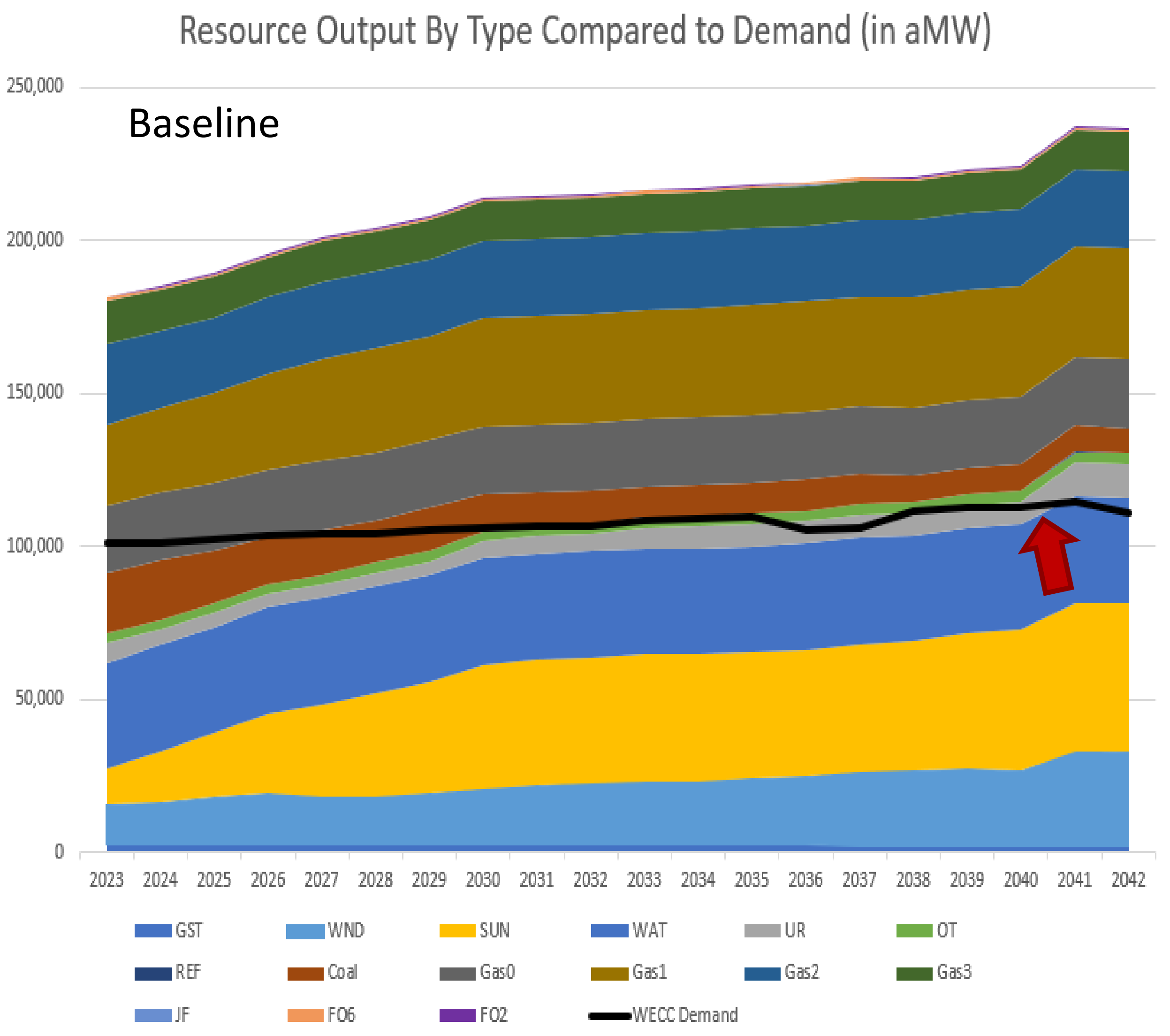
Significant Annual Price Uncertainty Depends Mostly on Policy

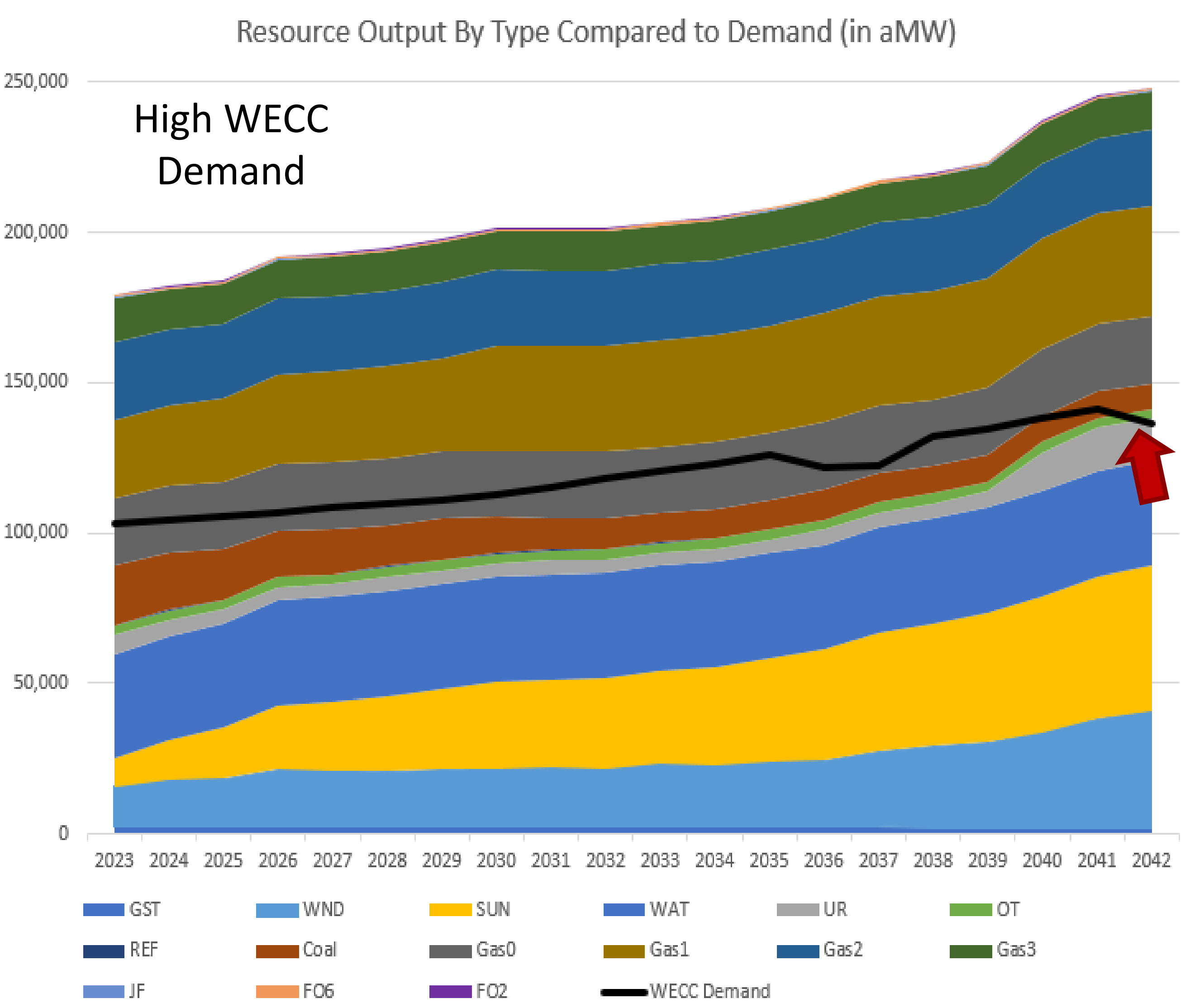
(1) Annual Mid-C prices have been fairly stable annually in recent history with variation closely tied to fuel price variability.

(2) Investments in lower variable cost resources like renewable generation will likely reduce correlation with fuel prices in the long run but create more volatile wholesale market prices based on availability of fuel.

(3) Depending on policies, future market structure and subsequent investment pace wholesale price trajectory may vary drastically.



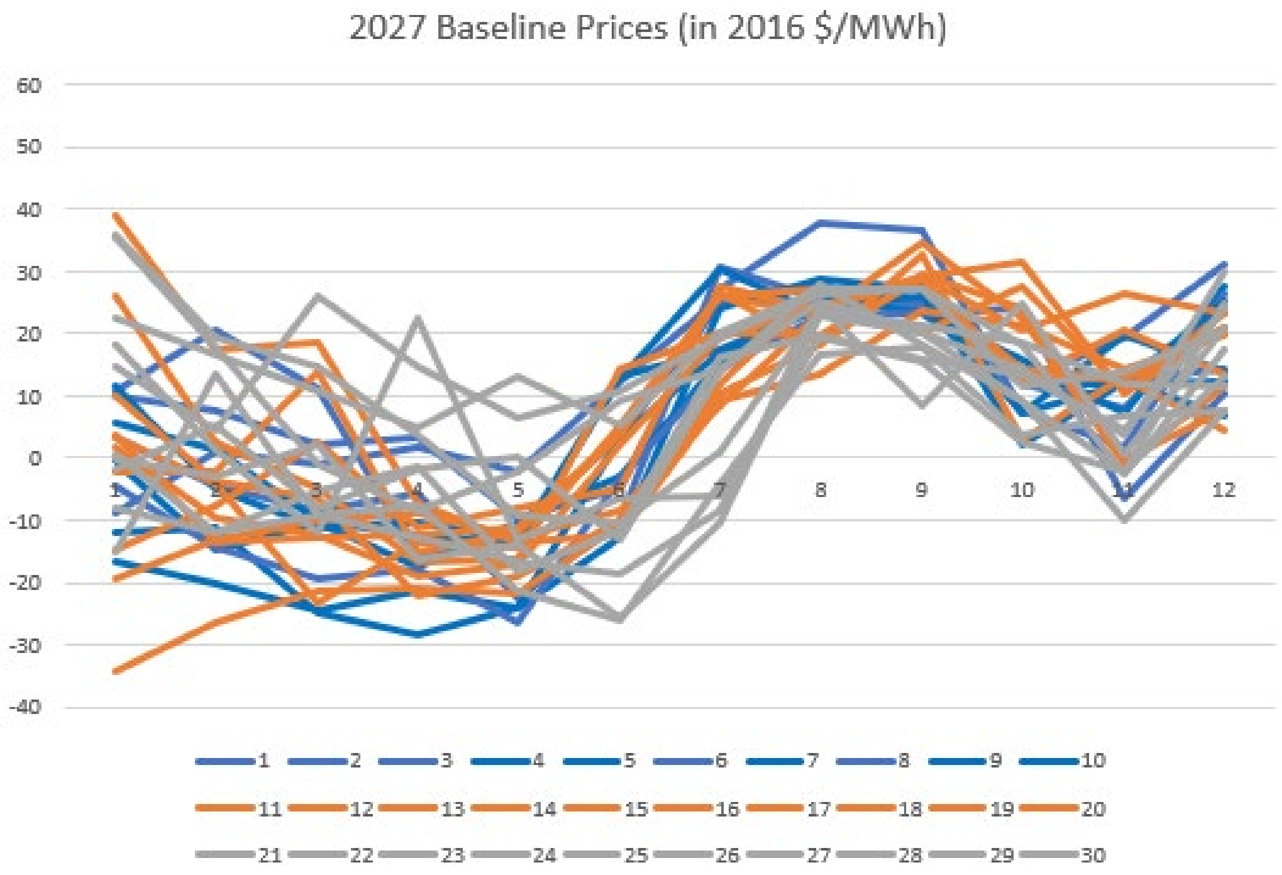




Since the zero emissions, low production cost resource expansion (and subsequent generation) outstrips growth of load during most periods, we expect emissions and prices to steadily fall.

Monthly Variation Will Still Depend Heavily on Hydro Condition

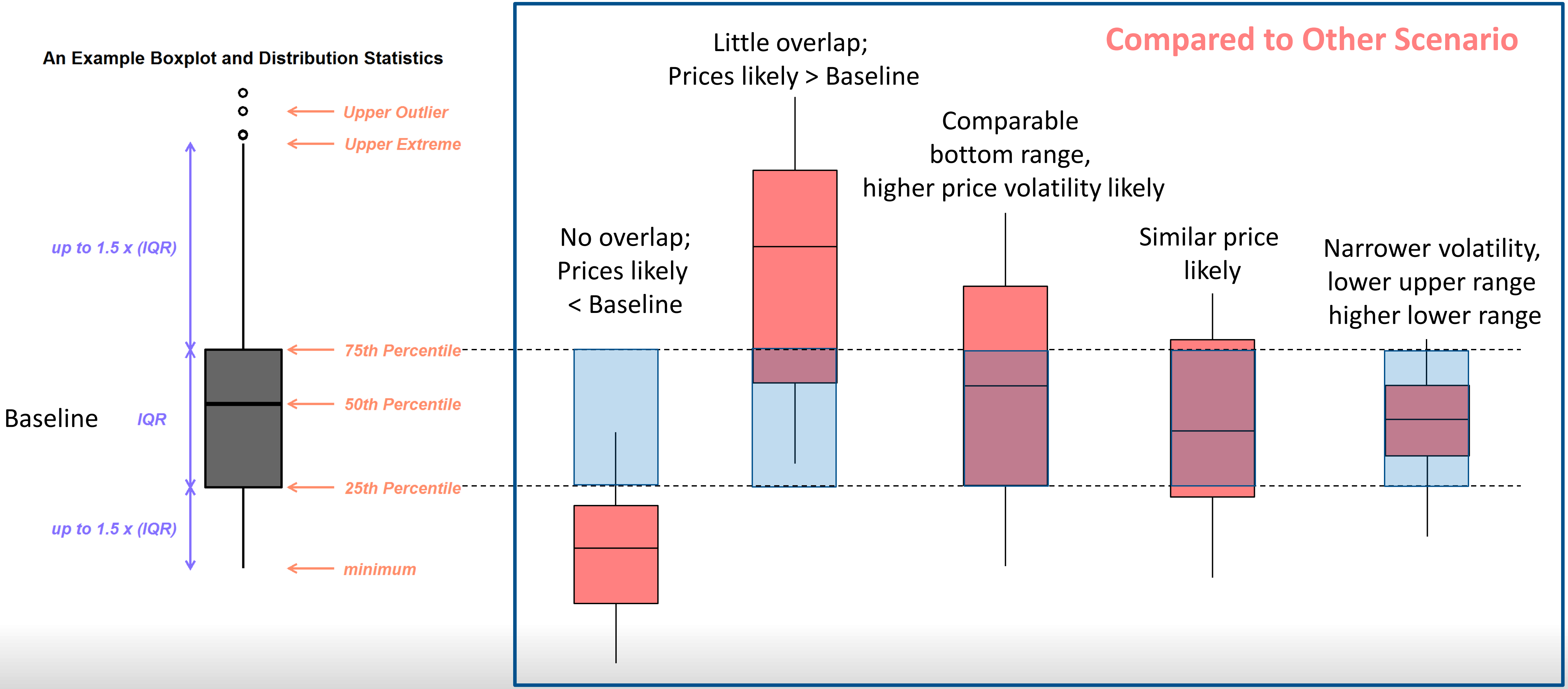
- Consistent with previous studies, Mid-C prices show greater dependency on hydro condition during the winter, spring and early summer depending on runoff.



Hourly Prices Summary

- In general, hourly prices show increasing wholesale price volatility in the winter within a decade and increasing volatility in the summer by the end of the study in most hours of the day.
- Most scenarios show continued price pressure around morning ramps in winter and evening ramps in summer and winter.
- Spring and Fall prices offer additional perspectives to consider to complement the analysis (see extra slides)

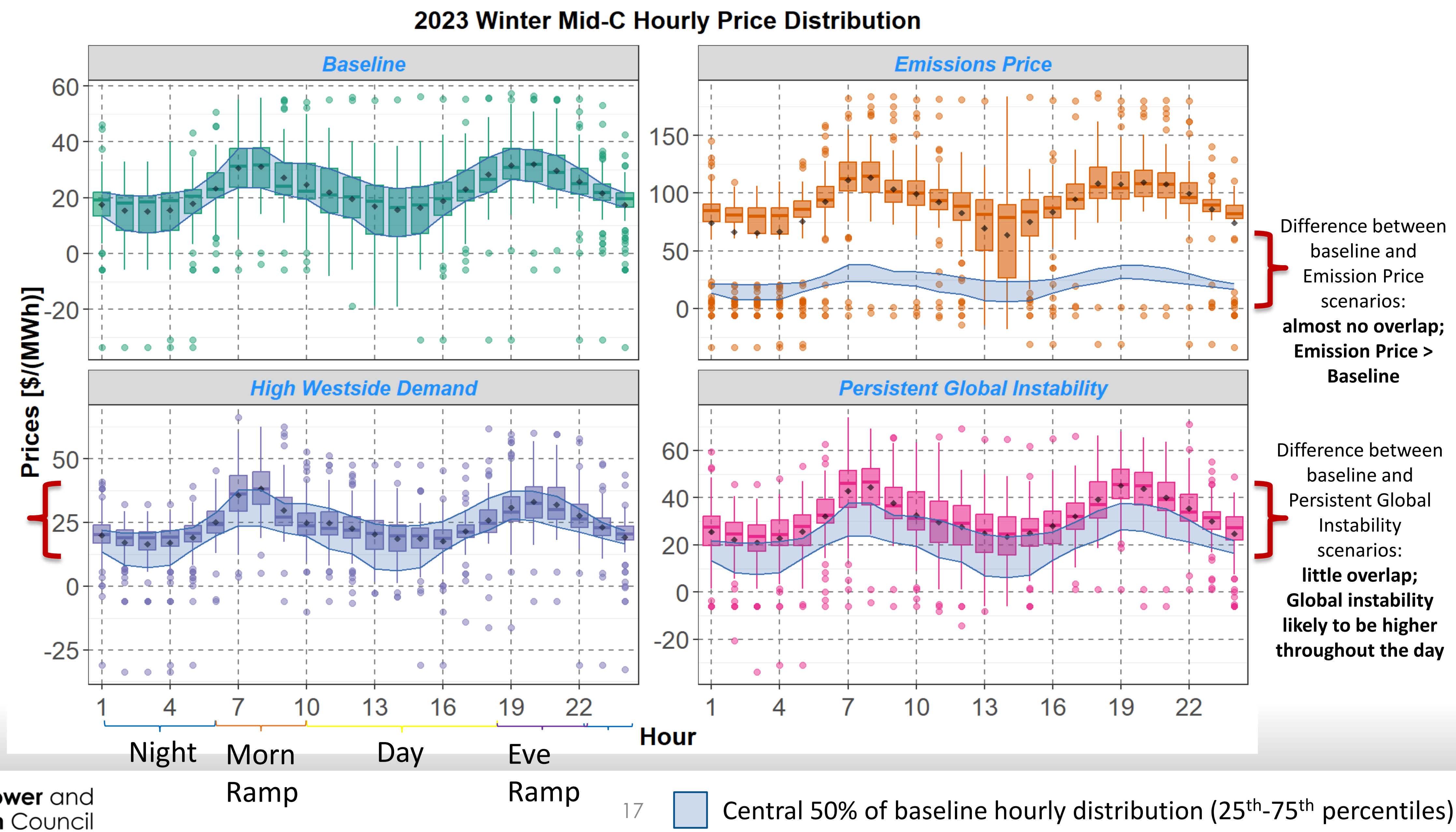
How to Interpret Box-and-Whisker Plots



Central 50% of baseline hourly distribution (25th-75th percentiles)

	2023	2033	2042
Winter	Price differences from the baseline observed mostly during the ramp hours* Global Instability higher volatility and prices than high WECC Emission price most expensive	Baseline, global instability, and emission price increased negative pricing across during day and night Daytime price reductions across scenarios High WECC demand narrow price distribution	Almost entirely negative pricing under baseline and emission price, but only likely in under global instability and high WECC with higher volatility High WECC demand likely most expensive Emission price likely cheapest except ramps
Summer	Price differences observed mostly during evening ramp hours* Persistent Global instability likely higher prices than High WECC demand Emission price most expensive	Increased volatility during ramp of high WECC demand, but lower prices during the day. Increased global instability prices. Reduction of morning ramp prices under emission price, including negative pricing	High WECC demand increased prices during ramp hours, but lower during the day. Global instability shows increased volatility. Emission price scenario low day and ramping prices, but higher night prices

