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

November 5, 2019

MEMORANDUM

TO: **Council Members**

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

SUBJECT: **Wholesale Electricity Price and Avoided CO_2 Emissions Rate Forecast Update**

BACKGROUND:

Presenter: John Ollis

Summary: This presentation will inform the Council on the results of the 2019 wholesale electricity price forecast and avoided CO_2 emissions rate study updates, and the response from the System Analysis Advisory Committee. These studies have been updated to incorporate more of the state policy goals and plant retirements that have been announced since the Seventh Power Plan's Mid-Term Assessment.

Relevance: The Council periodically updates a 20-year forecast of electric power prices and avoided emissions rate studies using the AURORA model. The AURORA model dispatches all resources in the WECC generating a fundamentals-based wholesale electricity price forecast.

The study of avoided carbon dioxide production rates of the northwest power system will evaluate what the implied avoided carbon emissions rate is in the WECC and the implications for regional conservation replacing the need for that production.

Since the development of the midterm and previous avoided emissions rate study, new state renewable and clean energy targets have been

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established in California, Colorado, Nevada, New Mexico, and Washington. These state policies along with the retirements and pressures on conventional fossil fuel resources continue to fundamentally change the wholesale market dynamics in the WECC, and this updated price forecast helps Staff and regional stakeholders observe the effects of these changes on Mid-C market prices and the implied avoided CO_2 emission rate.

Workplan: Complete Wholesale Electricity Price and Avoided Emissions Rate study (B.5.2)

Background: The Council's wholesale electricity price 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.

Additionally, the cost of future carbon dioxide regulation has been a significant factor in resource planning in the Pacific Northwest. To avoid making higher cost resource choices, a direct evaluation of this risk requires an estimate of the carbon dioxide emissions avoided by purchasing conservation or another resource. The Council has periodically updated this study using the AURORA model to help inform Council staff and regional stakeholder analysis.

More Info: Previous studies:

Wholesale Price Forecast in 7th Plan Midterm (see 3-10 through 3-17)

Avoided Carbon Dioxide Production Rates in the Northwest Power System

Wholesale Price Forecast and Avoided Carbon Dioxide Emissions Rate

November 13th, 2019

Council Meeting

John Ollis

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Why Update Before the Plan?

- Let stakeholders and Council members see the effect of state policies on power prices, market emissions rates and WECC-wide buildout to facilitate the following:
  1. Discussions regarding any necessary methodology changes in time for implementation in the plan.
  2. Conversations regarding regional and WECC-wide policy assumptions.
  3. A more recent forecast for Mid-C prices and avoided emissions rates for regional stakeholders that use results of the studies.

Study Timeline

- Fuel prices, state policies and some generating resource fixed costs updated as of October 2019
- Get updated guidance from SAAC about AURORA setup and methodologies before 2021 Power Plan runs.
- Present results at the November 2019 Council meeting

Limited Scenarios and Scope

Primary purpose of update is to observe effects of new state policies since midterm forecast!

Base Scenario Assumptions:

- Existing Policy
- Medium Gas Price
- Medium Regional Load
- *Gas plant builds limited in states with clean policies*

Per initial analysis…

Additional scenarios tested

- High and low gas price forecasts
- *Remove gas plant build limitations*
- Universal carbon pricing in WECC
  - Using 7th Plan Social Cost of Carbon assumptions like Marginal CO2 Study.

And stakeholder guidance

Limited Data Updates

1. Loads (not updated - 2018 hourly) and gas price forecasts (updated 2019 monthly) updated for study years.
2. Update resource additions and retirements in AURORA.
3. Update plant parameters for solar, solar with storage, wind and battery.
4. Update WECC-wide state policies.

	RPS	Clean/Carbon	No Coal
Washington	✓	✓	✓
Oregon	✓	✗	✓
Idaho	✗	✗	✗
Montana	✓	✗	✗
California	✓	✓	✓
Wyoming	✗	✗	✗
Nevada	✓	✓	✗
Colorado	✓	✓	✗
Utah	✓	✗	✗
Arizona	✓	✗	✗
New Mexico	✓	✓	✗
British Columbia	✓	✓	✓
Alberta	✓	✓	✓
Sum of ✓	10/13	5/13	5/13
Sum of ✓ ✓	11/13	7/13	5/13

Different Representation of State Policies in AURORA

- The RPS and clean energy requirements (in MWh) for the WECC were summed up for all the individual state requirements.