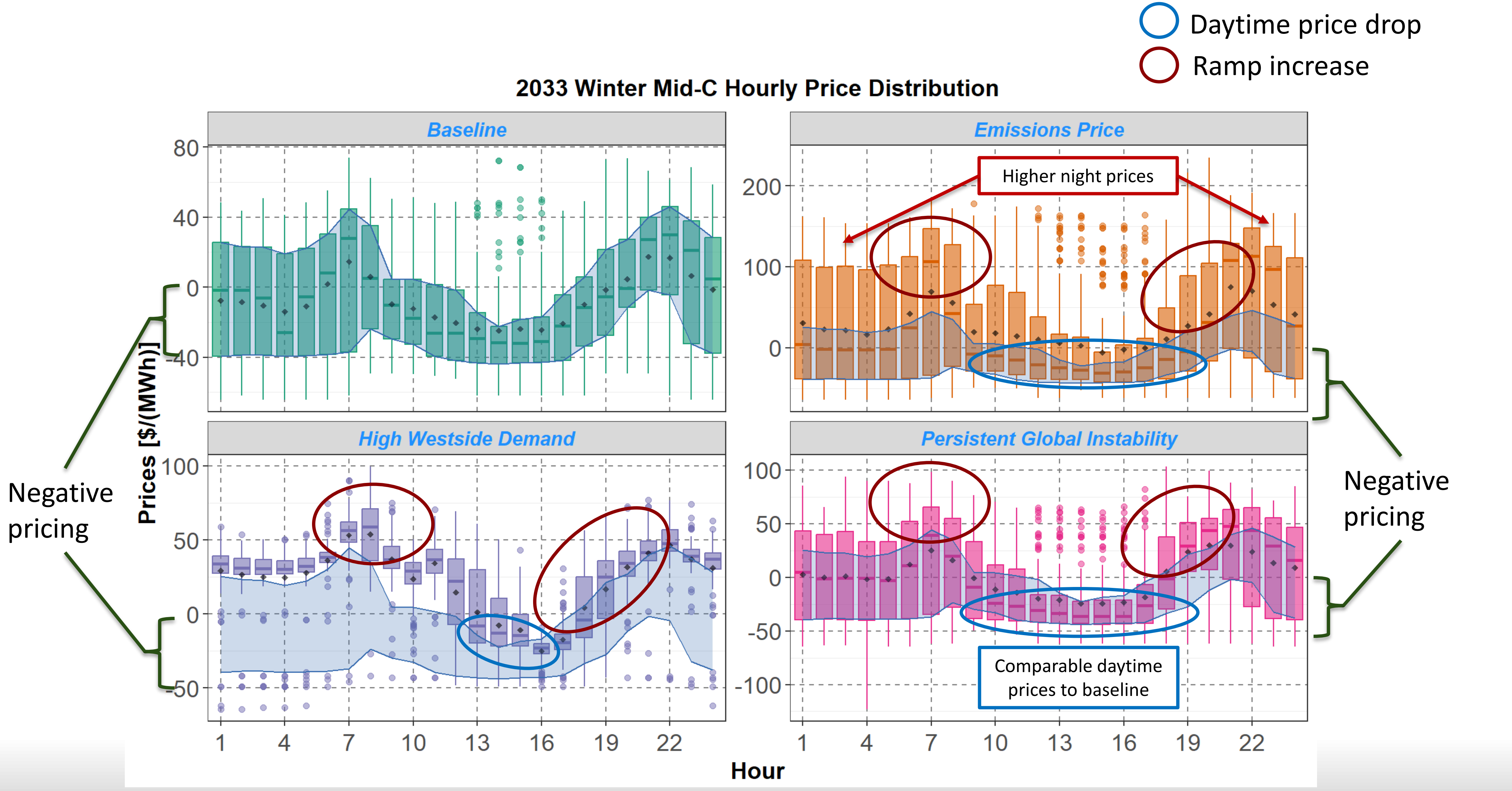
* Emission Price scenario an exception



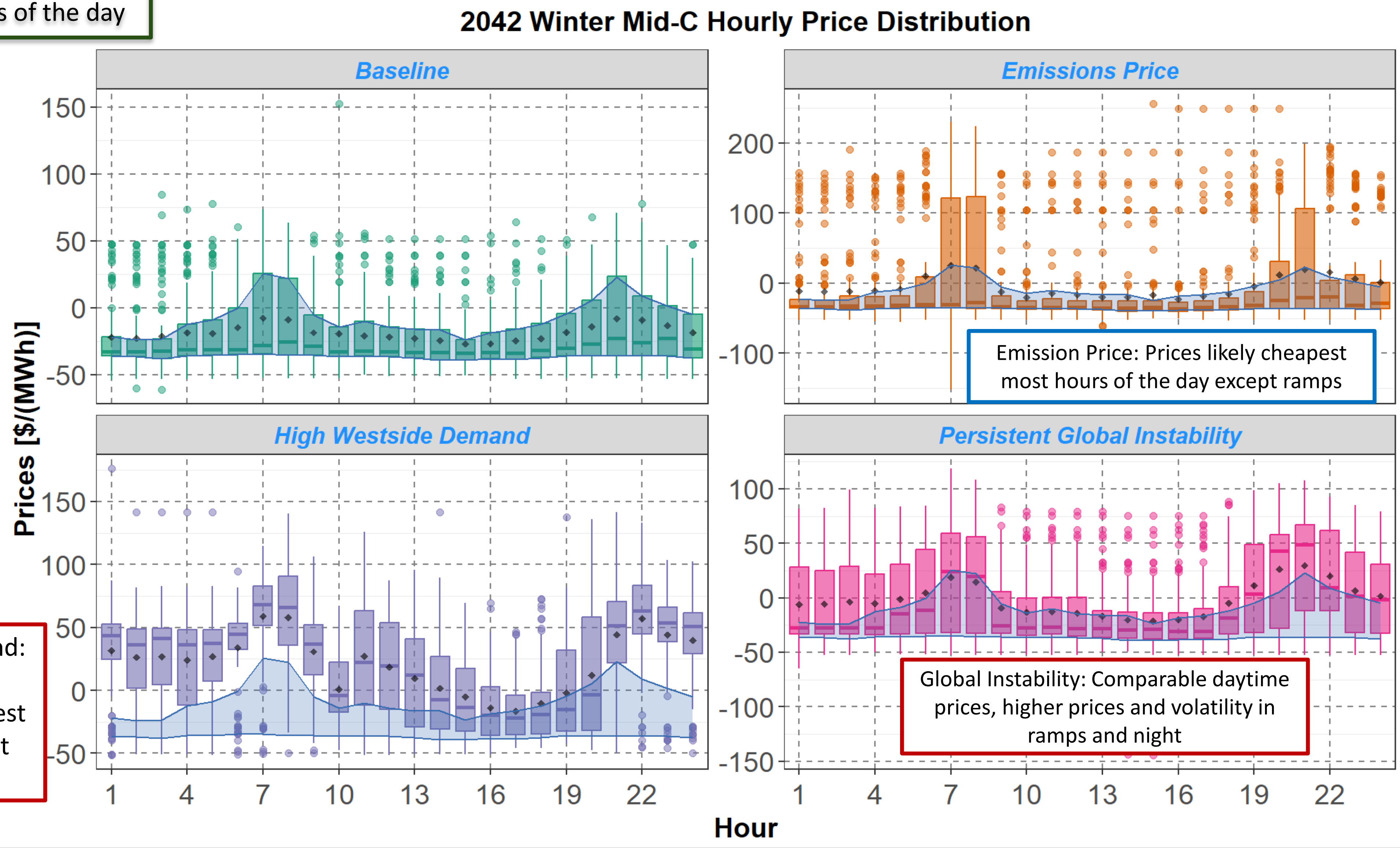
Difference between baseline and Emission Price scenarios: **almost no overlap; Emission Price > Baseline**

Difference between baseline and High WECC Demand scenarios: **A lot of overlap; High WECC Demand prices likely to be similar, with narrower range, except during morning ramp**

Difference between baseline and Persistent Global Instability scenarios: **little overlap; Global instability likely to be higher throughout the day**

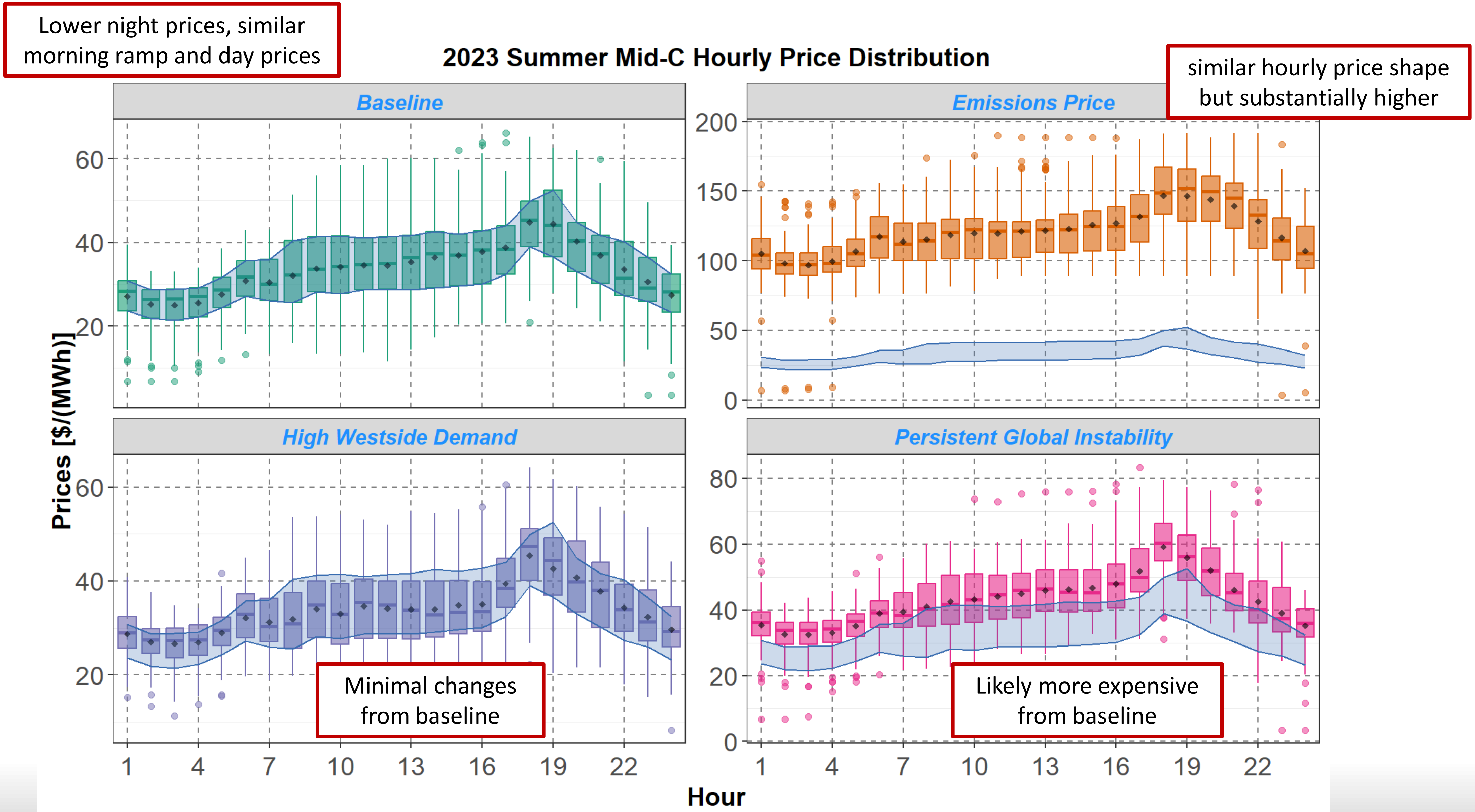

Daytime price drop
Ramp increase
2033 Winter Mid-C Hourly Price Distribution
Baseline
Emissions Price
High Westside Demand
Persistent Global Instability
Higher night prices
Comparable daytime prices to baseline
Negative pricing
Negative pricing
Prices [$/(MWh)]
Hour
Central 50% of baseline hourly distribution (25th-75th percentiles)

Baseline and Emission Price likely experience negative pricing most hours of the day



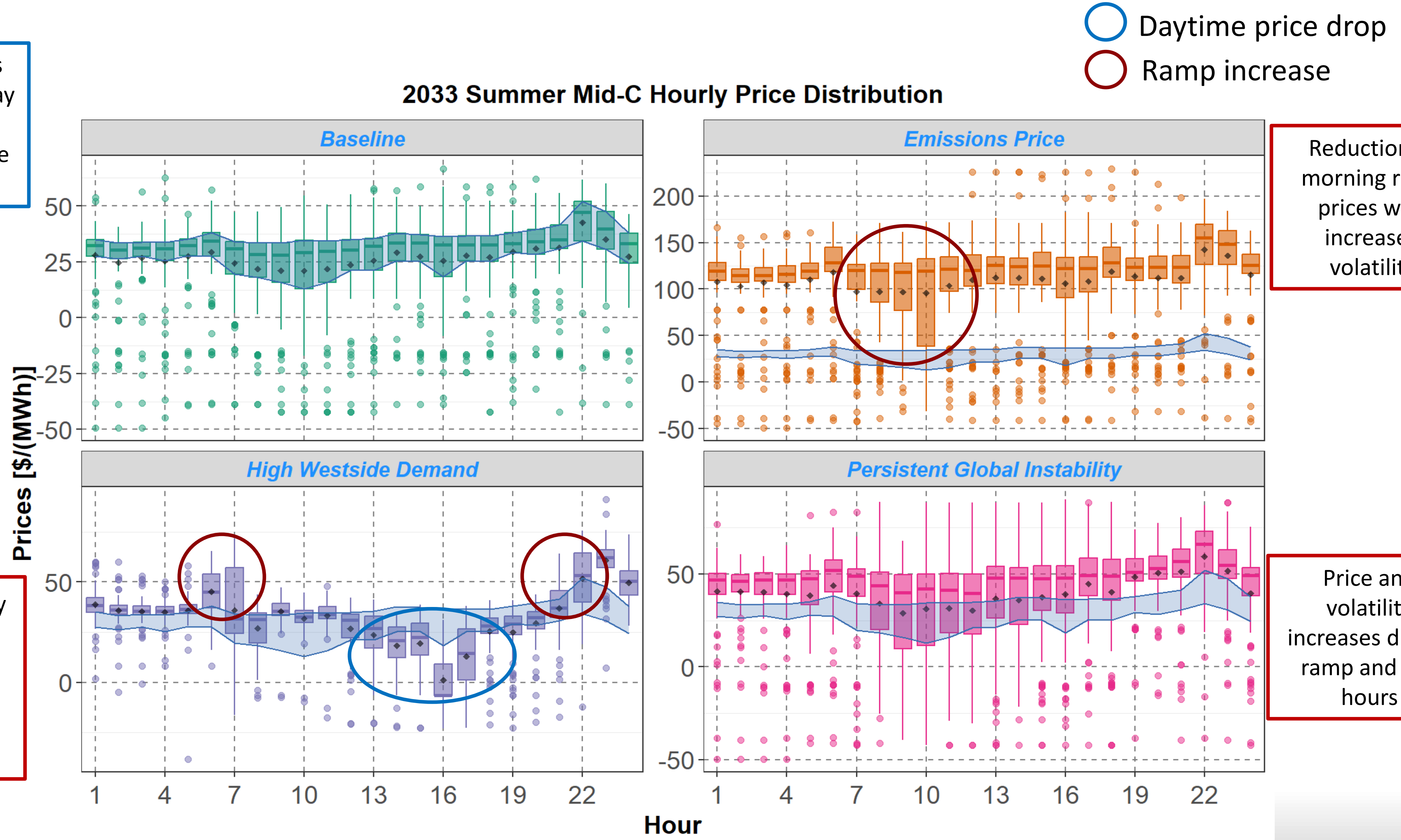
High WECC Demand: Increased price volatility and highest prices throughout the day

Central 50% of baseline hourly distribution (25th-75th percentiles)



Central 50% of baseline hourly distribution (25th-75th percentiles)

Consistent prices throughout the day except evening ramp, higher price volatility

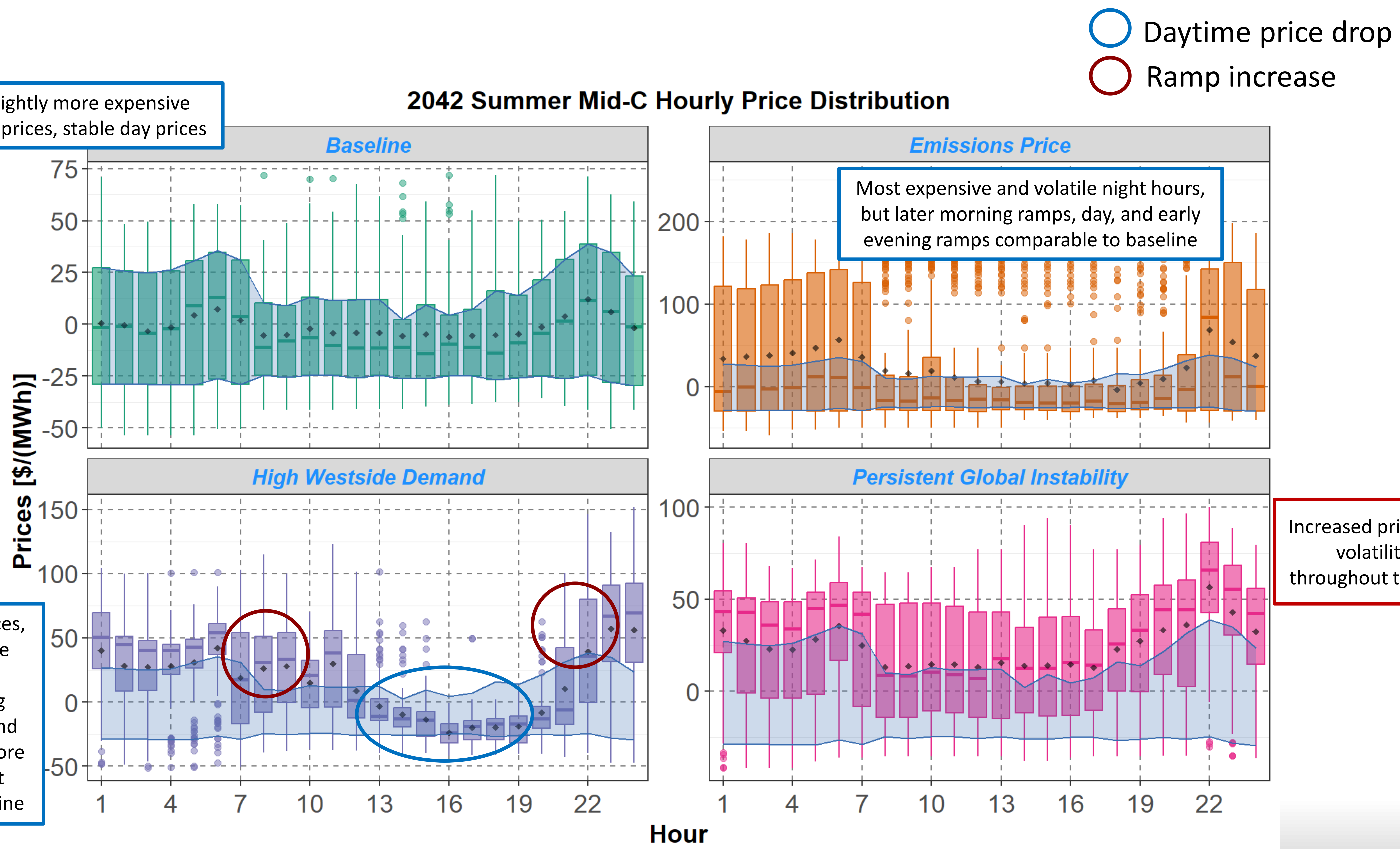


Reduction of morning ramp prices with increased volatility

Price and volatility increases in morning and evening ramps, price drop in the later day hours

Price and volatility increases during ramp and day hours

Central 50% of baseline hourly distribution (25th-75th percentiles)



Ramps slightly more expensive than night prices, stable day prices

Most expensive and volatile night hours, but later morning ramps, day, and early evening ramps comparable to baseline

Higher ramps prices, but smaller price volatility in the negative pricing during the day and early evening , more expensive night prices from baseline

Increased price and volatility throughout the day

Central 50% of baseline hourly distribution (25th-75th percentiles)

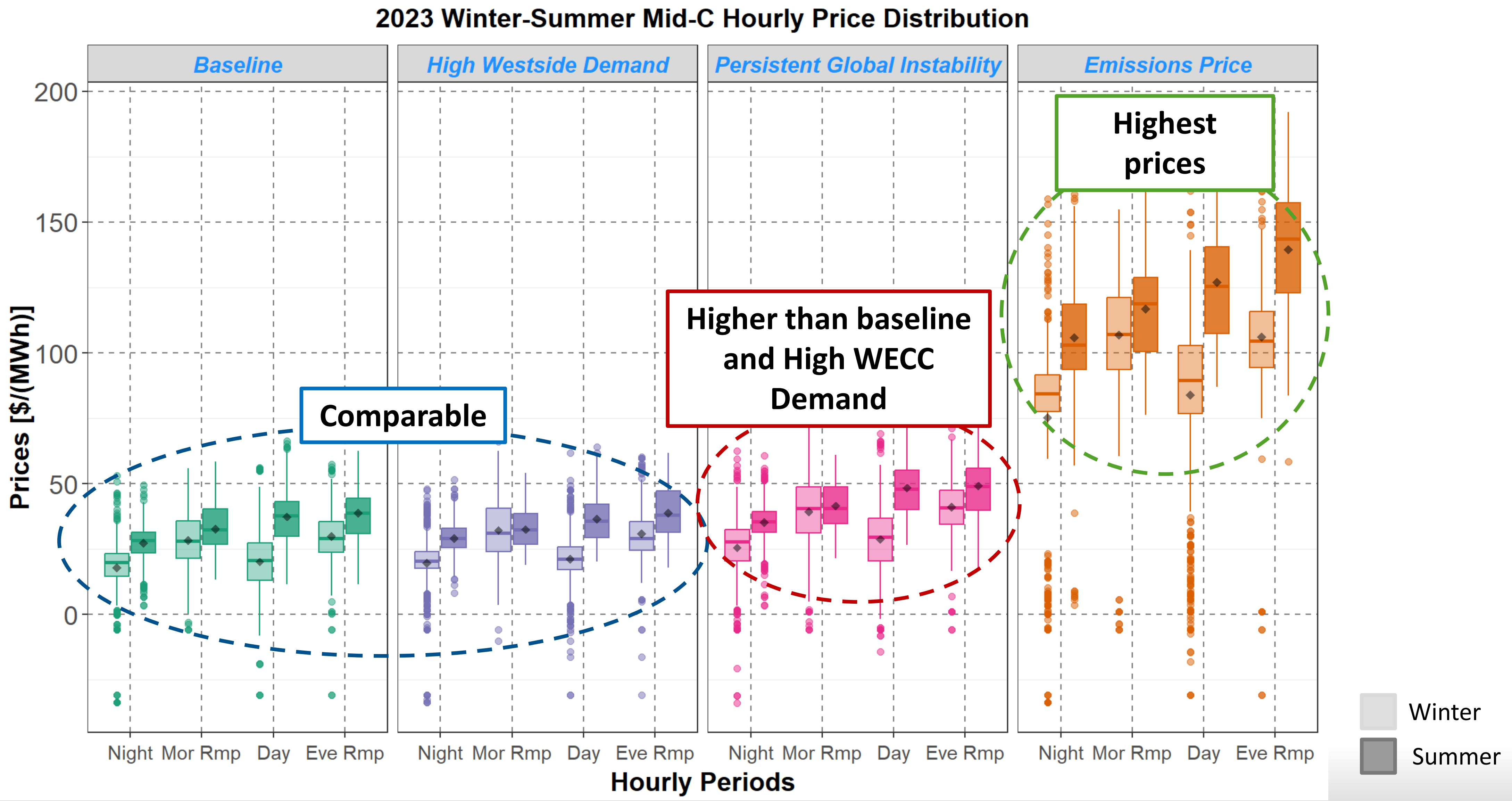
Trends in Hourly Periods in comparison to baseline

- 2023:
  - Emission Price scenario experiences most expensive prices
  - Persisted Global Instability shows higher prices throughout the day than baseline and High WECC Demand
  - Increased summer evening ramp and day prices

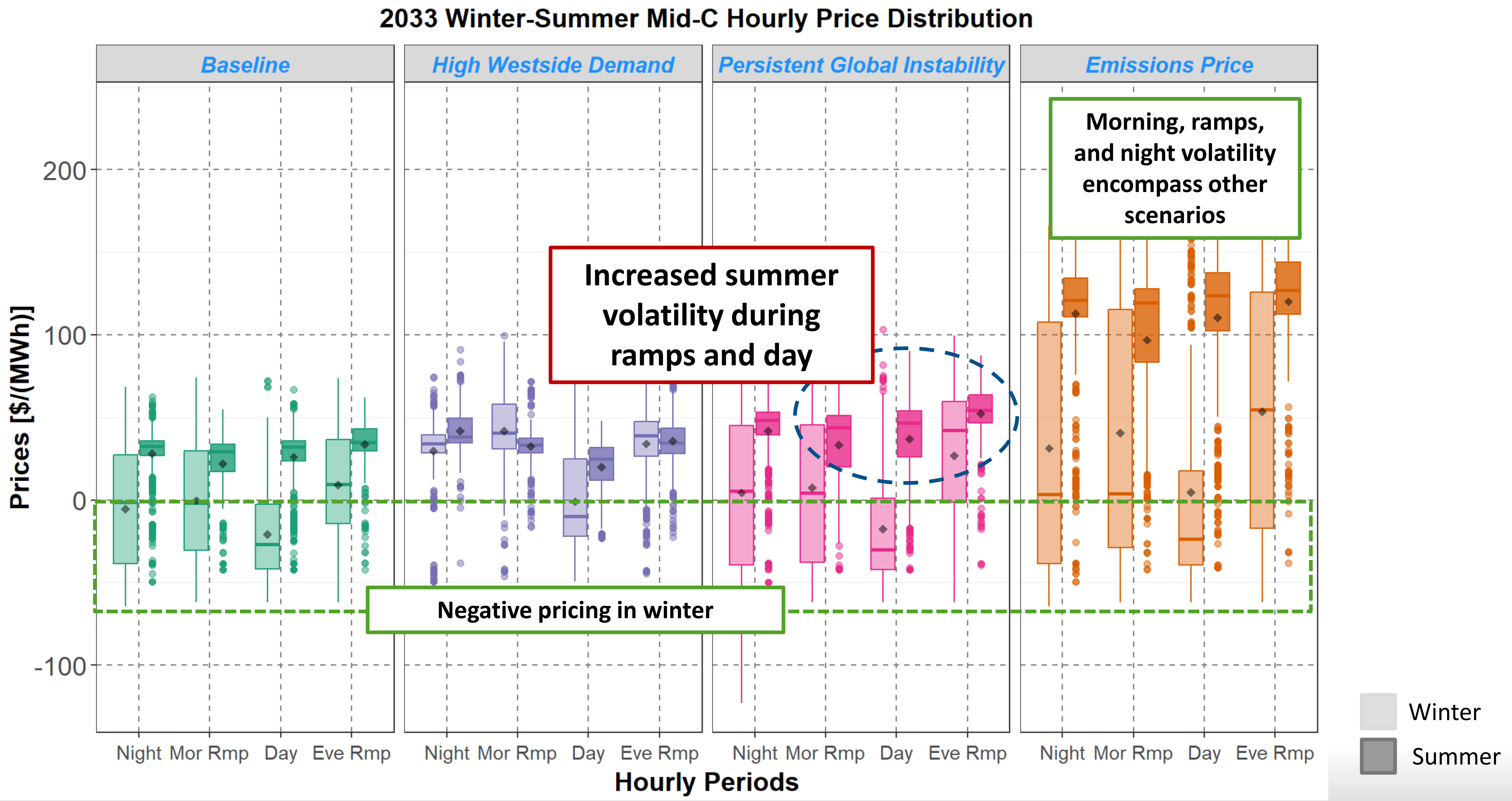
- 2033
  - Increased winter volatility but higher summer prices
  - Baseline and Global Instability increased winter volatility, High WECC Demand mostly during the day hours
  - Emission price scenario with wide winter price volatility

- 2042:
  - Winter and summer negative pricing under the Baseline, seasonal negative pricing for High WECC Demand, Global Instability, and Emission Price
  - Under Emission Price, winter sees narrow prices, and increased volatility in the summer, especially during the night

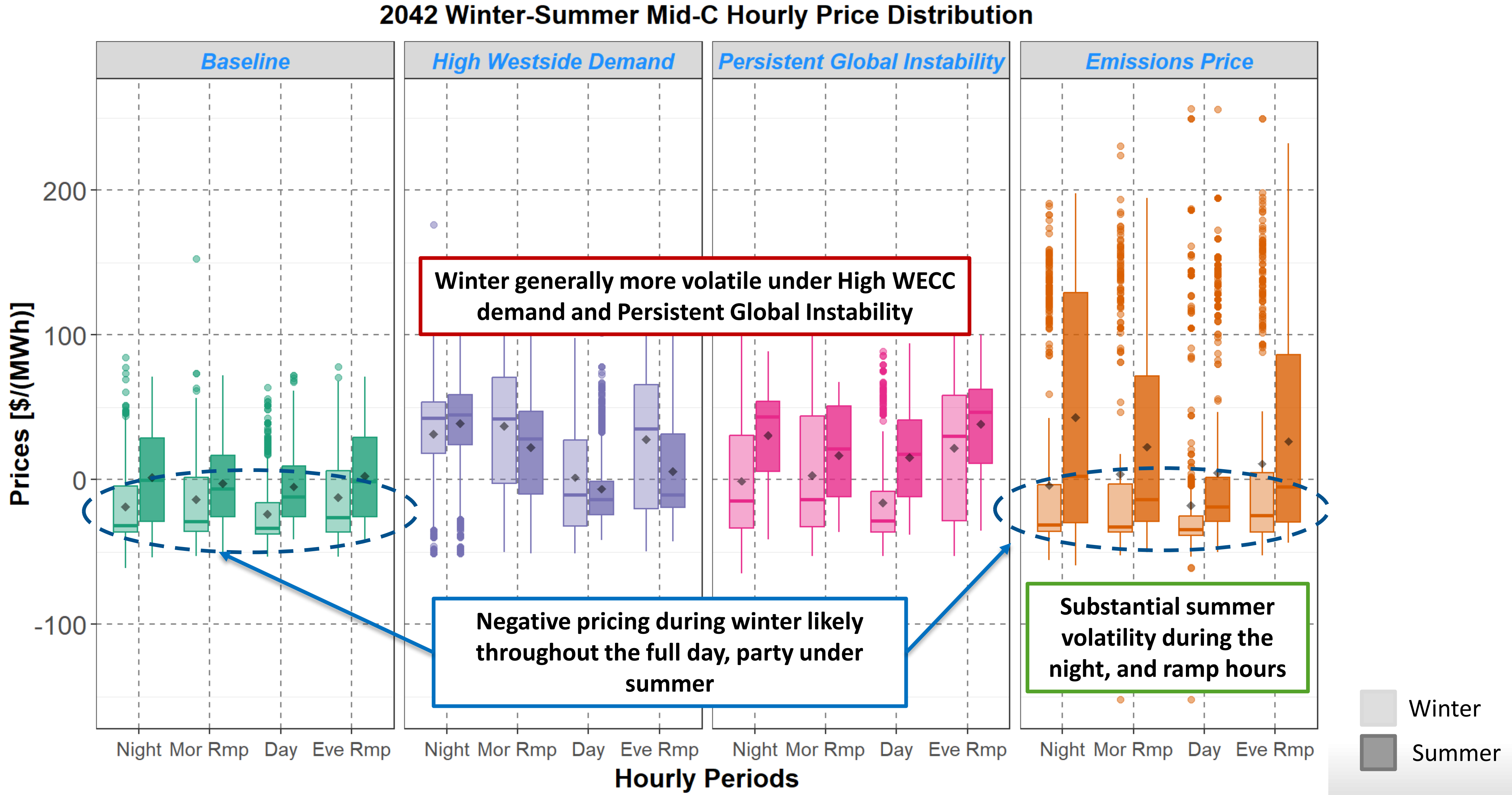
Summer prices expected to be higher during day, evening ramp and night hours



Substantial winter price volatility compared to narrow distribution of summer prices



Seasonal volatility depending on scenario



Avoided Market Emissions Rates

Used in power planning for Council and regional stakeholders, state agencies for building codes, energy efficiency planners etc.

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.

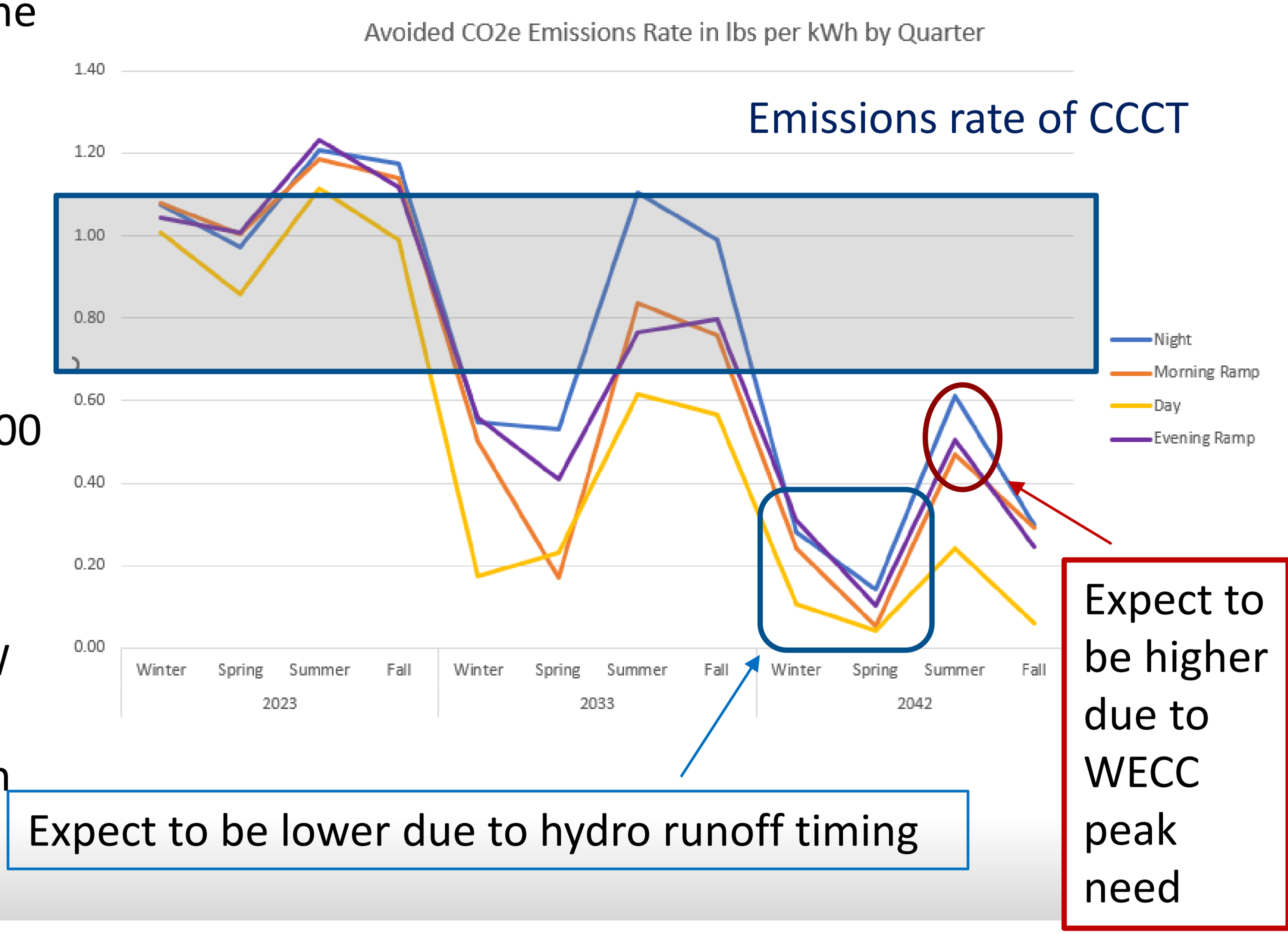
Avoided Emissions Rate Methodology

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

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

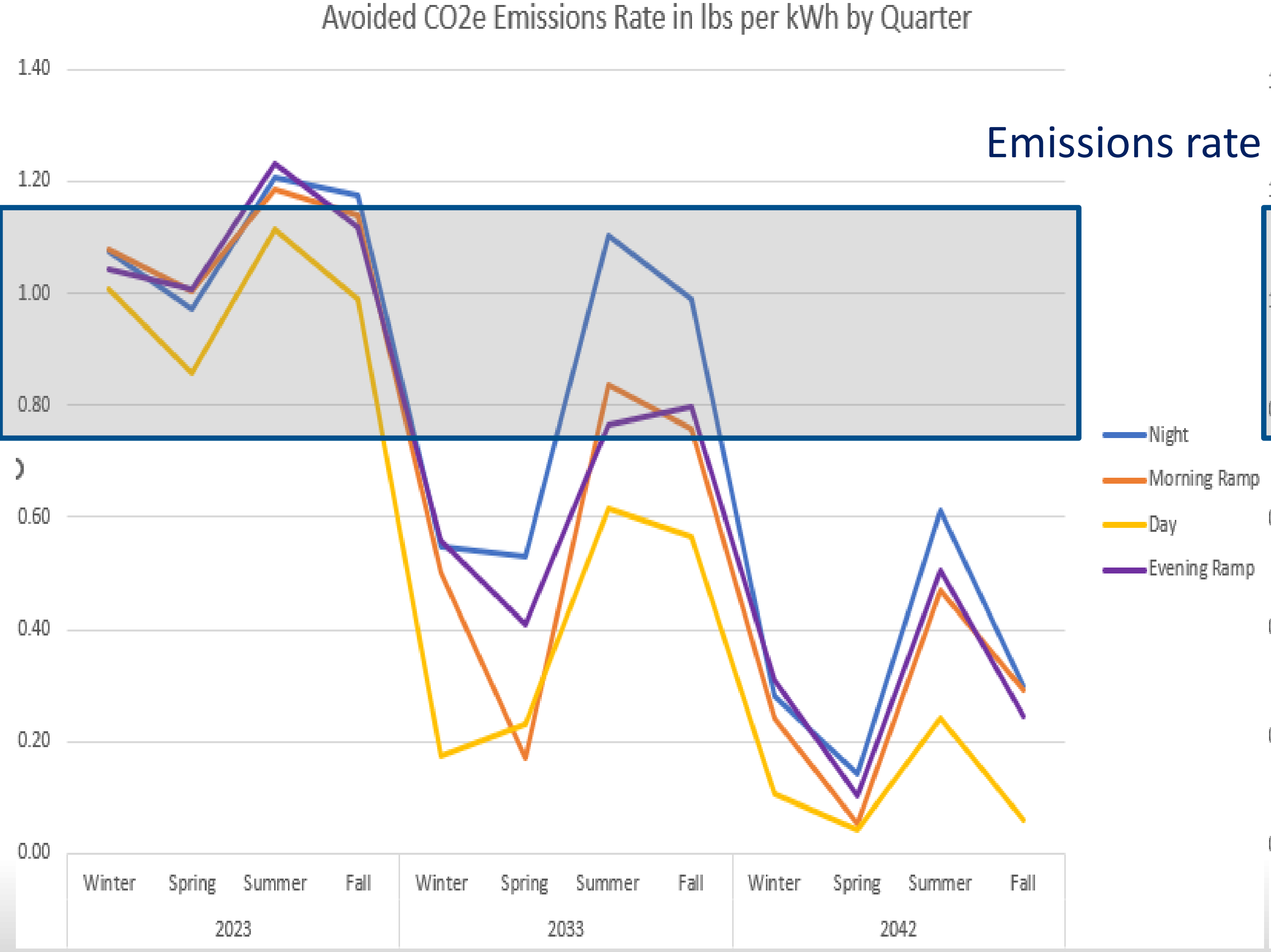
Variable Definition:

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



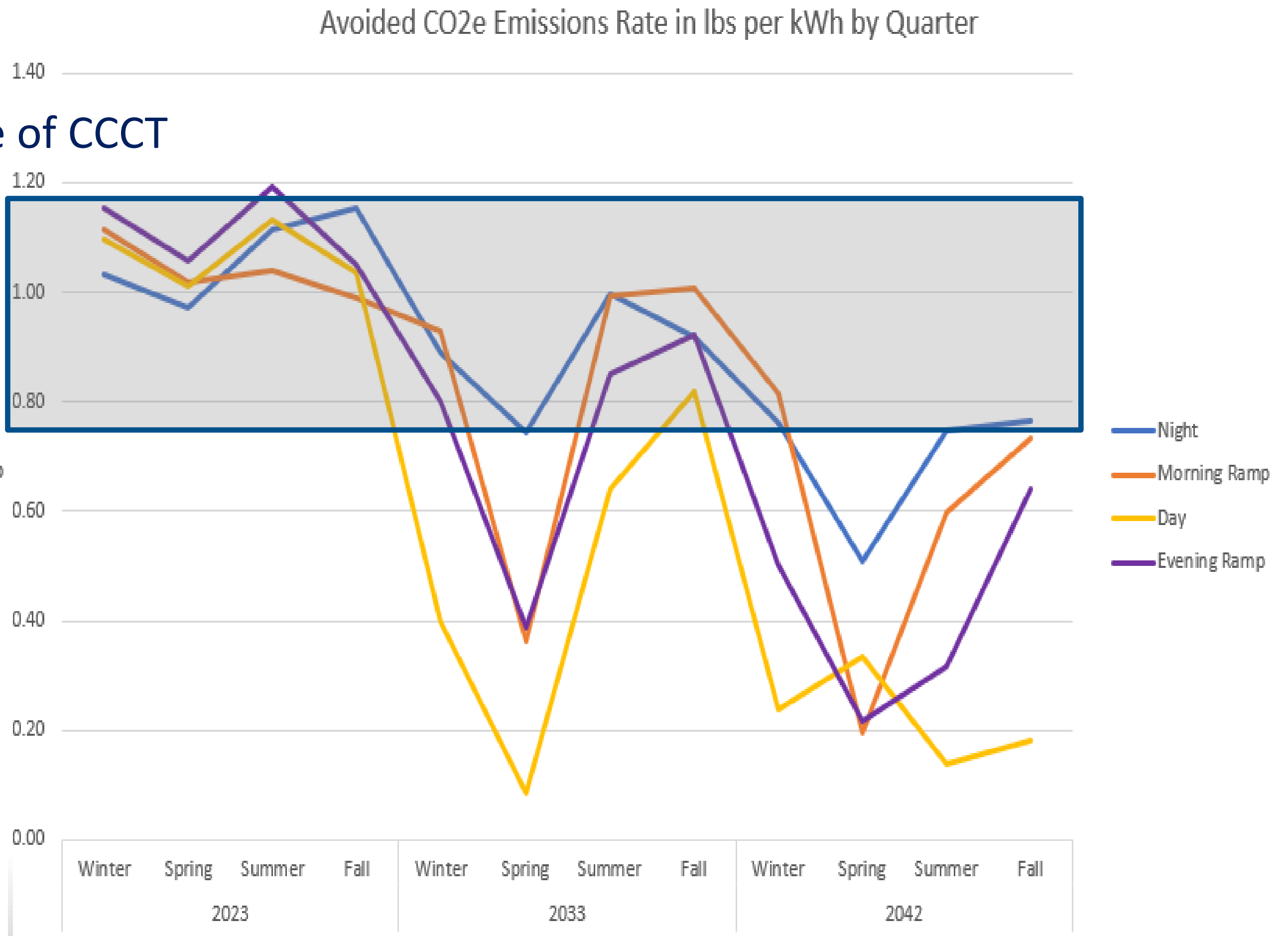
Avoided Emissions Rates Drivers Part 1

Baseline



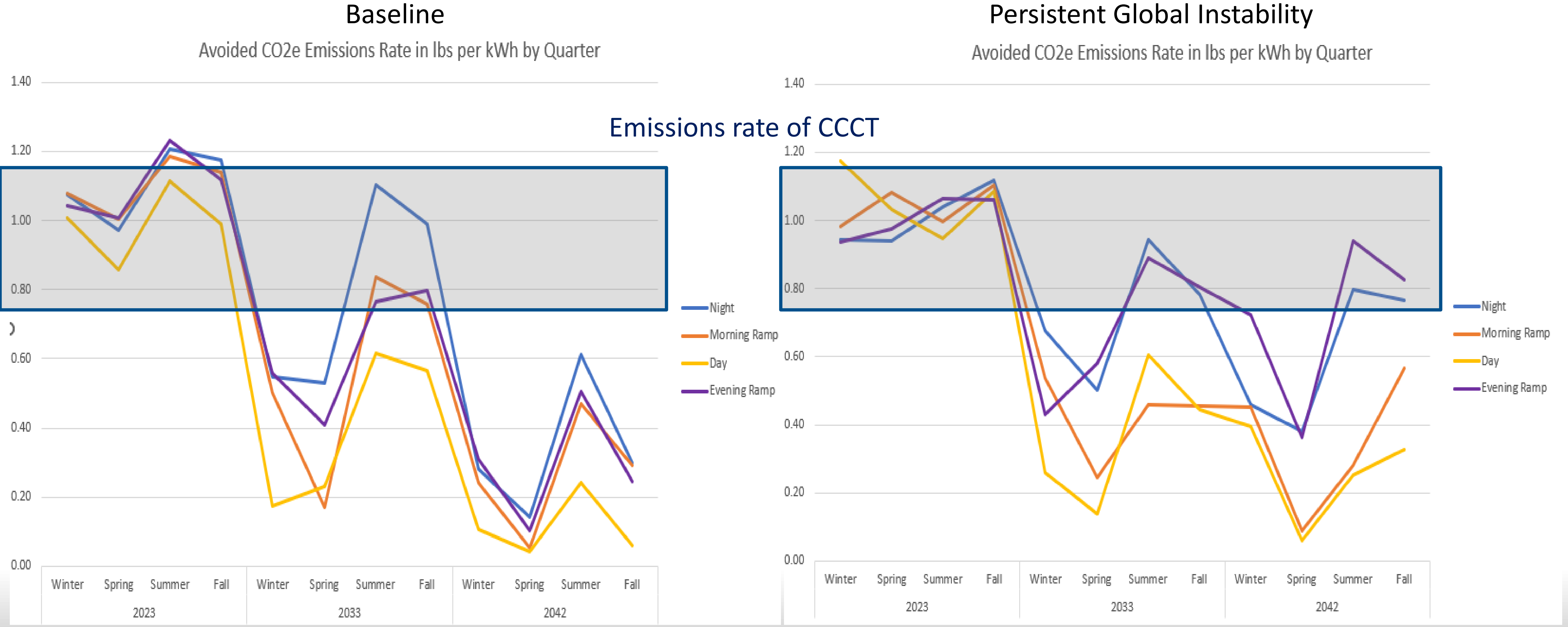
Emissions rate of CCCT

High WECC Demand



Higher demand keeps avoided emissions rates higher in general

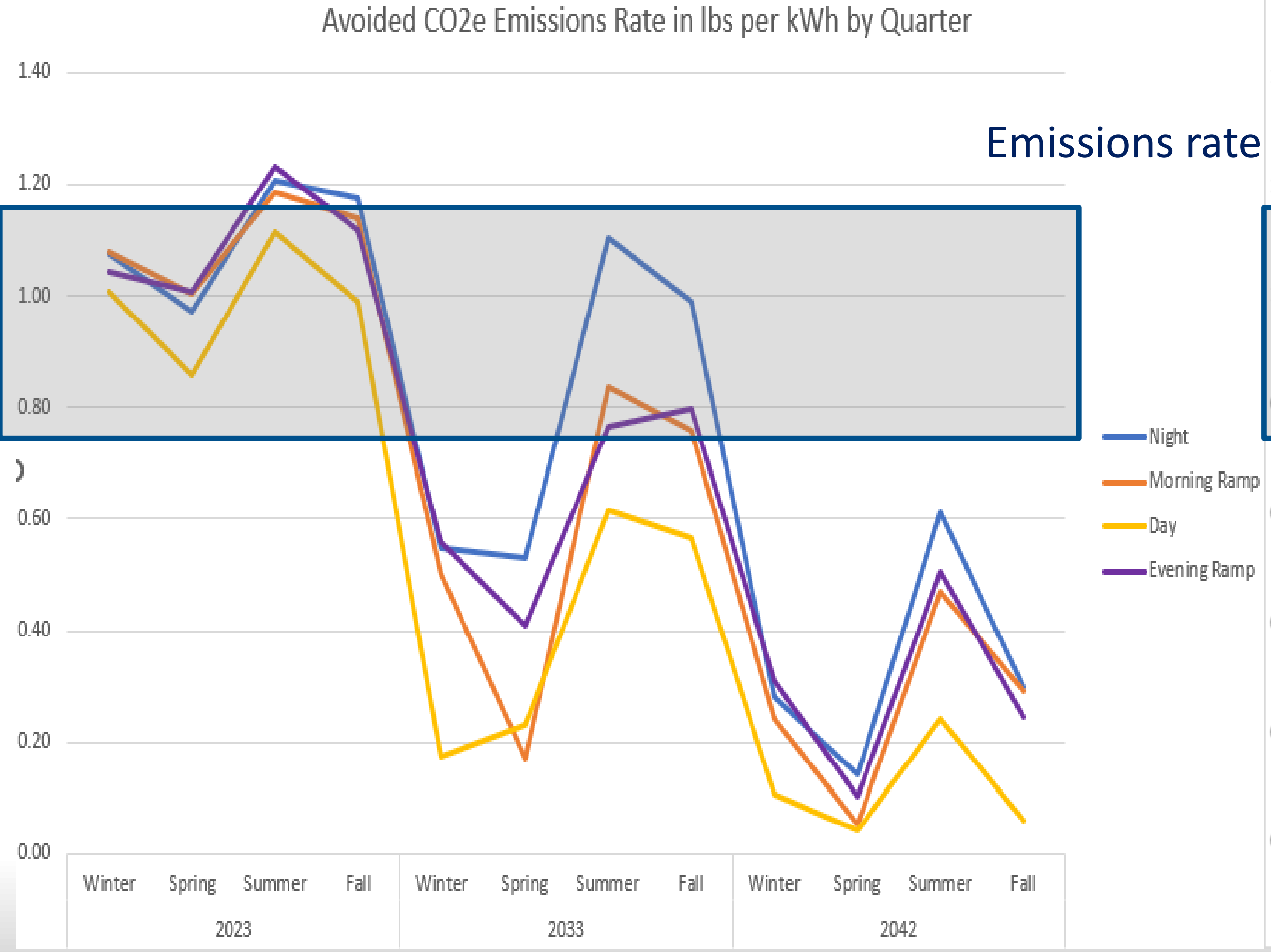
Avoided Emissions Rates Drivers Part 2



Higher gas prices, inefficient builds keeps emissions rates higher during summer evenings and nights