  1. $\text{WECC\_RPS}_i = (\sum_{\forall RPS}(\%Reqt_{RPS})(Demand_{RPS}))_i$

  2. $\text{WECC\_Clean}_i = \left(\sum_{\forall Clean}(\%Reqt_{Clean})\,(Demand_{Clean})\right)_i$

  where *RPS* and *Clean* index the loads with a requirement, and i is year of the requirement

- Additionally all *RPS* and *Clean* resources can meet the WECC requirements.

New RPS Resources Available	New Clean Resources Available
Solar	All RPS-resources
Solar with Storage	Hydro
Wind	
Geothermal	

Build requirements specific to states will likely cause larger builds…

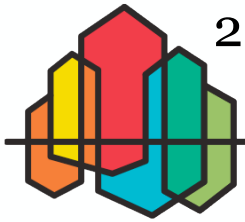
Three Main Components of the Study

- **WECC Buildout**
  - See effects of new state policies
- **Mid-C Pricing**
  - Mid-C Prices versus prices throughout WECC
  - Effect of gas price on Mid-C Pricing
  - Effect of hydro condition on Mid-C pricing
  - Daily price shape change throughout time
- **Avoided Emissions Rate**
  - Effect of hydro condition on market emissions rate

Initial Scope and Adjustments

- Two buildouts:
  1. Existing State Policy
  2. Existing State Policy plus Social Cost of Carbon Adder

- Buildouts were heavily relying on natural gas buildouts early in places in which there have been state government or regulatory resistance to building gas plants.
- Buildouts repeated with gas build limitations
  1. Existing State Policy
  2. Existing State Policy plus Social Cost of Carbon Adder



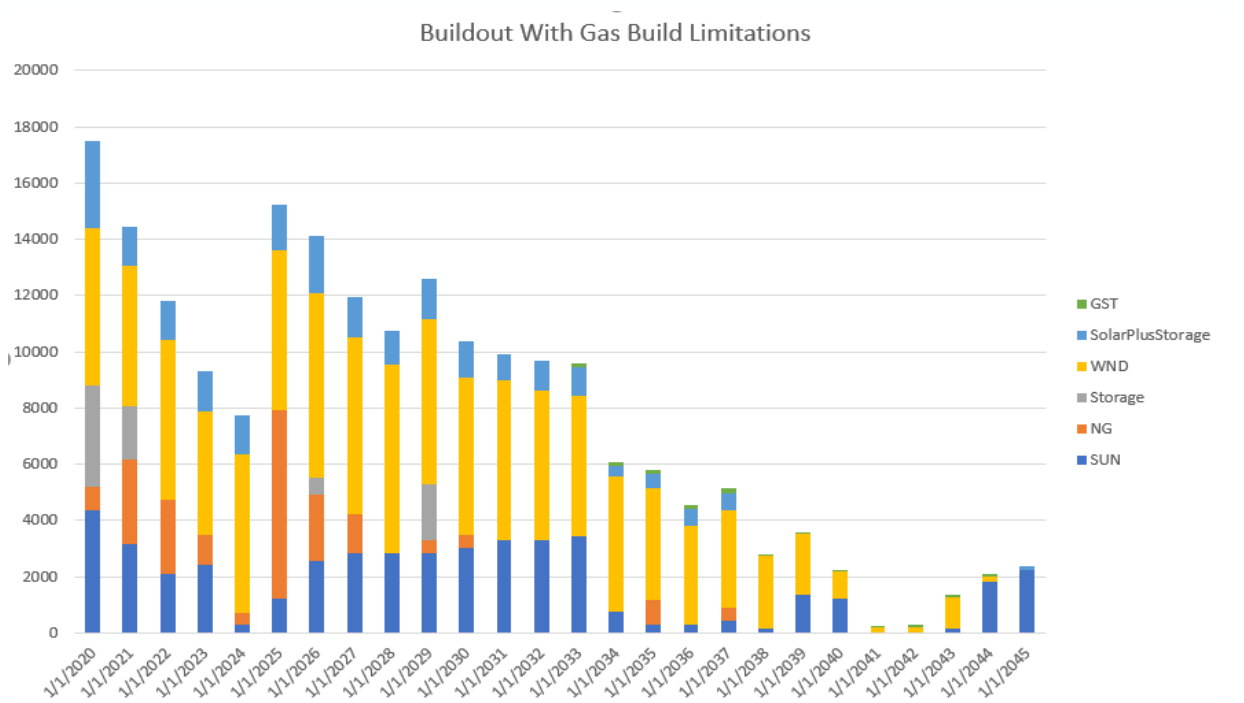
How Were Gas Plants Limited?