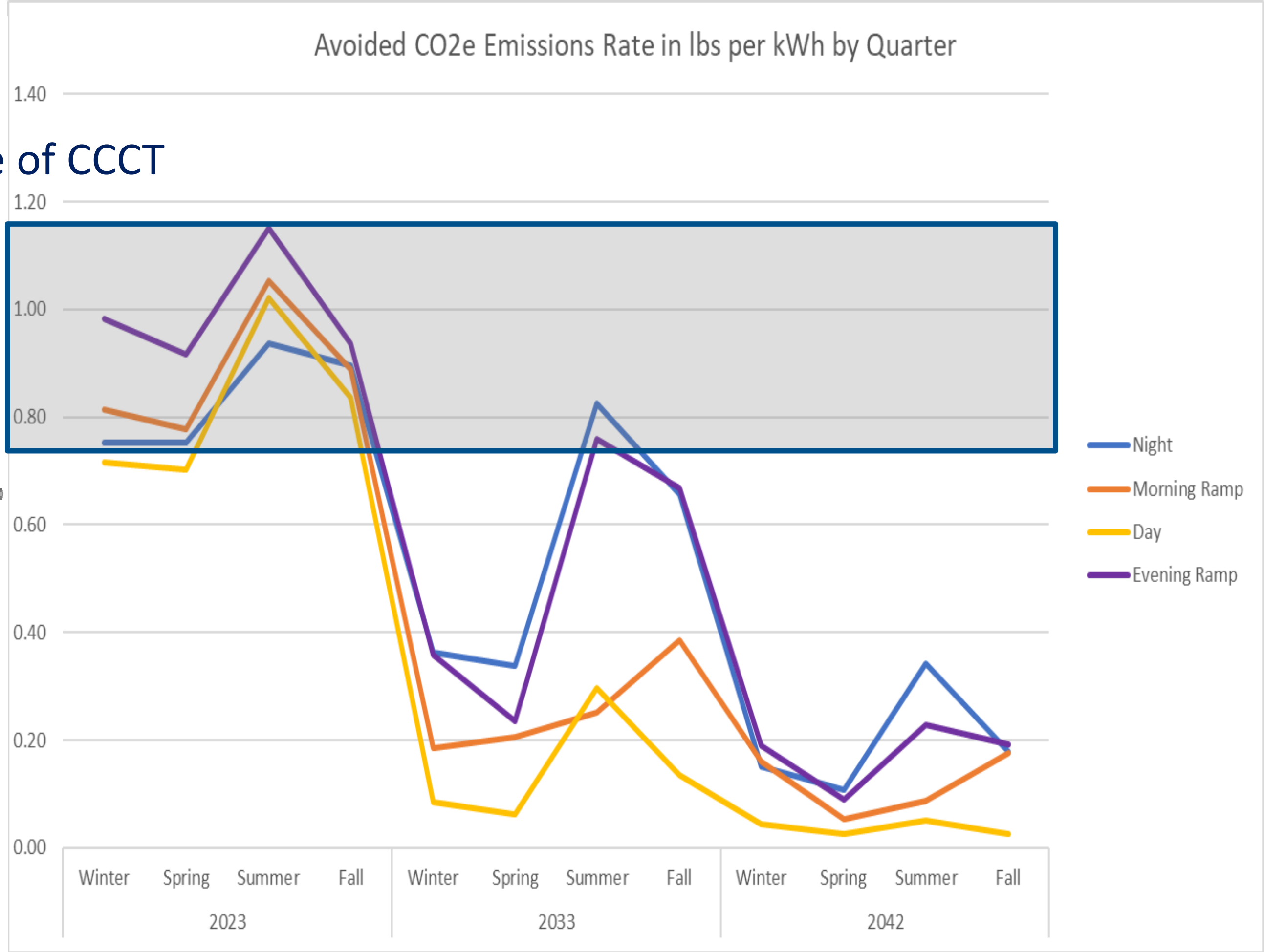
Avoided Emissions Rates Drivers Part 3

Baseline



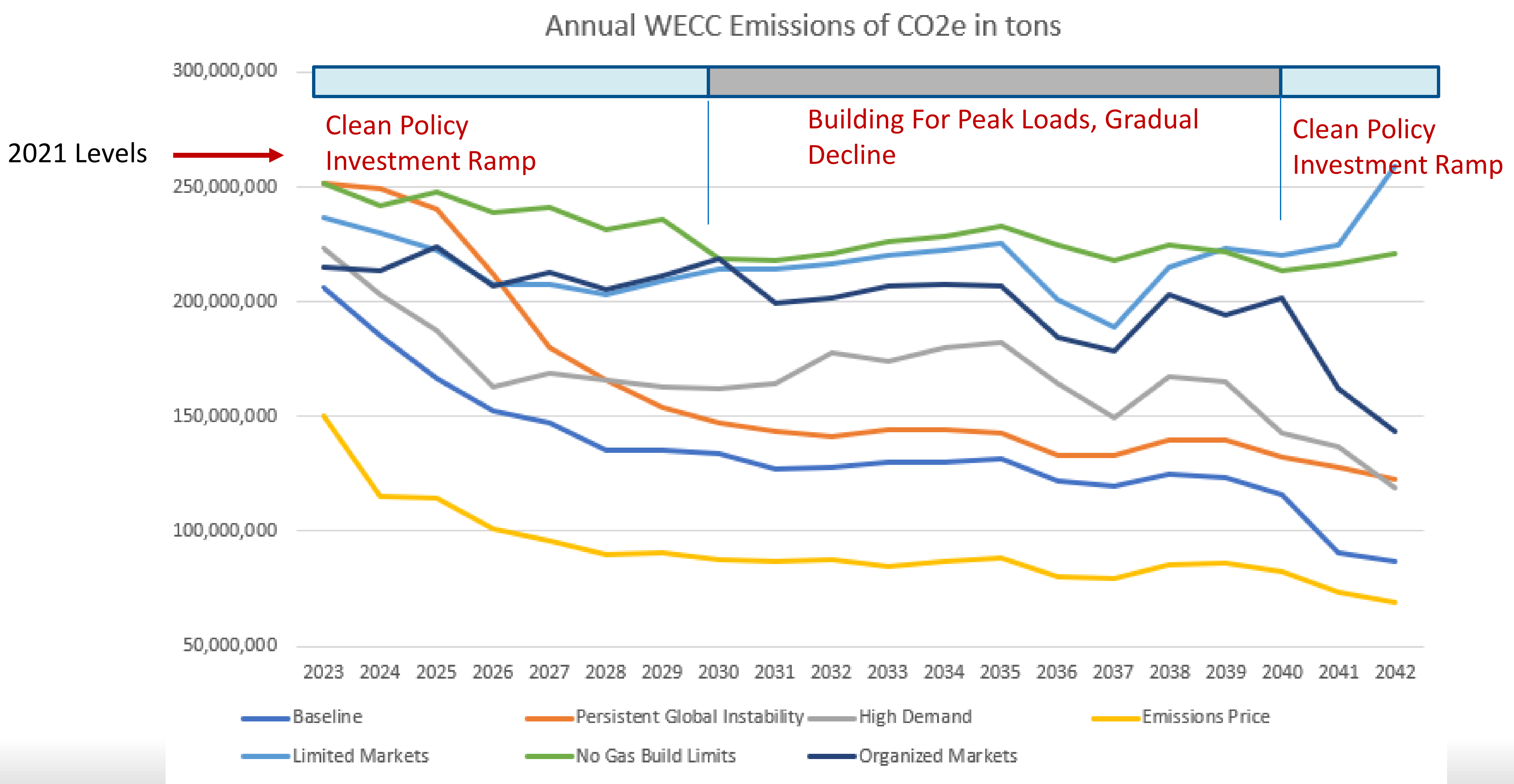
Emissions rate of CCCT

Emissions Price



Emissions pricing lowers emissions rates in general

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


Annual WECC Emissions of CO2e in tons
2021 Levels
Clean Policy Investment Ramp
Building For Peak Loads, Gradual Decline
Clean Policy Investment Ramp
300,000,000
250,000,000
200,000,000
150,000,000
100,000,000
50,000,000
2023
2024
2025
2026
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2028
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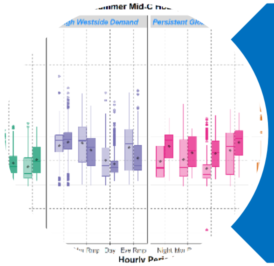
Baseline
Persistent Global Instability
High Demand
Emissions Price
Limited Markets
No Gas Build Limits
Organized Markets

Monitoring Risks During the Energy Transition

Rate/effectiveness of fixed cost investment lowering production costs and emissions



Rate of increase and timing of price volatility

Adoption of enabling market structures and/or policies

Analytical Work Before Next Assessment

- Improve transmission assumptions
  - Significant modeling issues with large renewable buildouts and constrained transmission

- Improve understanding of market structure and policy assumptions
  - Significant uncertainty on end state of WECC markets

Questions

John Ollis
jollis@nwcouncil.org

Dor Hirsh Bar Gai
dhirshbargai@nwcouncil.org

Extra Slides

Observations By Scenario – *Energy Transition*

- A Persistent Global Instability scenario in slightly slower and less optimized early builds which leads to slightly higher prices, emissions and system costs.
  - Higher gas prices keep wholesale costs high, but like the baseline overall price volatility seems to increase near the end of this decade.
  - Prices stay higher than the baseline given the higher price of gas
- The High Westside Demand scenario shows an increase in wholesale prices and system costs by the end of the study.
  - Less negative pricing by end of study due to increased demand
  - Lower prices in the evening ramp and day due to significantly larger buildout in the PNW than in other scenarios.

Observations By Scenario – *Energy Transition*

- The Emissions Price scenario results in a sharp decline of production costs across the regions (until stabilizing in 2030) due to rapid growth of renewables; but production costs relatively high to all scenarios due to emissions pricing.
  - Trading out existing resource usage
  - Prices stay relatively high given the cost of emitting resource dispatch
- An Organized Market scenario reduced the buildout pressure in CA by increasing build in Canada, Mountain West and PNW
  - Early increase in wholesale prices due to leveraging more heavily on efficiencies existing system which causes more higher priced resources to be utilized more often to defer fixed cost investment
  - Recall that due to lower and more efficient build of clean energy resources to maintain reserve margins this scenario had lower system costs in general

Observations By Scenario – *Traditional Investment*

- The No Gas Build Limits scenario looks much more like the traditional market paradigm with production costs and fixed costs at parity.
  - Emissions and market emissions rates are slightly reduced due to investment in efficient gas investment, but not enough to meet policy targets.
  - Prices stay stable with more efficient gas plants replacing older less efficient gas plants
- The Limited Markets scenario had the least investment but was also the least adequate and close to meeting policies.
  - Overall increases in prices and emissions throughout time
  - By late 2020's prices during peak seasons are extremely high for a sustained period.

Scenario Description Review: Limited Markets

- Removed planning reserve margins
  - Implemented by setting operating pool planning reserve margins to -99 in AURORA
  - All other inputs the same as the baseline

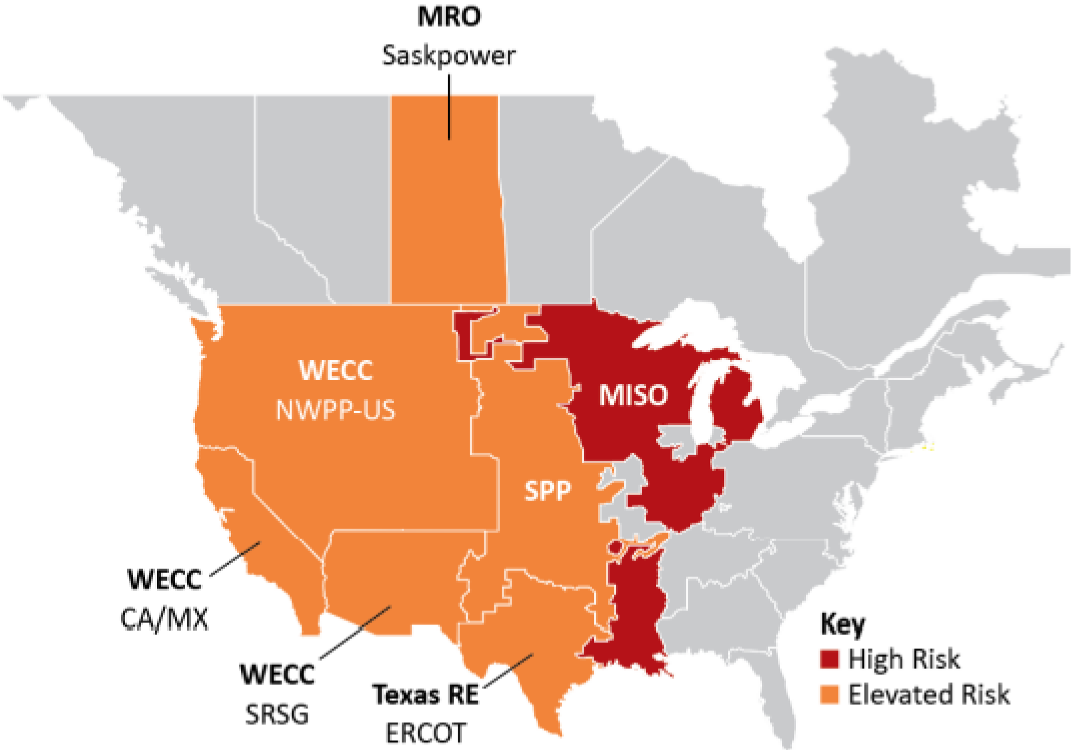


Figure 1: Summer Reliability Risk Area Summary

Scenario Description Review: High WECC Demand

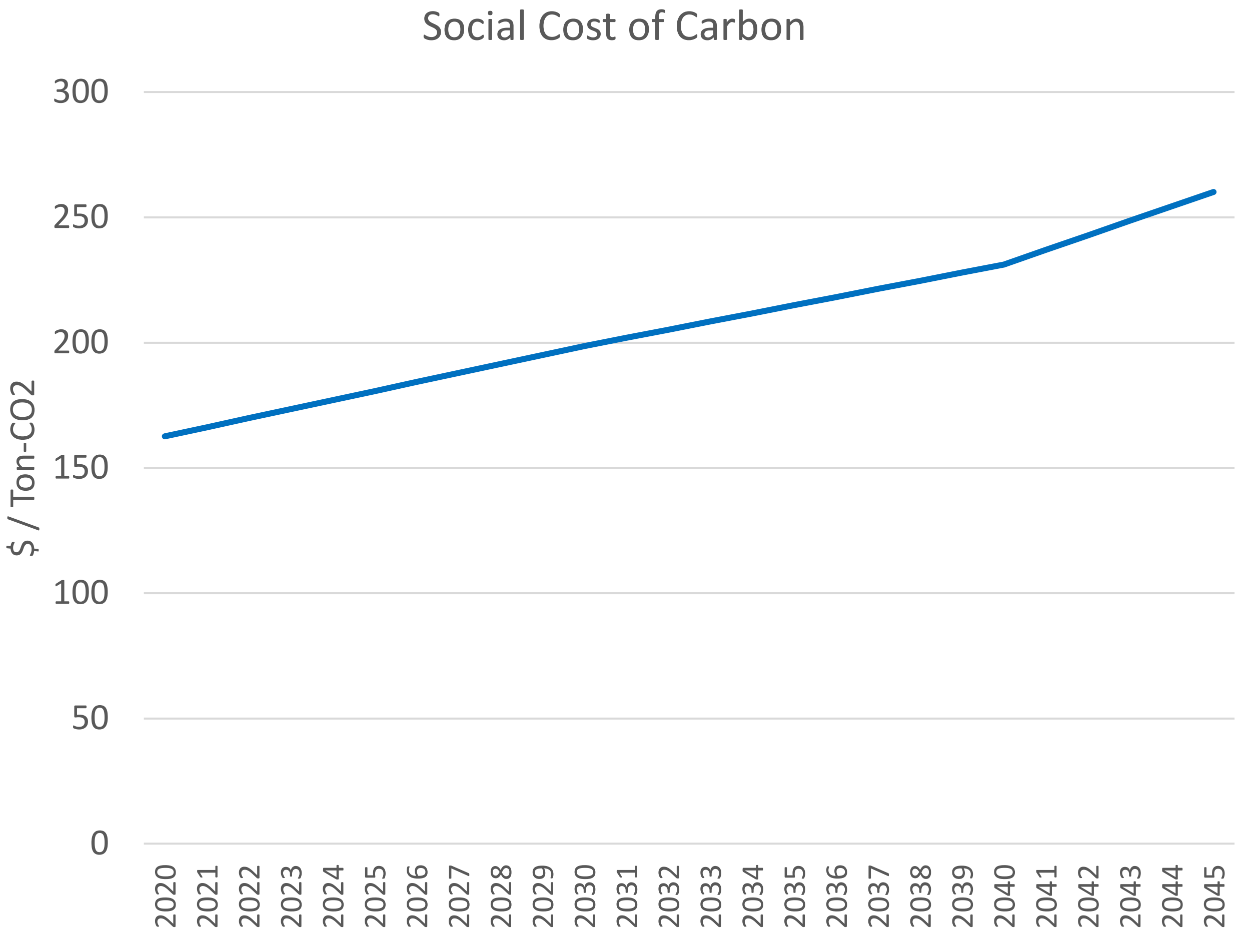
- High electrification Pacific NW, California, BC and Alberta
  - High demand only in those areas, baseline forecast elsewhere
  - All other inputs the same as the baseline, except updating policy targets (in MWhs)

Scenario Description Review: Persistent Global Instability

- Changed ramping limitations of resources to be slower initially but the nearer to 2030 converge to the normal ramp rate.
  - Implemented by changing maximum annual new additions on short duration storage, solar and wind generation until 2030.
  - Other resource ramps unchanged due to online date or previous restrictions
  - All other inputs the same as the baseline

Scenario Description Review: High Social Cost of Carbon

- Significantly higher carbon price
  - Universal SCC across the region
    - $162 (2020) - $260 (2045)
  - All other settings the same as the Baseline



@ 2012 $ value

Response to literature and National Academies findings to reevaluate current SCC values

Scenario Description Review: Organized Market

- Simulate WECC as a "perfect" coordinated/ cooperated market
  - Single zone and reserve pool (18%).
  - Unified wheeling costs set to $0
  - All other settings the same as the Baseline

Scenario Description Review: No Gas Build Limits

- Remove gas build limitations to test if policies were relaxed
  - Leave build rates and totals at default
  - Allow gas builds in all zones

Review:

Three climate change data sets selected to encompass the range of hydro and load variation

	Winter Generation	Summer Generation	Winter HDD	Summer CDD
A	-	low	low	high
C	high	low	-	-
G	near low	high	high	near low

We will be looking at power prices over 30 different climate change sets and weather conditions…

Description	Letter in index	Hydro Year 2020s	Hydro Year 2030s	Hydro Year 2040s
CanESM2_RCP85_BCSD_VIC_P1	A1	2020	2030	2040
CanESM2_RCP85_BCSD_VIC_P1	A2	2021	2031	2041
CanESM2_RCP85_BCSD_VIC_P1	A3	2022	2032	2042
CanESM2_RCP85_BCSD_VIC_P1	A4	2023	2033	2043
CanESM2_RCP85_BCSD_VIC_P1	A5	2024	2034	2044
CanESM2_RCP85_BCSD_VIC_P1	A6	2025	2035	2045
CanESM2_RCP85_BCSD_VIC_P1	A7	2026	2036	2046
CanESM2_RCP85_BCSD_VIC_P1	A8	2027	2037	2047
CanESM2_RCP85_BCSD_VIC_P1	A9	2028	2038	2048
CanESM2_RCP85_BCSD_VIC_P1	A10	2029	2039	2049
CCSM4_RCP85_BCSD_VIC_P1	C1	2020	2030	2040
CCSM4_RCP85_BCSD_VIC_P1	C2	2021	2031	2041
CCSM4_RCP85_BCSD_VIC_P1	C3	2022	2032	2042
CCSM4_RCP85_BCSD_VIC_P1	C4	2023	2033	2043
CCSM4_RCP85_BCSD_VIC_P1	C5	2024	2034	2044
CCSM4_RCP85_BCSD_VIC_P1	C6	2025	2035	2045
CCSM4_RCP85_BCSD_VIC_P1	C7	2026	2036	2046
CCSM4_RCP85_BCSD_VIC_P1	C8	2027	2037	2047
CCSM4_RCP85_BCSD_VIC_P1	C9	2028	2038	2048
CCSM4_RCP85_BCSD_VIC_P1	C10	2029	2039	2049
CNRM-CM5_RCP85_MACA_VIC_P1	G1	2020	2030	2040
CNRM-CM5_RCP85_MACA_VIC_P1	G2	2021	2031	2041
CNRM-CM5_RCP85_MACA_VIC_P1	G3	2022	2032	2042
CNRM-CM5_RCP85_MACA_VIC_P1	G4	2023	2033	2043
CNRM-CM5_RCP85_MACA_VIC_P1	G5	2024	2034	2044
CNRM-CM5_RCP85_MACA_VIC_P1	G6	2025	2035	2045
CNRM-CM5_RCP85_MACA_VIC_P1	G7	2026	2036	2046
CNRM-CM5_RCP85_MACA_VIC_P1	G8	2027	2037	2047
CNRM-CM5_RCP85_MACA_VIC_P1	G9	2028	2038	2048
CNRM-CM5_RCP85_MACA_VIC_P1	G10	2029	2039	2049

Solar and Solar Plus Storage Build Comparisons

WECC

Year	Baseline	Global Instability	Limited	High Demand West*	Clean Baseload Delay	High SCC	Organized Market	No Gas Build Limits	2021 Plan Baseline
2025	21,528	10,702	7,608	3,872	28,731	20,364	3,000	6,105	51,538
2030	42,206	53,011	19,739	12,007	80,626	42,461	14,858	28,226	89,838
2035	45,141	73,260	24,164	15,440	108,716	44,944	15,757	29,682	100,357
2040	56,494	94,010	36,089	20,440	135,212	63,724	17,008	39,879	135,054
2045	75,890	106,744	43,761	37,552	157,962	83,414	17,008	46,303	147,554

Year	Baseline	Global Instability	Limited	High Demand West*	Clean Baseload Delay	High SCC	Organized Market	No Gas Build Limits	2021 Plan Baseline
2025	23,386	8,000	0	25,506	24,000	23,500	0	0	46,600
2030	60,503	12,000	0	55,821	65,118	62,370	1,563	0	86,600
2035	60,503	36,000	0	63,821	68,399	62,448	1,663	0	145,500
2040	63,429	36,830	0	90,693	76,383	68,268	8,263	28	179,800
2045	63,429	53,033	0	116,304	91,122	72,152	13,728	337	198,000

Battery and Pumped Storage Build Comparisons

WECC

Year	Baseline	Global Instability	Limited	High Demand West*	Clean Baseload Delay	High SCC	Organized Market	No Gas Build Limits	2021 Plan Baseline
2025	13,634	15,926	26,522	17,270	16,153	18,878	45,000	26,476	6,004
2030	13,940	22,473	32,433	18,109	17,108	19,430	52,000	27,506	6,004
2035	13,965	22,895	35,047	19,977	18,427	20,418	57,000	29,687	6,004
2040	14,861	23,391	36,918	21,444	19,955	23,409	58,000	32,179	6,004
2045	18,390	32,163	41,372	22,744	19,994	30,644	58,000	35,333	6,055

Year	Baseline	Global Instability	Limited	High Demand West*	Clean Baseload Delay	High SCC	Organized Market	No Gas Build Limits	2021 Plan Baseline
2025	0	0	0	0	0	0	0	0	0
2030	0	3,100	0	1,300	0	0	0	0	4,900
2035	2,200	5,300	0	3,500	0	2,200	0	0	5,650
2040	2,200	5,300	0	3,500	2,200	2,200	0	0	6,050
2045	2,200	11,940	0	3,500	2,200	2,200	0	0	9,690

Wind and Gas Build Comparisons

WECC

Year	Baseline	Global Instability	Limited	High Demand West*	Clean Baseload Delay	High SCC	Organized Market	No Gas Build Limits	2021 Plan Baseline
2025	12,155	7,200	12,800	12,769	19,553	15,689	5,454	1,217	16,775
2030	18,634	24,335	16,566	21,769	26,007	24,348	16,831	2,218	35,175
2035	27,906	26,483	16,566	26,769	30,289	30,031	18,958	2,218	37,063
2040	38,221	28,987	16,566	65,309	31,402	35,744	36,756	39,969	43,657
2045	69,769	30,808	16,566	94,384	39,063	48,390	62,913	59,176	51,481

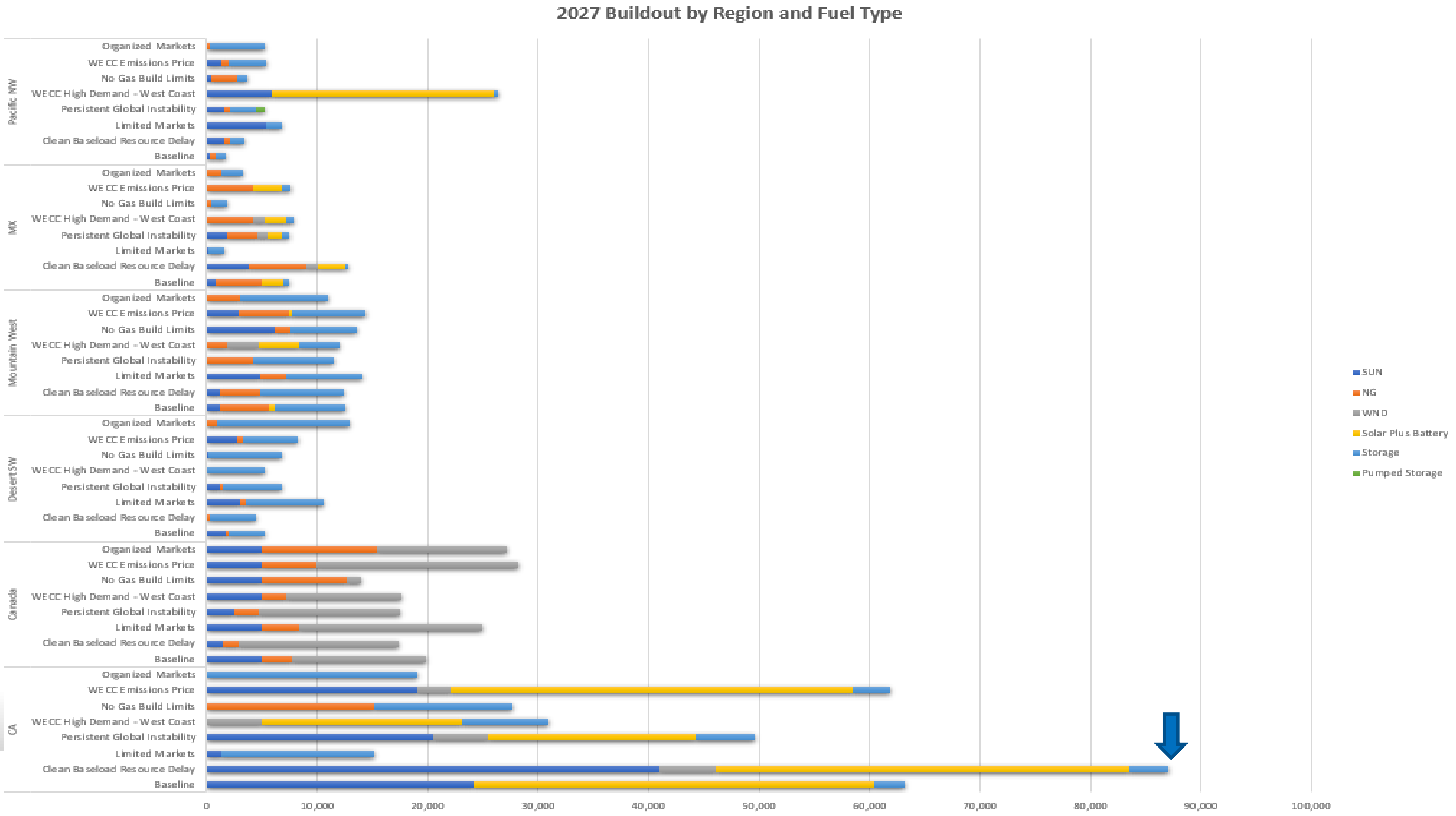
Year	Baseline	Global Instability	Limited	High Demand West*	Clean Baseload Delay	High SCC	Organized Market	No Gas Build Limits	2021 Plan Baseline
2025	7,305	3,575	3,702	5,319	5,307	9,066	8,351	16,013	11,351
2030	14,332	13,803	6,930	13,621	12,808	16,714	18,843	29,378	14,873
2035	14,806	14,514	7,359	14,806	13,519	18,859	22,994	34,592	16,058
2040	15,235	14,514	8,646	15,901	13,519	18,859	24,481	39,969	16,532
2045	15,235	15,372	8,646	15,901	13,519	20,146	24,481	59,176	16,532

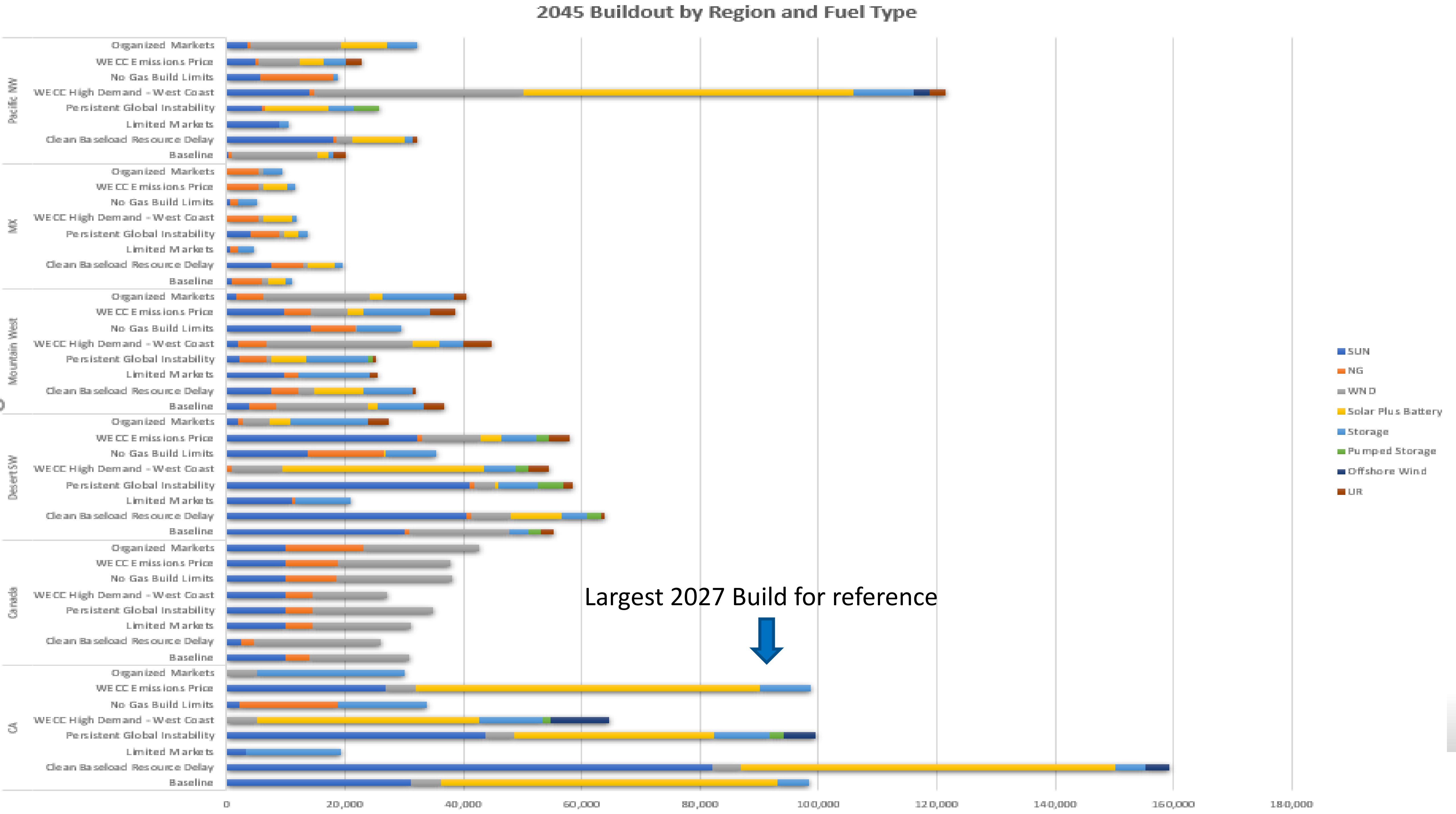
Offshore Wind and Proxy Clean Build Comparisons

WECC

Year	Baseline	Global Instability	Limited	High Demand West*	Clean Baseload Delay	High SCC	Organized Market	No Gas Build Limits	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	157	0	0	0	7,663
2040	0	595	0	2,152	586	0	0	0	10,000
2045	0	5,356	0	12,600	4,000	0	0	0	10,000

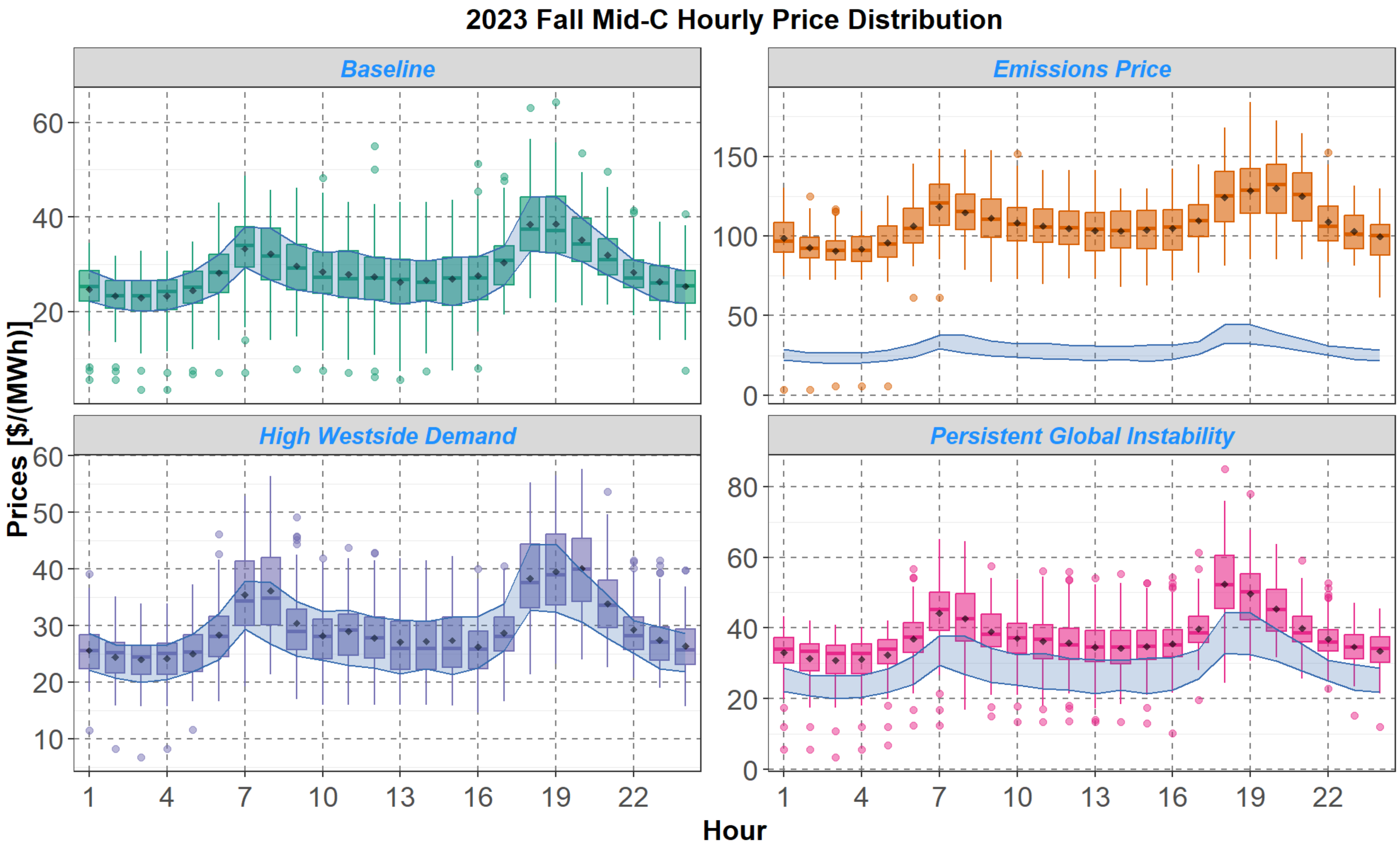
Year	Baseline	Global Instability	Limited	High Demand West*	Clean Baseload Delay	High SCC	Organized Market	No Gas Build Limits	2021 Plan Baseline
2025	0	0	0	0	0	0	0	0	0
2030	1,368	0	0	0	0	0	0	0	0
2035	3,420	684	0	684	0	4,104	0	0	0
2040	3,420	684	0	9,576	1,368	4,104	0	0	0
2045	7,524	2,052	0	10,944	2,052	10,260	5,472	0	0


2027 Buildout by Region and Fuel Type
Pacific NW
MX
Mountain West
Desert SW
Canada
CA
Organized Markets
WECC Emissions Price
No Gas Build Limits
WECC High Demand - West Coast
Persistent Global Instability
Limited Markets
Clean Baseload Resource Delay
Baseline
0
10,000
20,000
30,000
40,000
50,000
60,000
70,000
80,000
90,000
100,000
SUN
NG
WND
Solar Plus Battery
Storage
Pumped Storage


2045 Buildout by Region and Fuel Type
Pacific NW
MX
Mountain West
Desert SW
Canada
CA
Organized Markets
WECC Emissions Price
No Gas Build Limits
WECC High Demand - West Coast
Persistent Global Instability
Limited Markets
Clean Baseload Resource Delay
Baseline
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000
180,000
SUN
NG
WIND
Solar Plus Battery
Storage
Pumped Storage
Offshore Wind
UR
Largest 2027 Build for reference

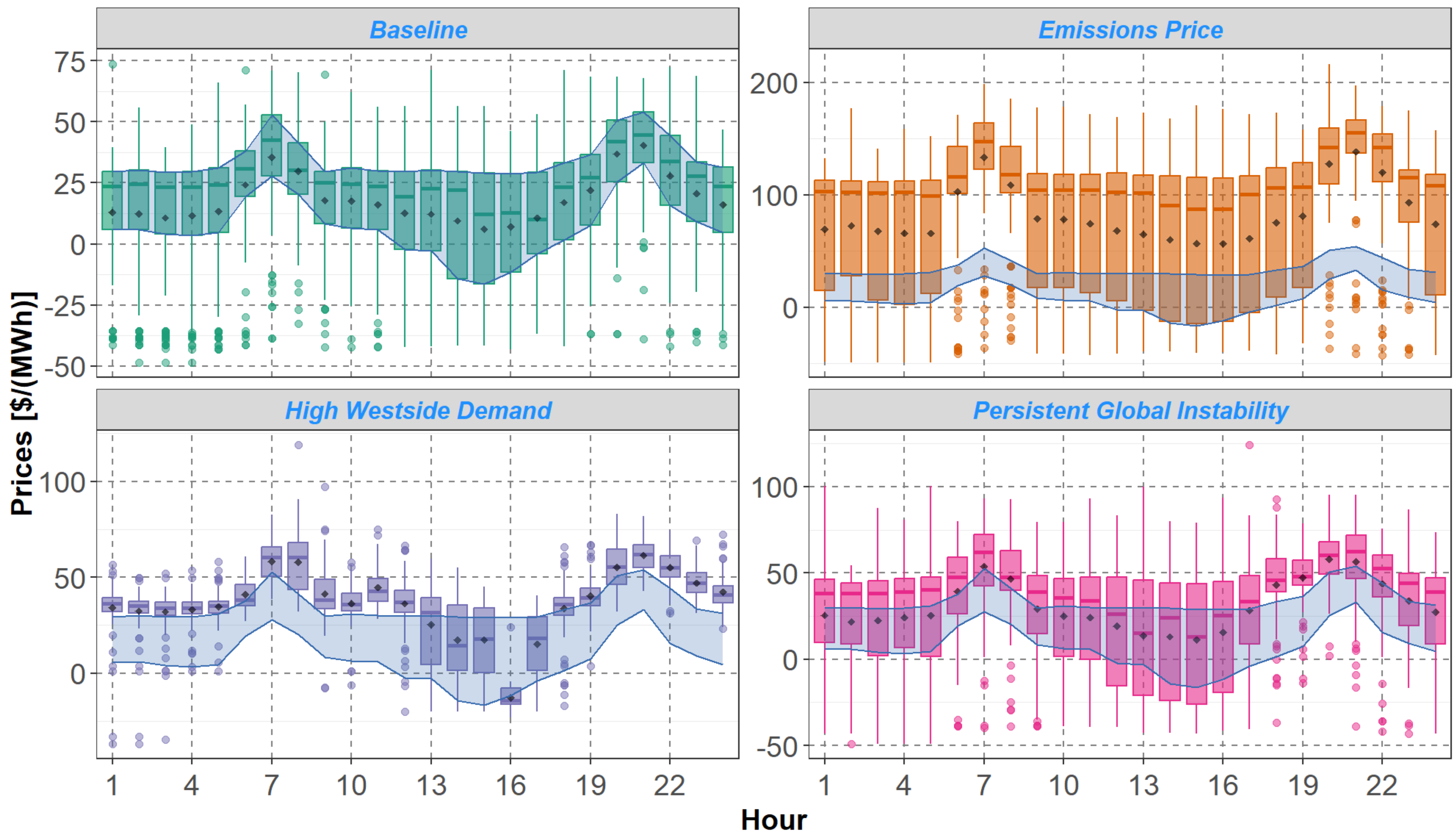
Observations

- Most scenarios have around 30% curtailment of renewables or hydro by the end of the study except WECC High Demand West Coast (24%), Limited Markets (15%) and Organized Market (21%)
- Most scenarios have decreasing thermal plant capacity factors from around 40% at beginning of the study to 25% to 33%, but the Limited Markets scenario thermal plant capacity factors go up to over 50%.