Observation	Limitation	AURORA Change	Justification for Change
Big first year gas build in Arizona, Alberta, and California	Only Alberta can build in 2020, all rest delayed until 2021	New Resource first build date	Unlikely builds considering time and political pressures
Big gas build throughout study all over WECC does not reflect risk of current regulatory, legal and political barriers associated with building fossil fuel plants in some places.	Alberta, Utah and Wyoming can build gas at similar rate, but lower max build. CA, WA, OR can't build gas. Other entities are limited to building before 2026.	Changed ramps and max build constraints. More restrictions on CCCTs than SCCTs	States that rely on exporting to states with, or where there is a clean policy in 2045 unlikely to build a 20 year gas asset after 2025.

Observations:

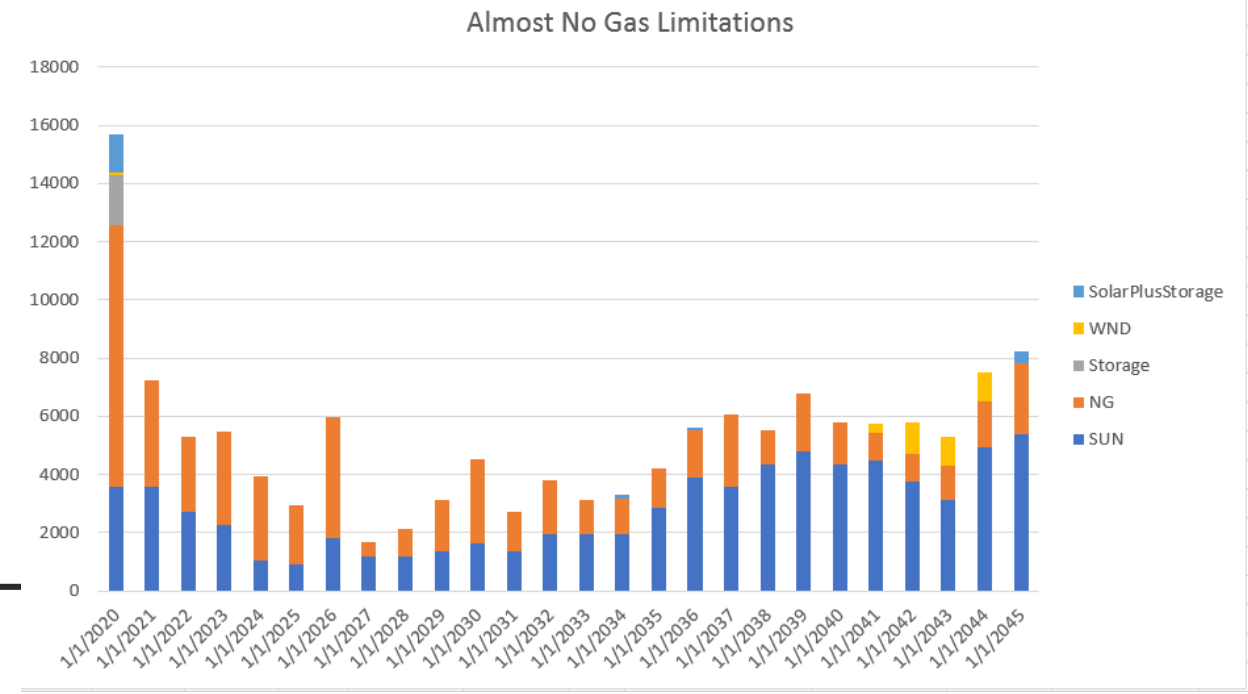
Huge first year diverse renewable and storage build, followed by consistent investment in clean energy sources with some gas

Are other regions actually going to meet their stated reserve margins?