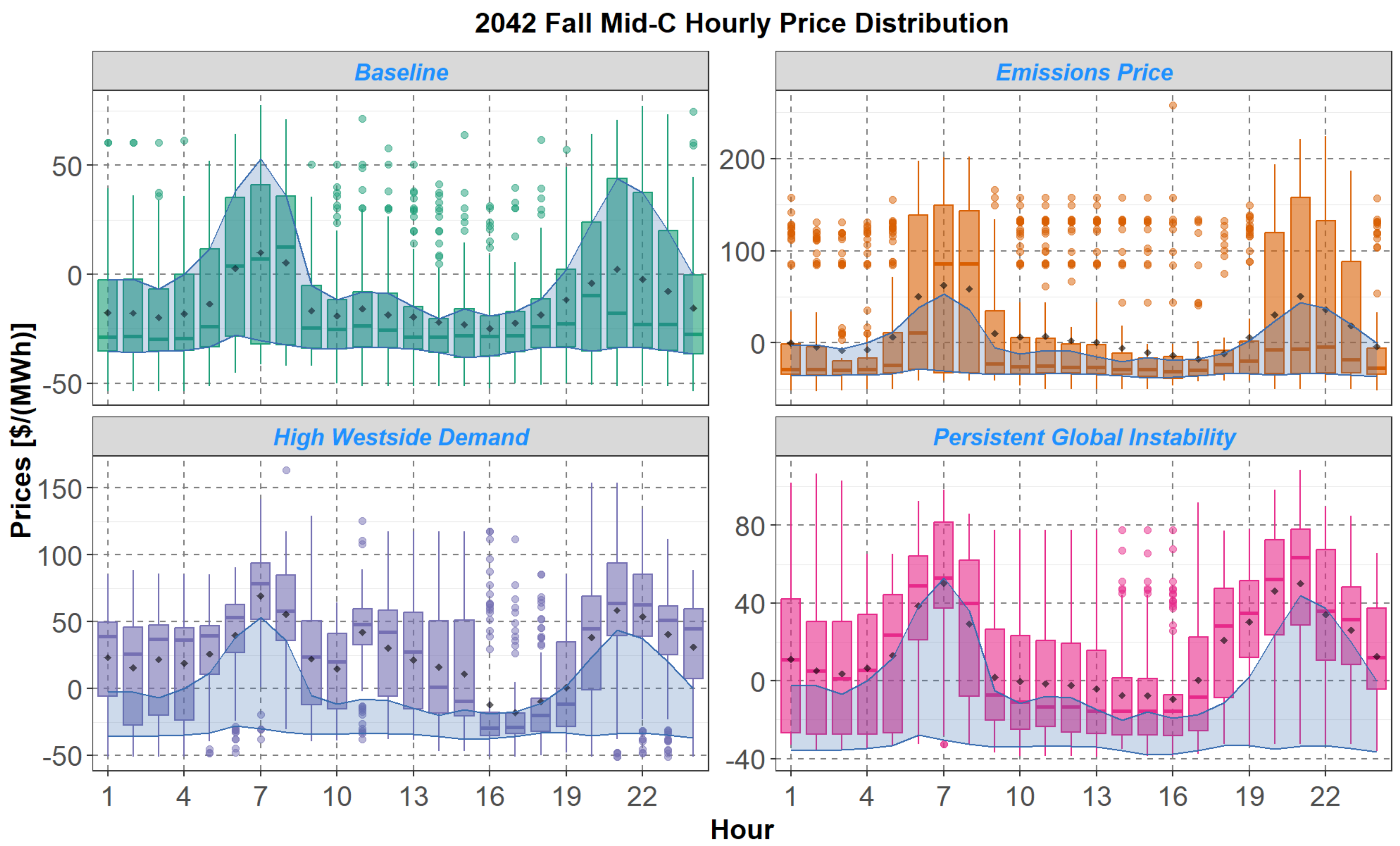


Central 50% of baseline hourly distribution (25th-75th percentiles)

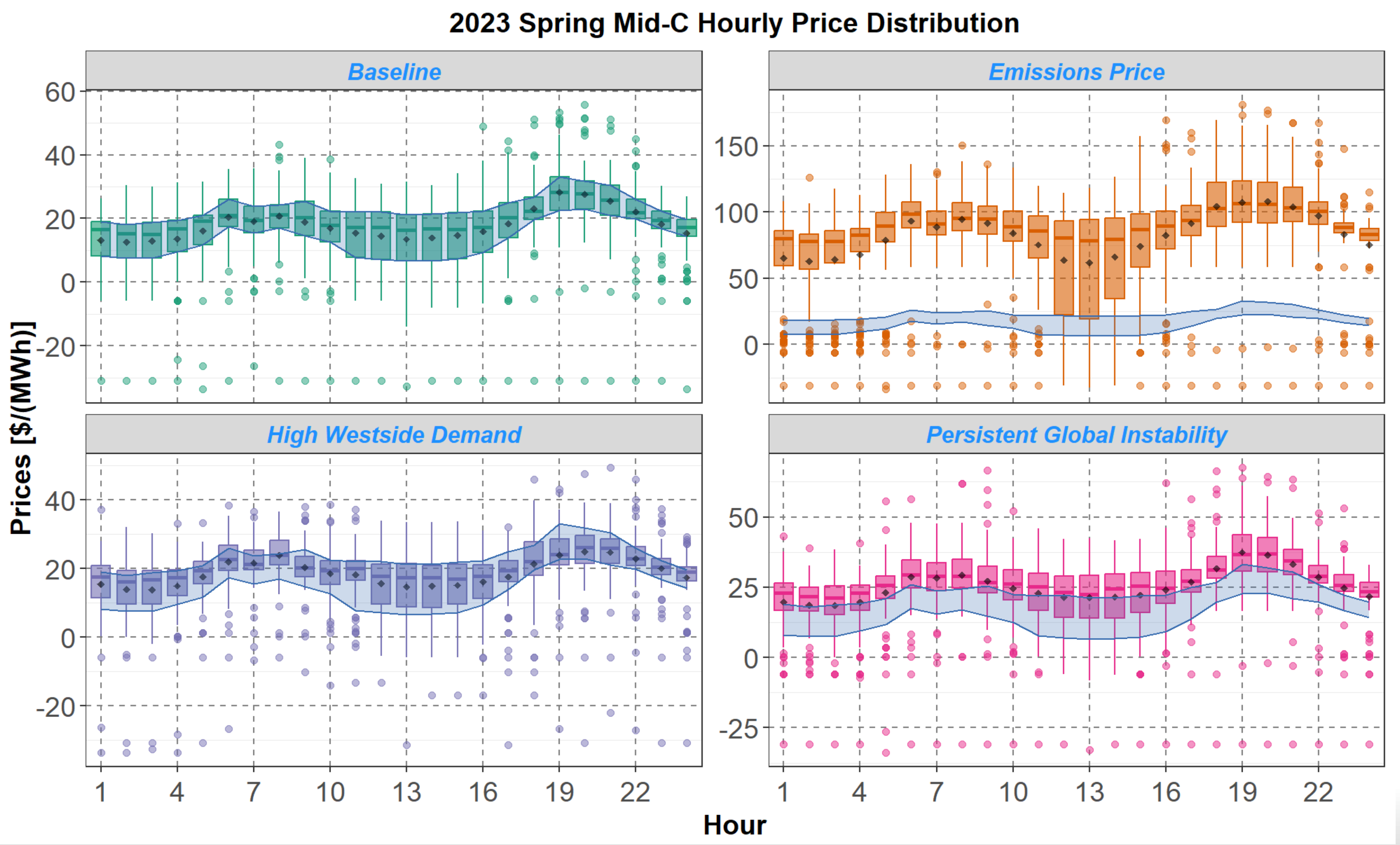
2033 Fall Mid-C Hourly Price Distribution



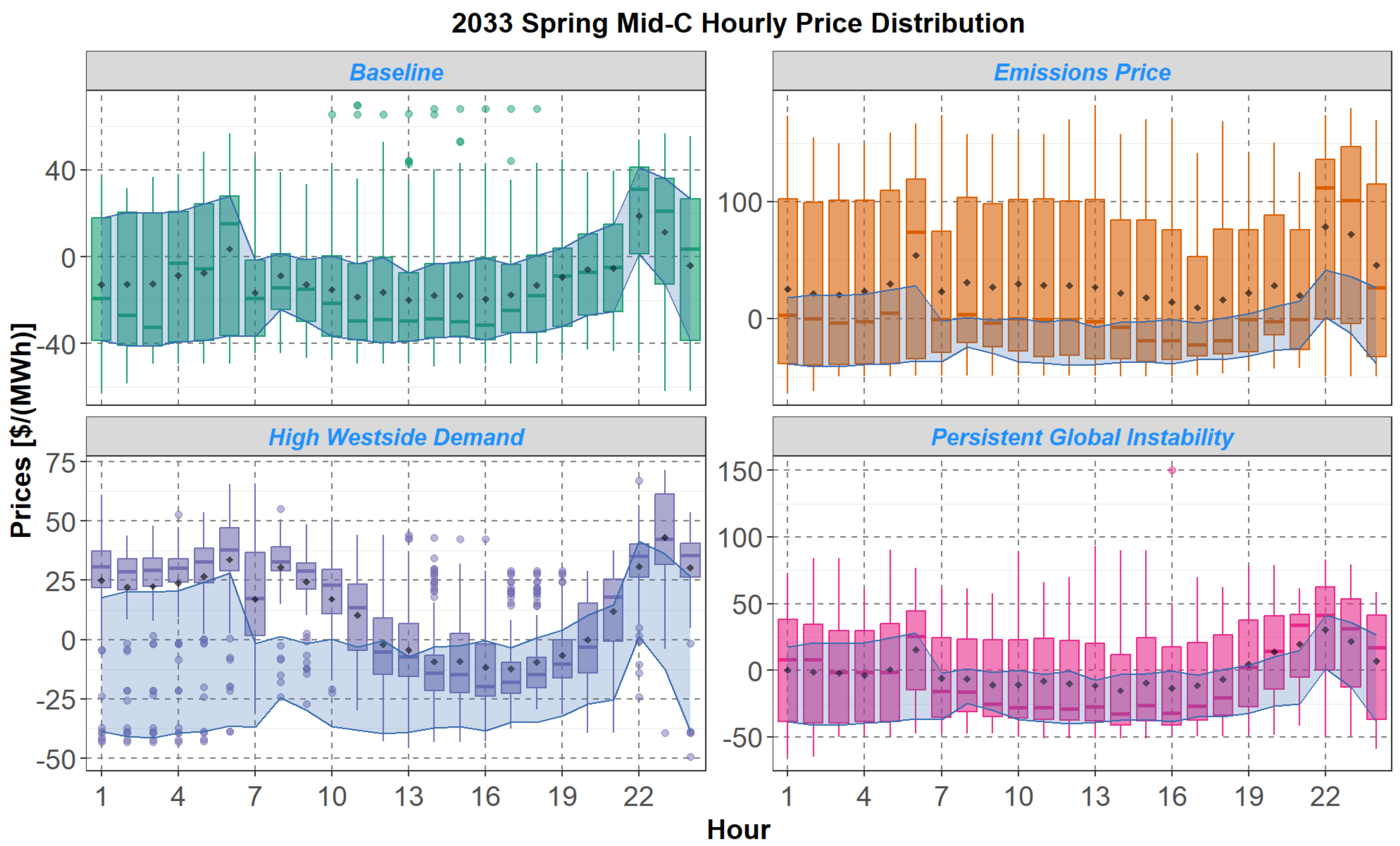
Central 50% of baseline hourly distribution (25^{th}-75^{th} percentiles)



Central 50% of baseline hourly distribution (25th-75th percentiles)



Central 50% of baseline hourly distribution (25th-75th percentiles)



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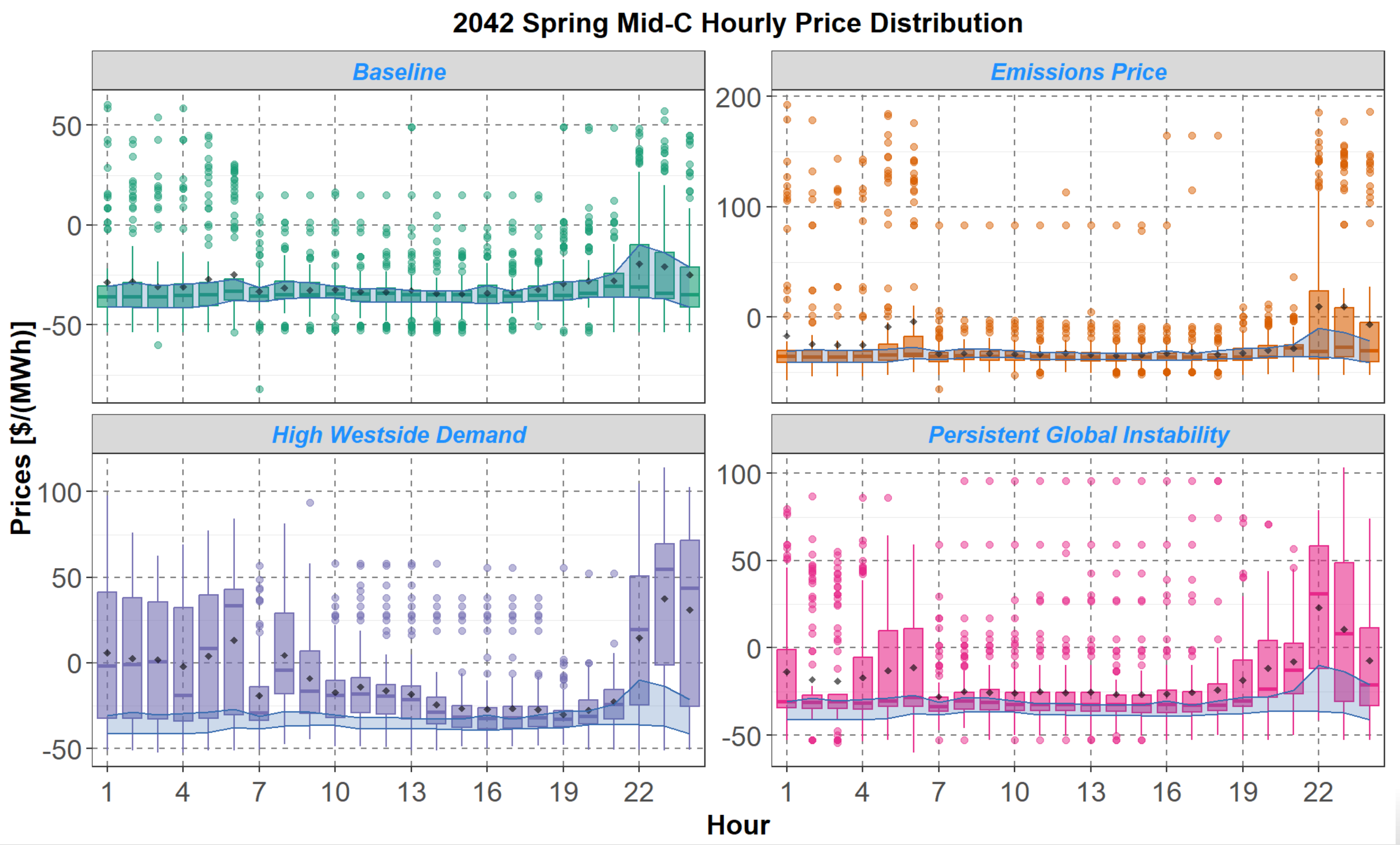
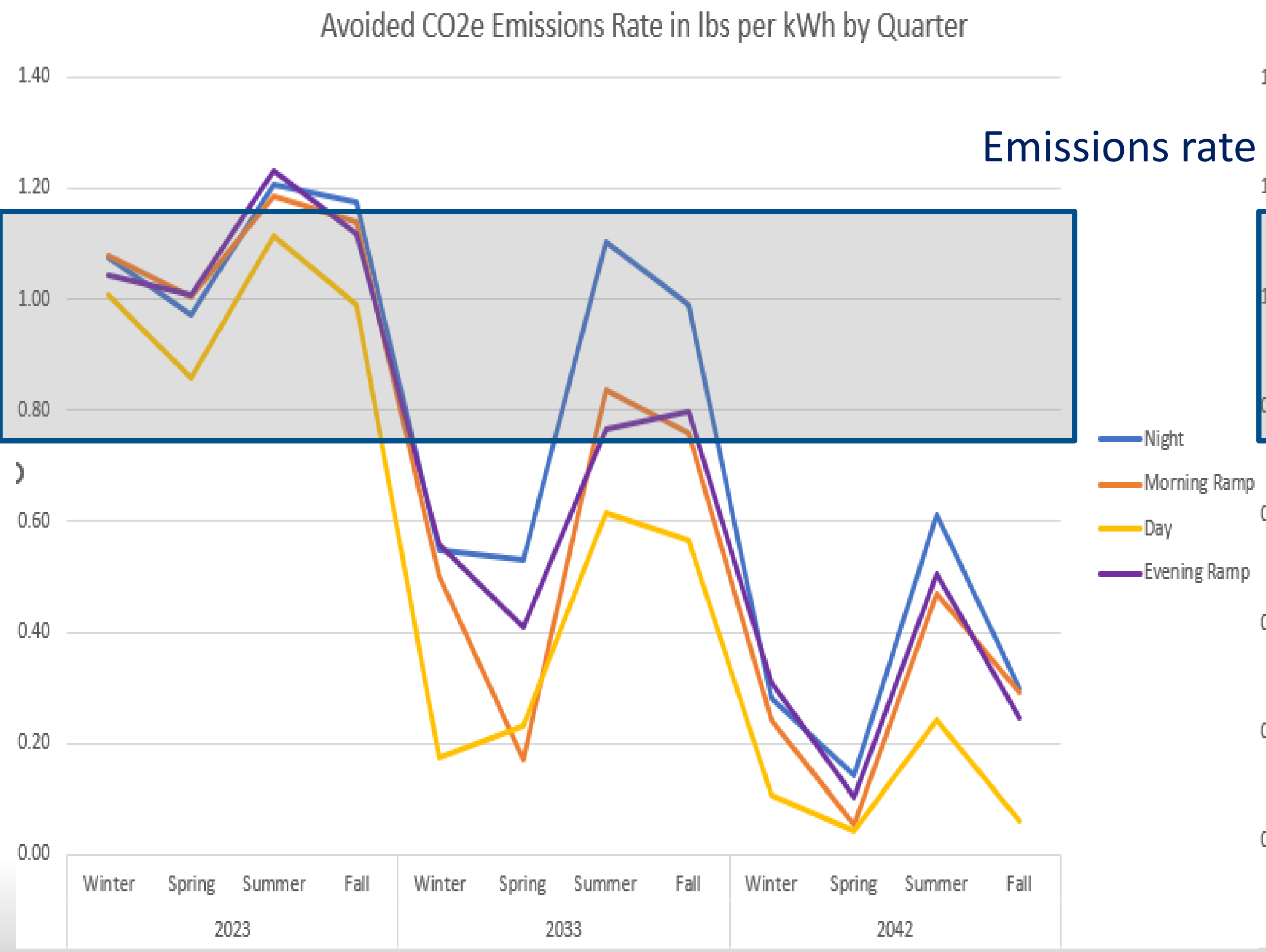
Central 50% of baseline hourly distribution (25th-75th percentiles)



50% of baseline hourly distribution (25th-75th percentiles)

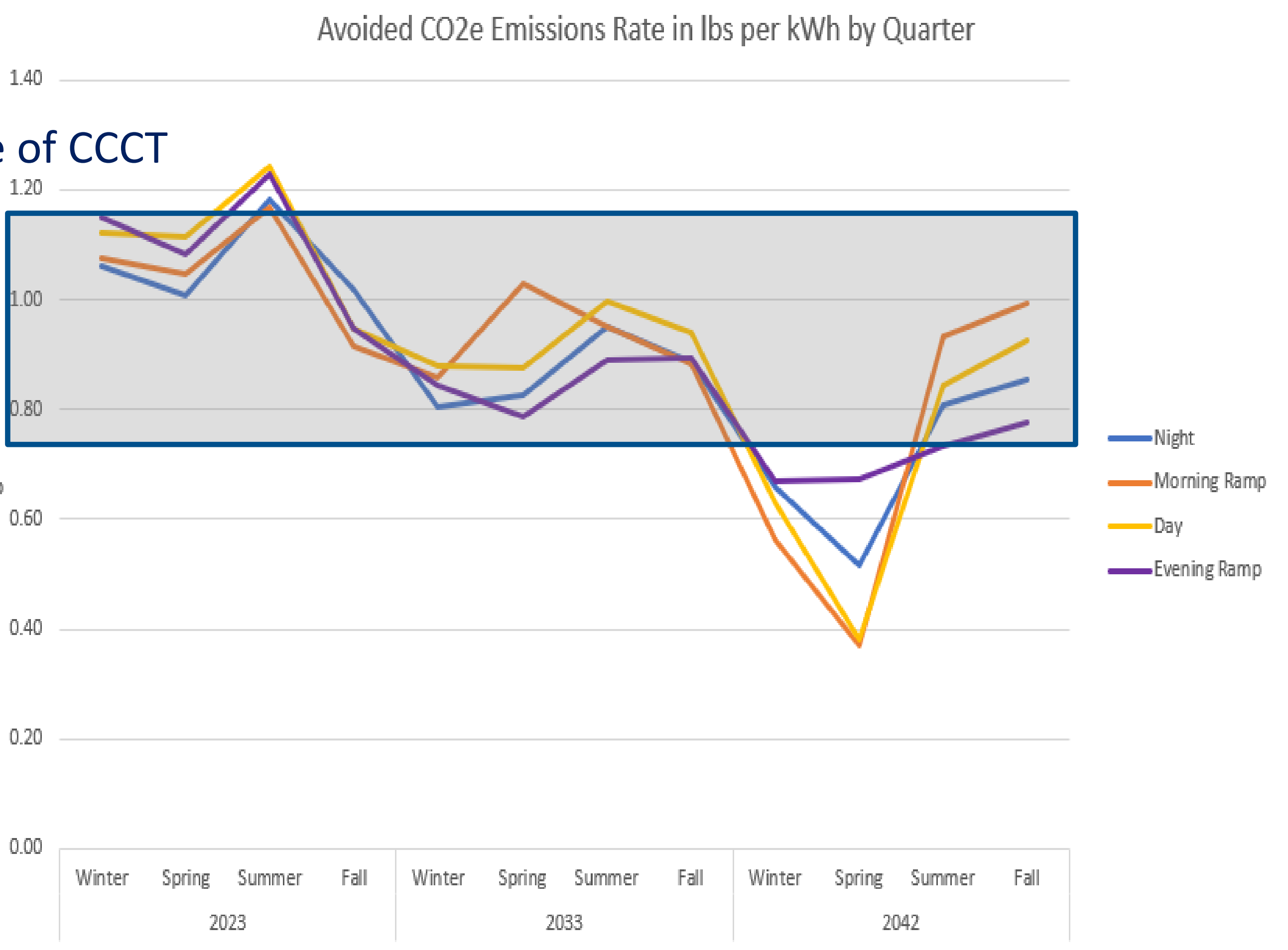
Avoided Emissions Rates Drivers Part 4

Baseline

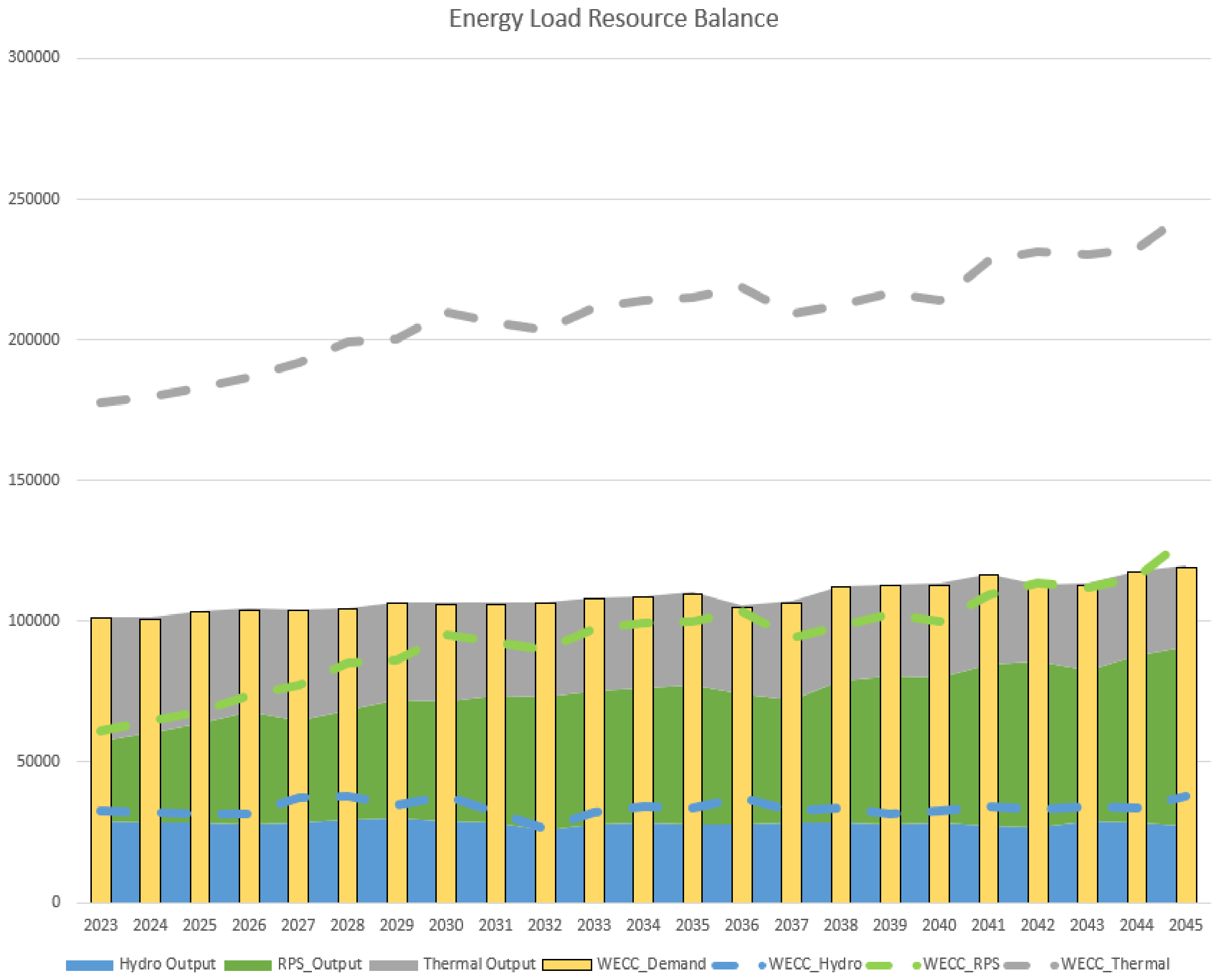


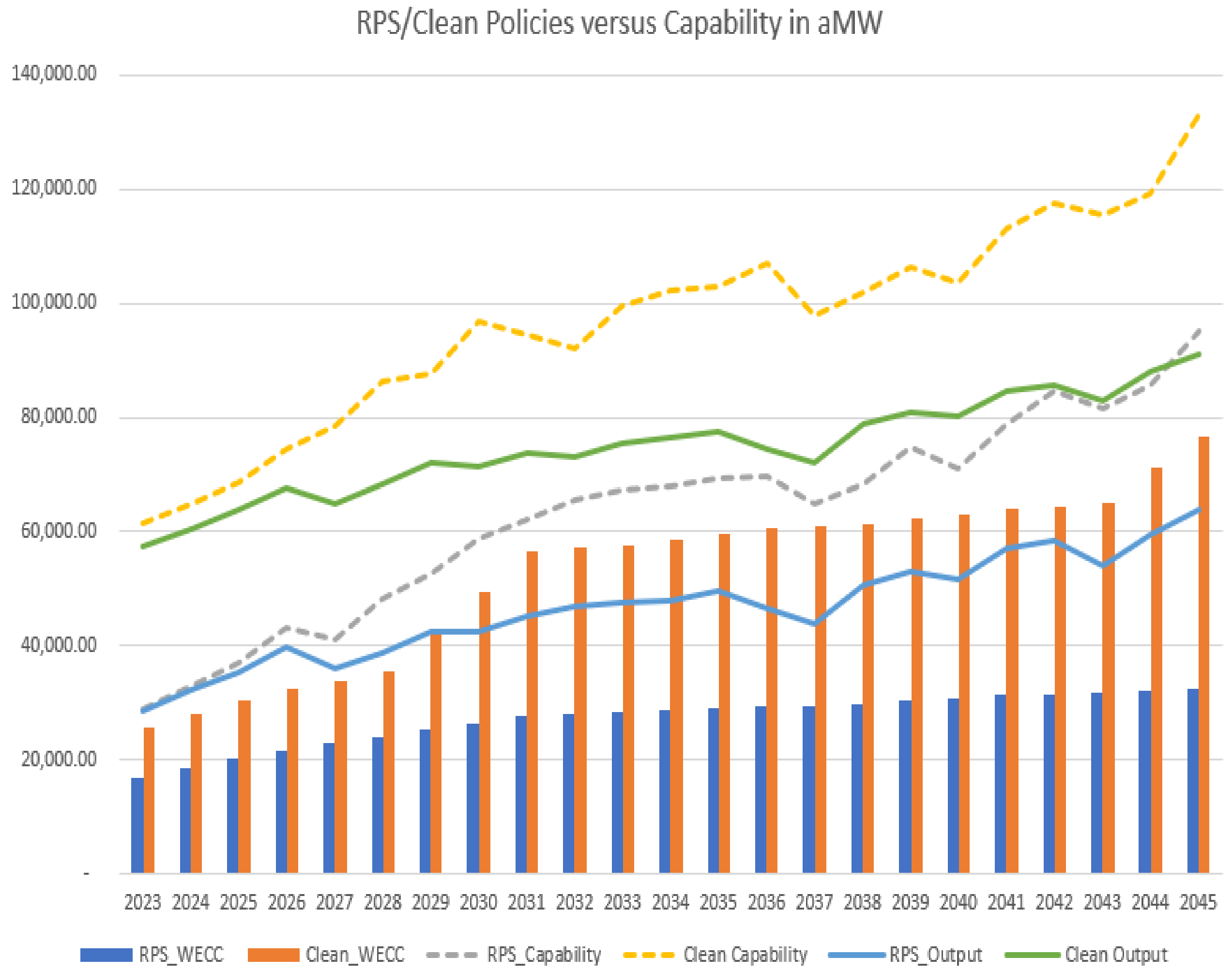
Emissions rate of CCCT

No Gas Build Limits

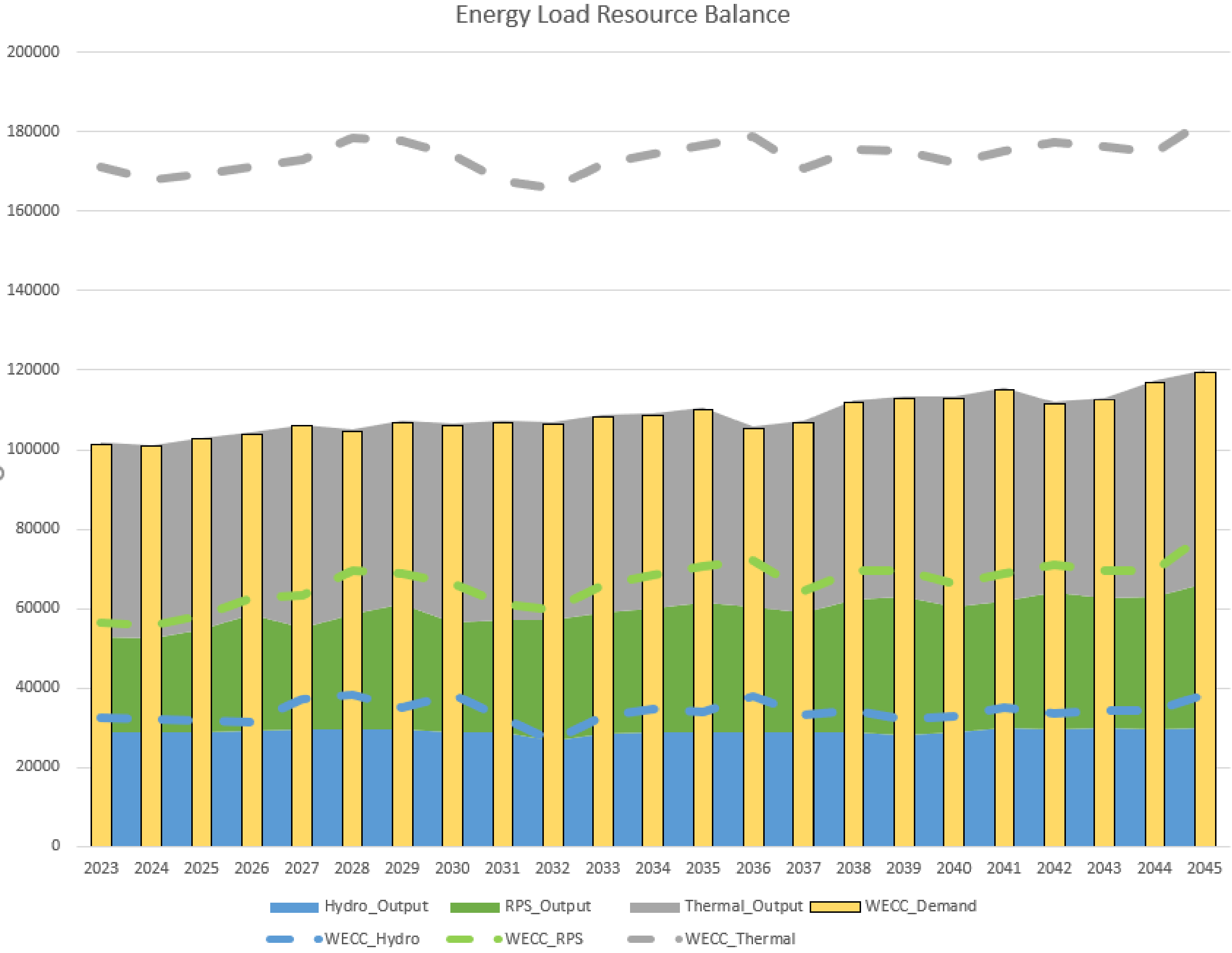


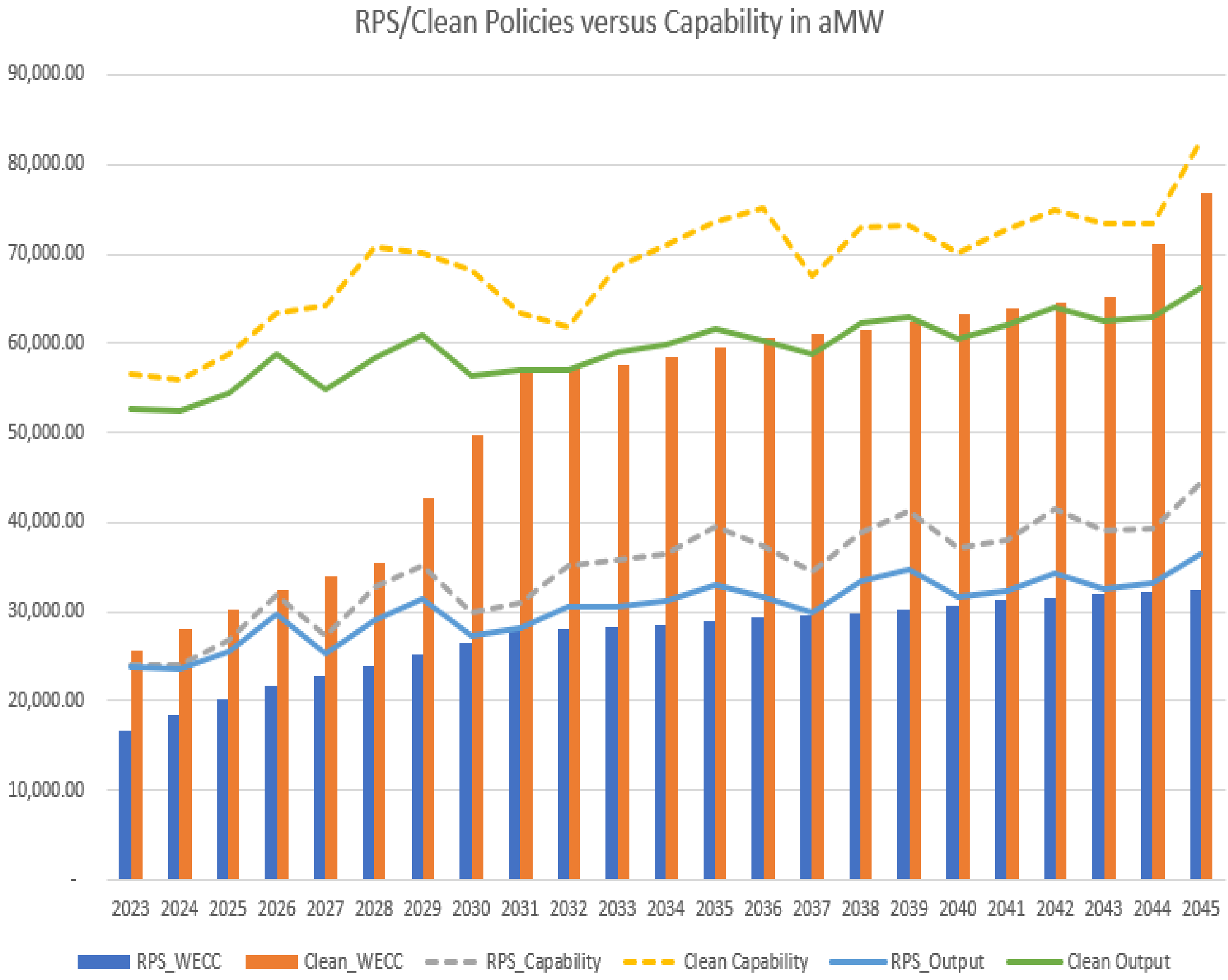
Baseline


Energy Load Resource Balance
300000
250000
200000
150000
100000
50000
0
2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045
Hydro Output
RPS_Output
Thermal Output
WECC_Demand
WECC_Hydro
WECC_RPS
WECC_Thermal

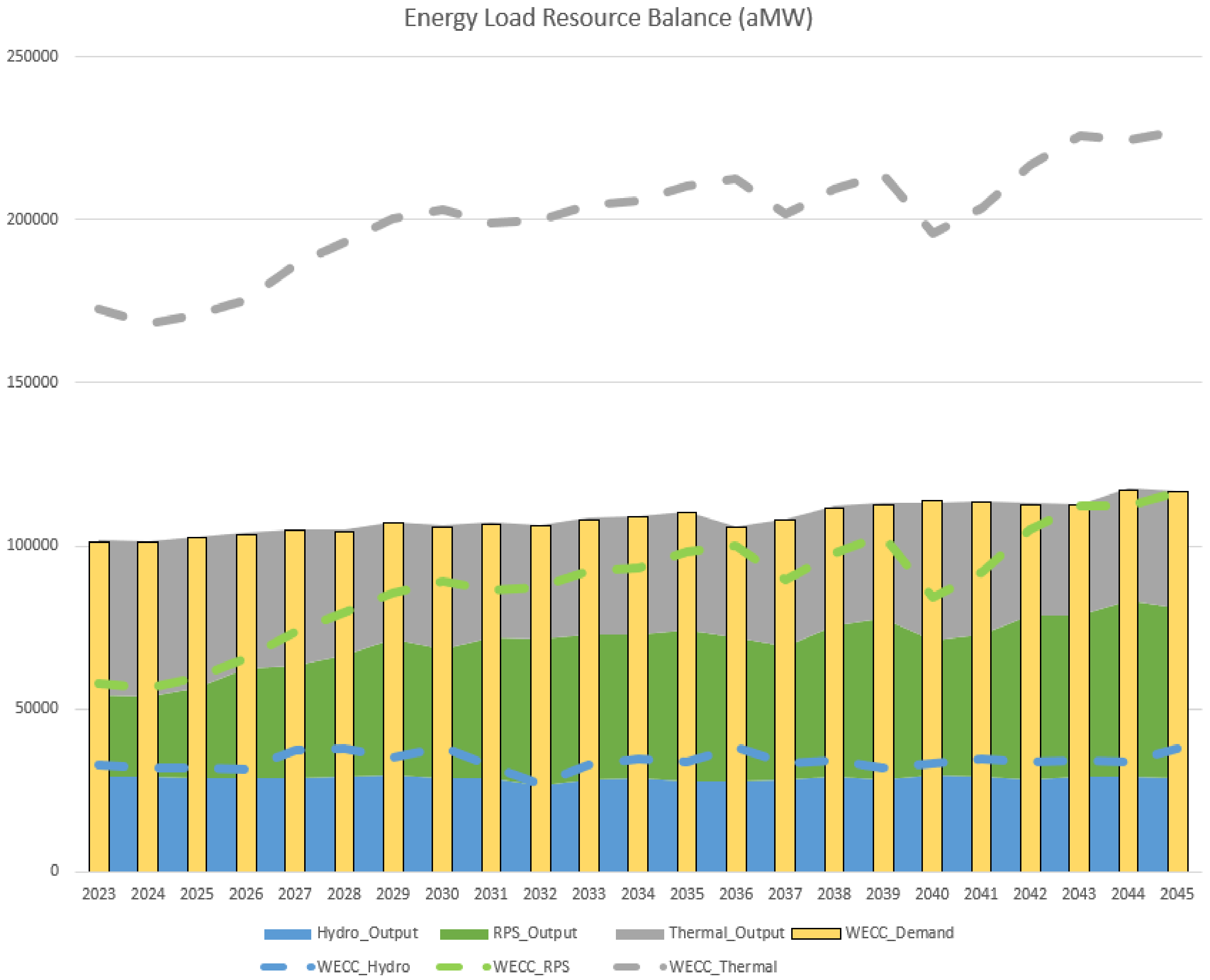

RPS/Clean Policies versus Capability in aMW
140,000.00
120,000.00
100,000.00
80,000.00
60,000.00
40,000.00
20,000.00
-
2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045
RPS_WECC
Clean_WECC
RPS_Capability
Clean Capability
RPS_Output
Clean Output

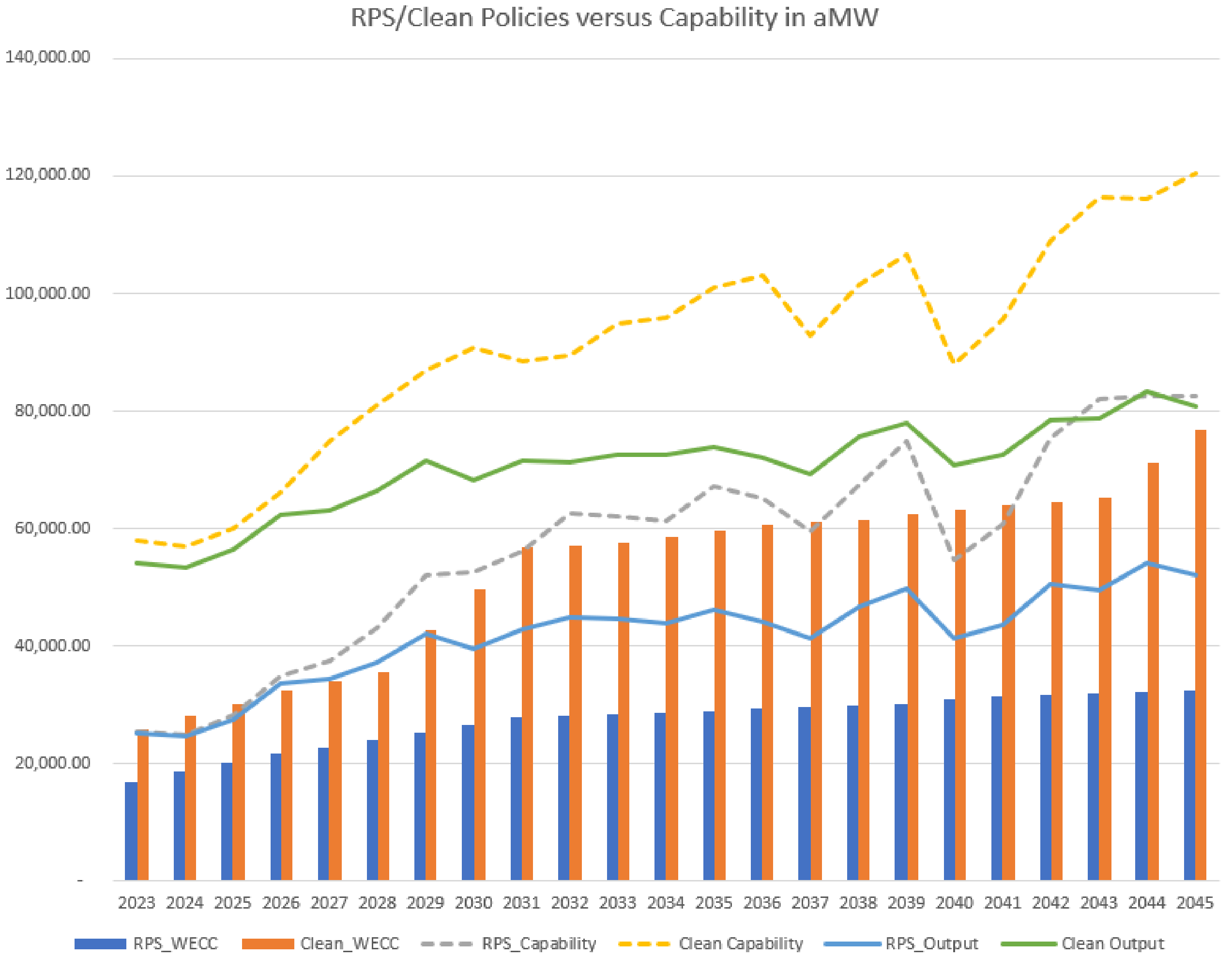
Limited Markets



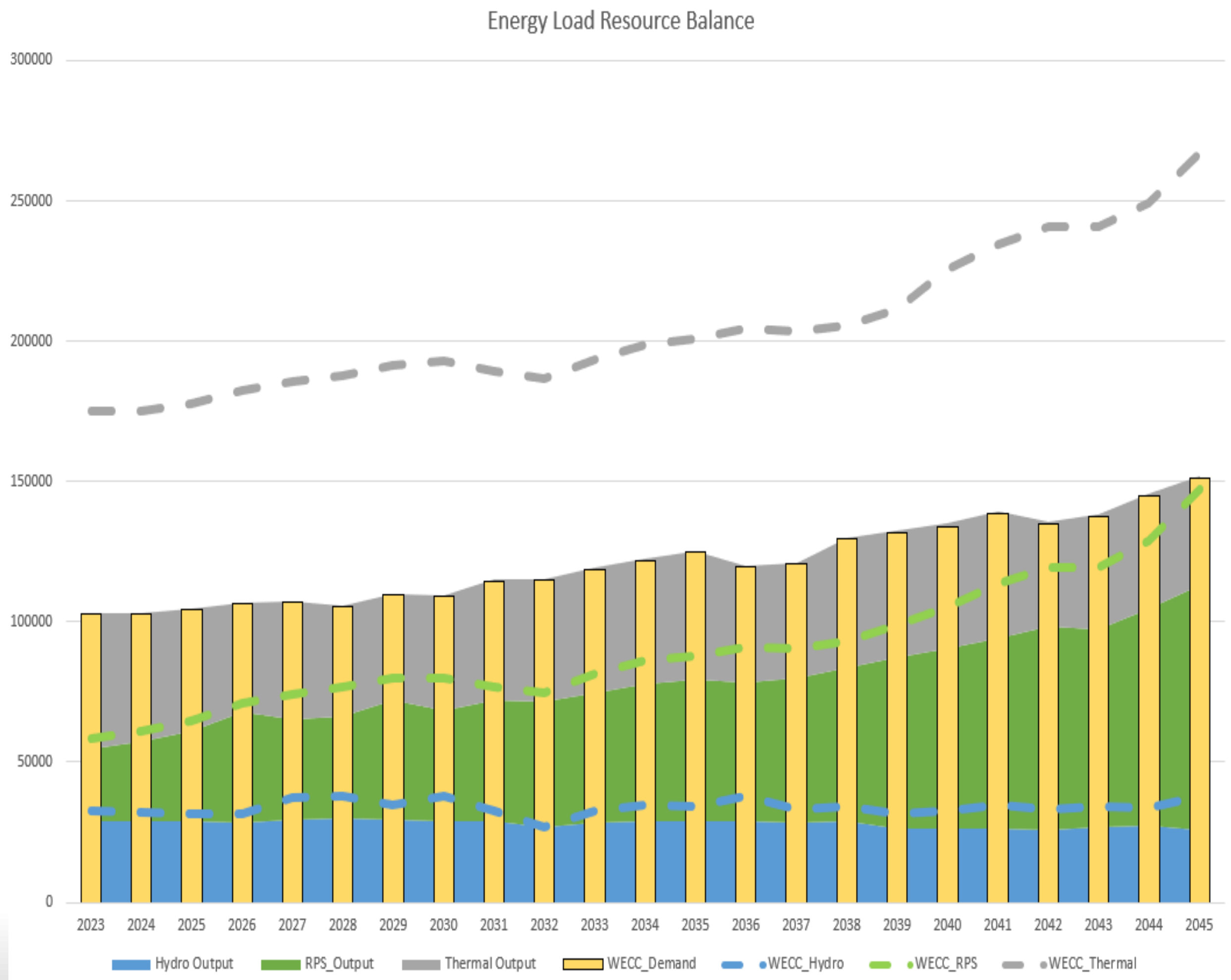


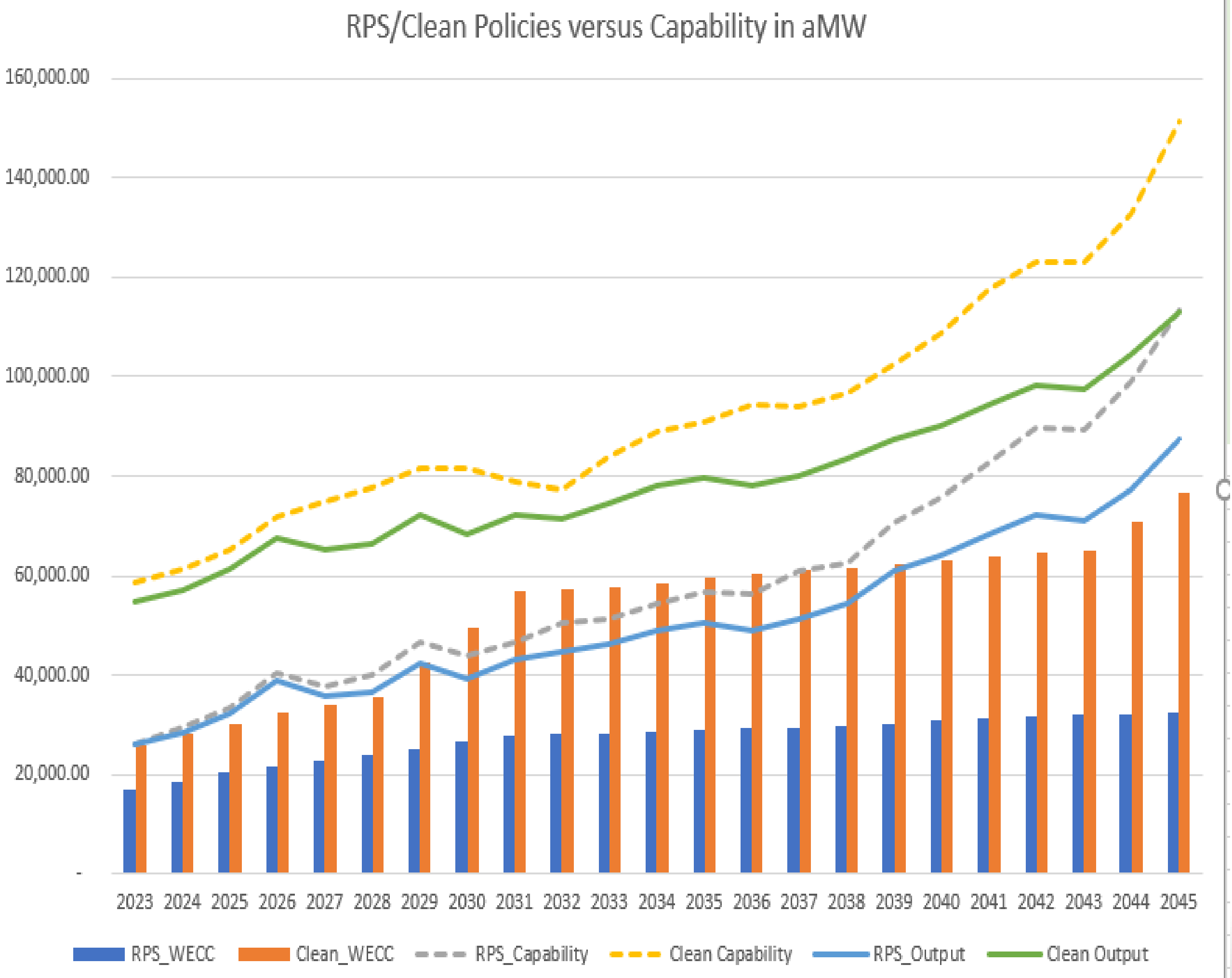
Persistent Global Instability



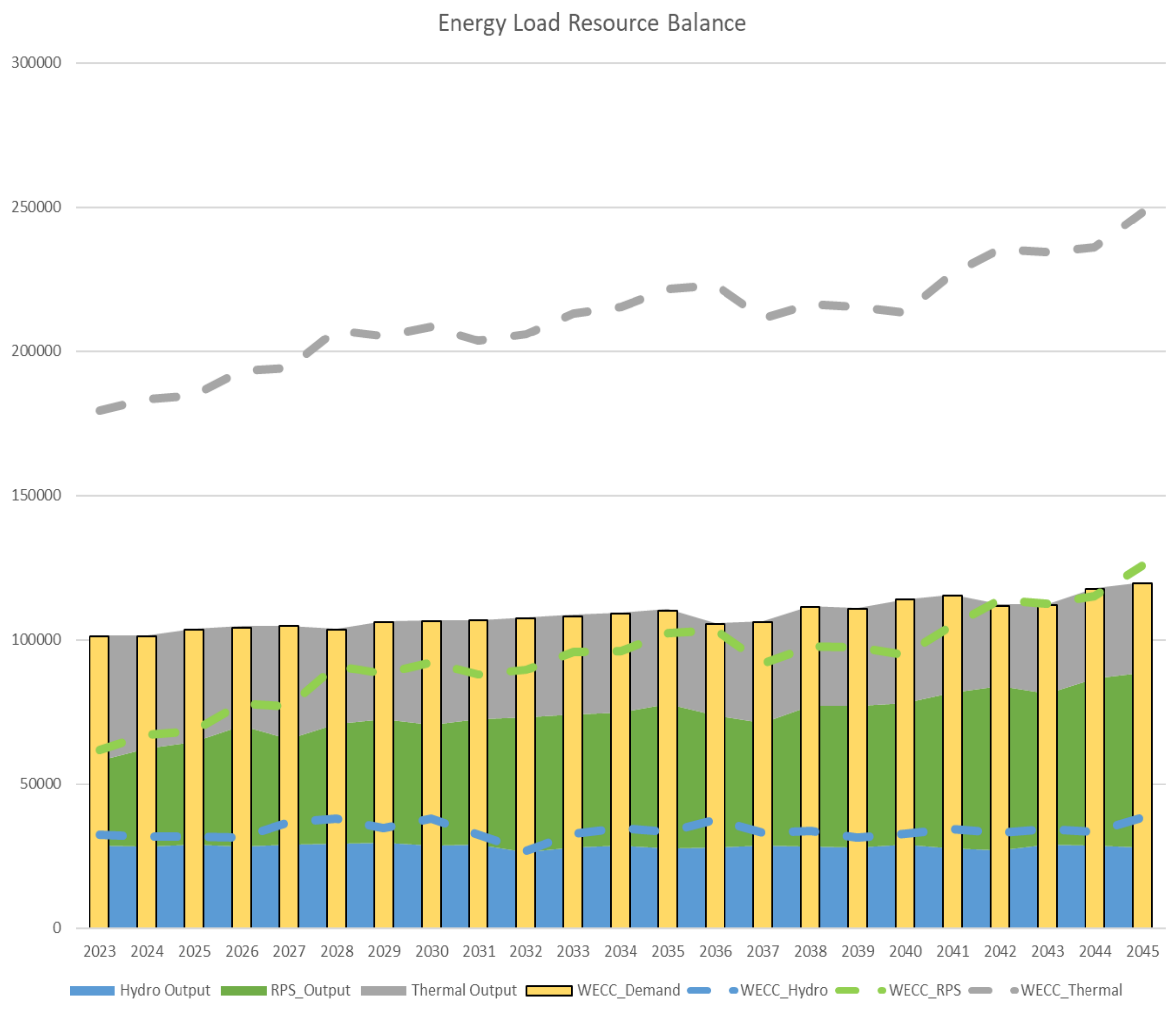


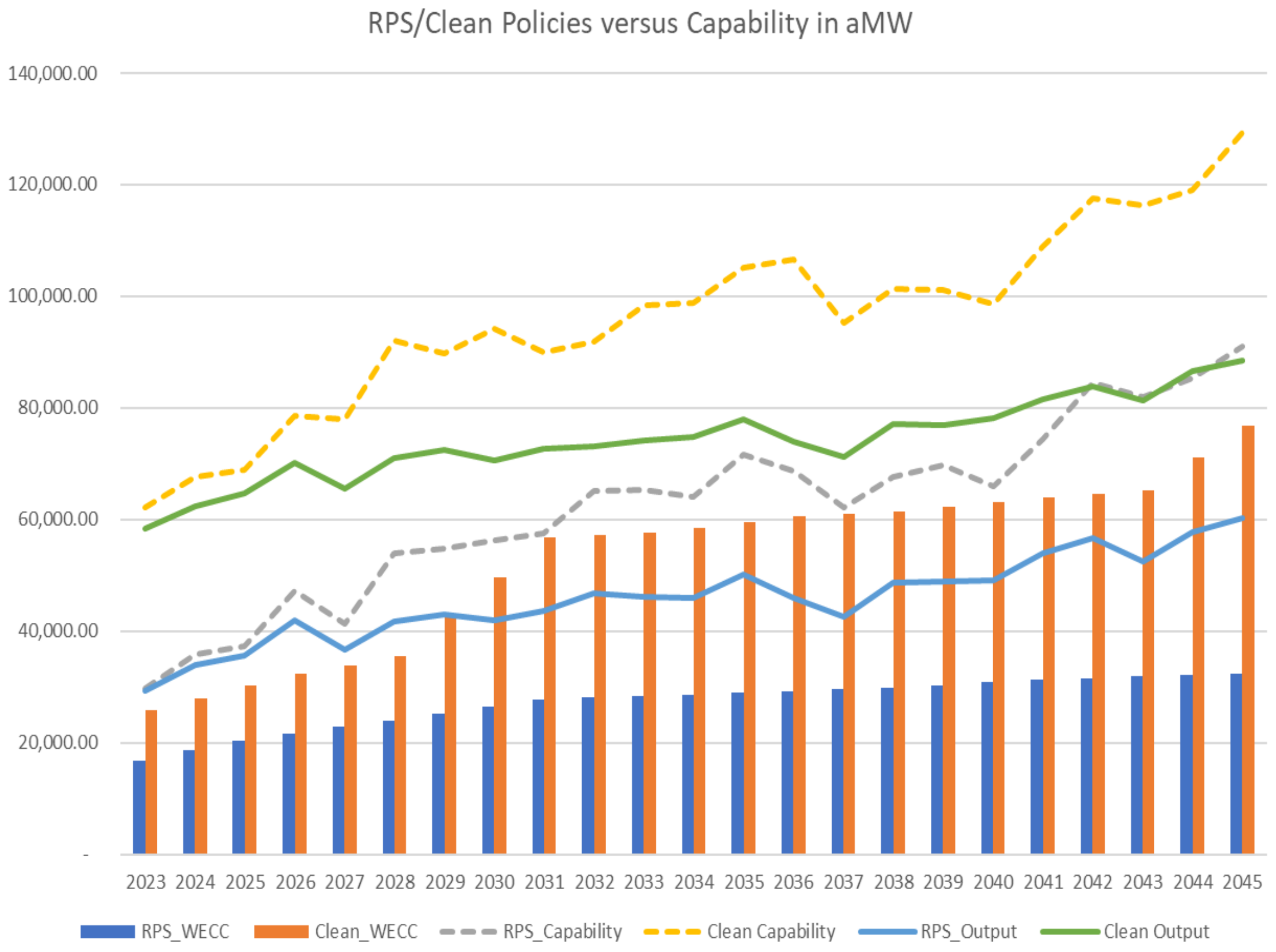
High West Coast Demand



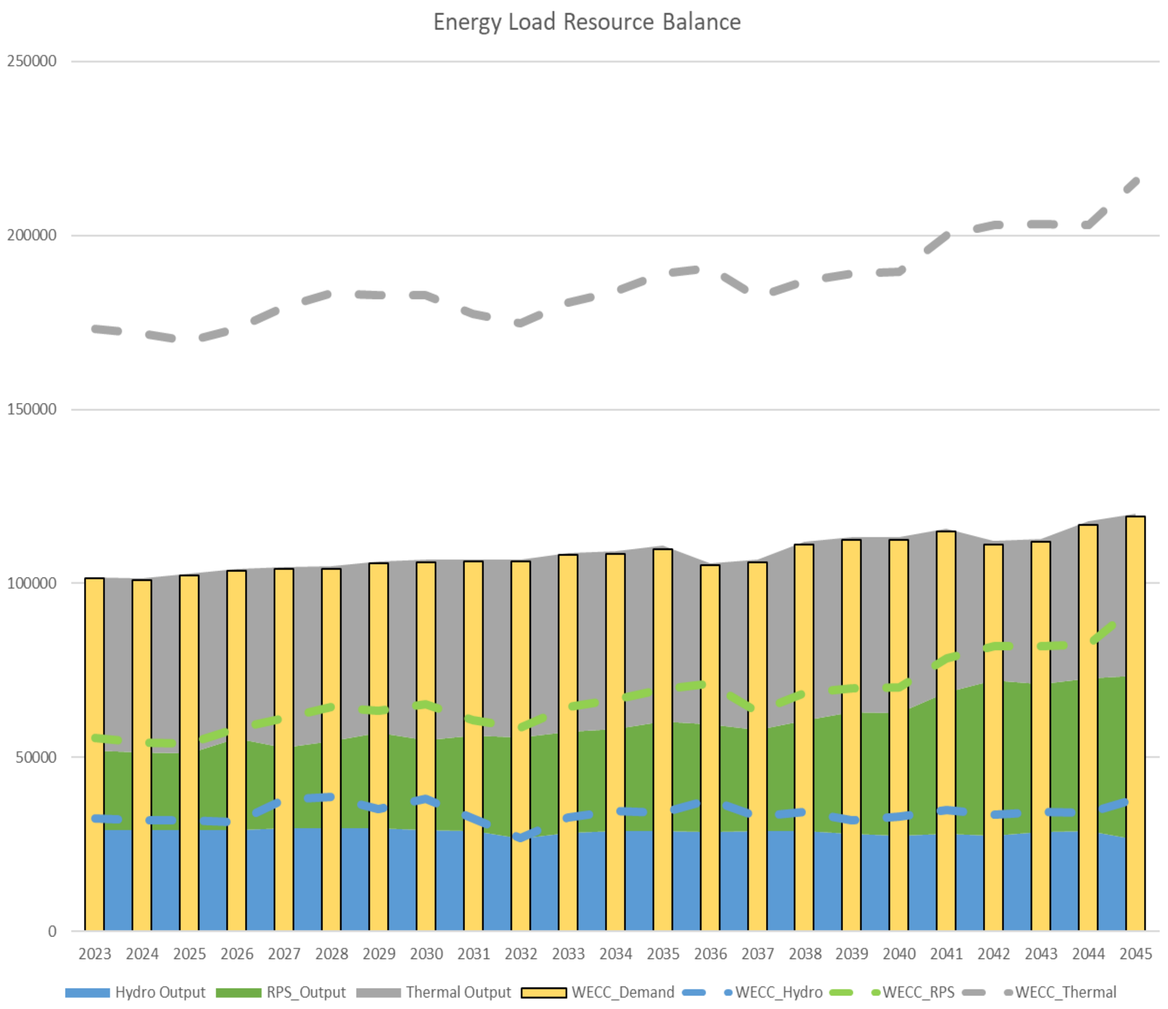


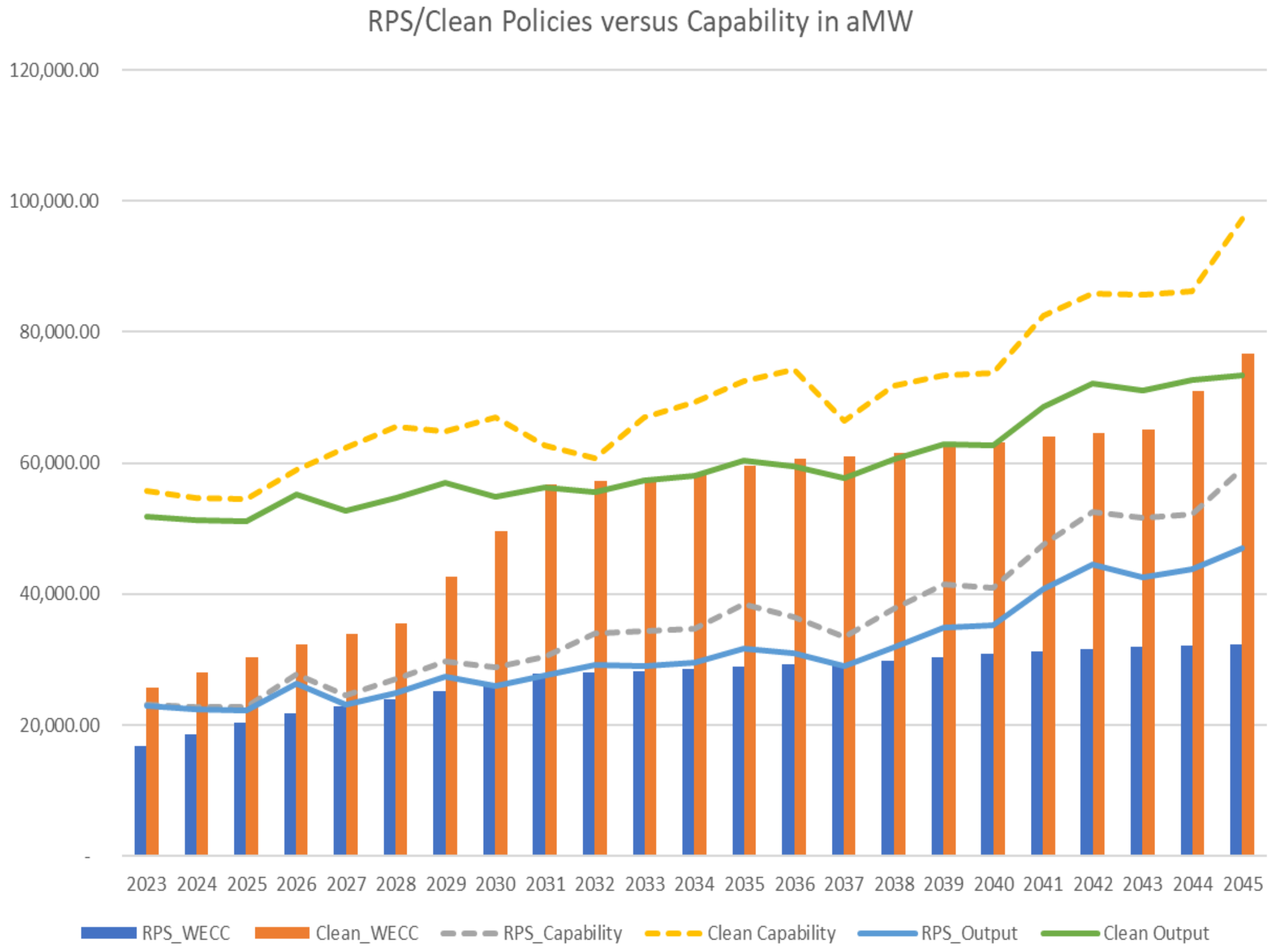
High Social Cost of Carbon





Organized Market





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No Gas Build Limits