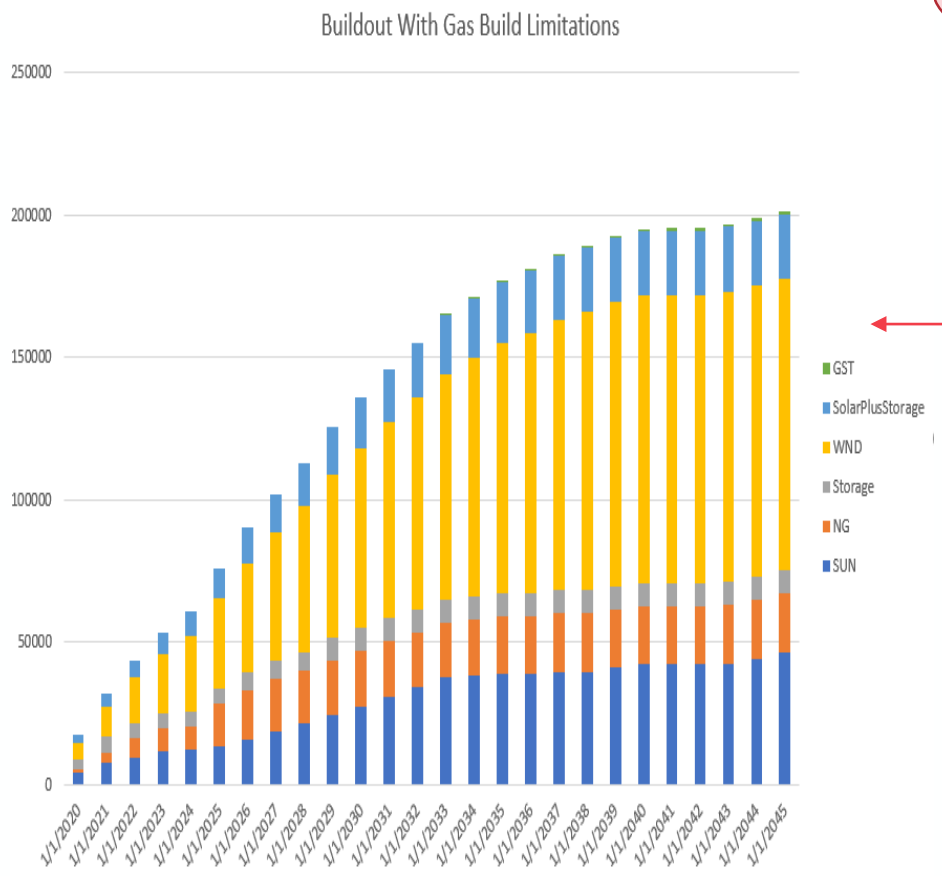
Observations:

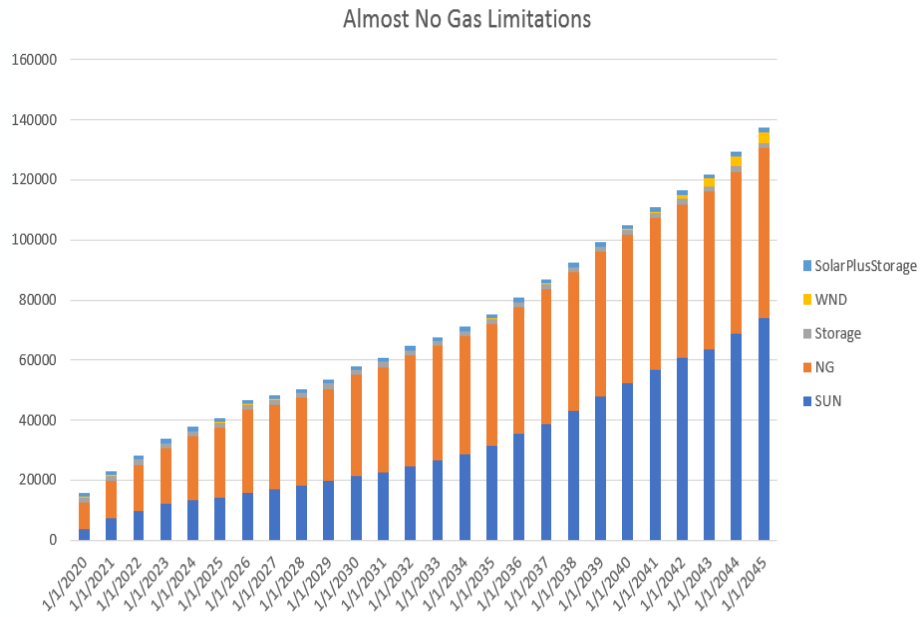
Huge first year gas build, followed by consistent investment in gas, lower renewable build



Comparison of Buildout by Scenario – *Cumulative Buildout in Nameplate MWs by Year*

More nameplate MW of resources are needed when there are gas plant build limitations.



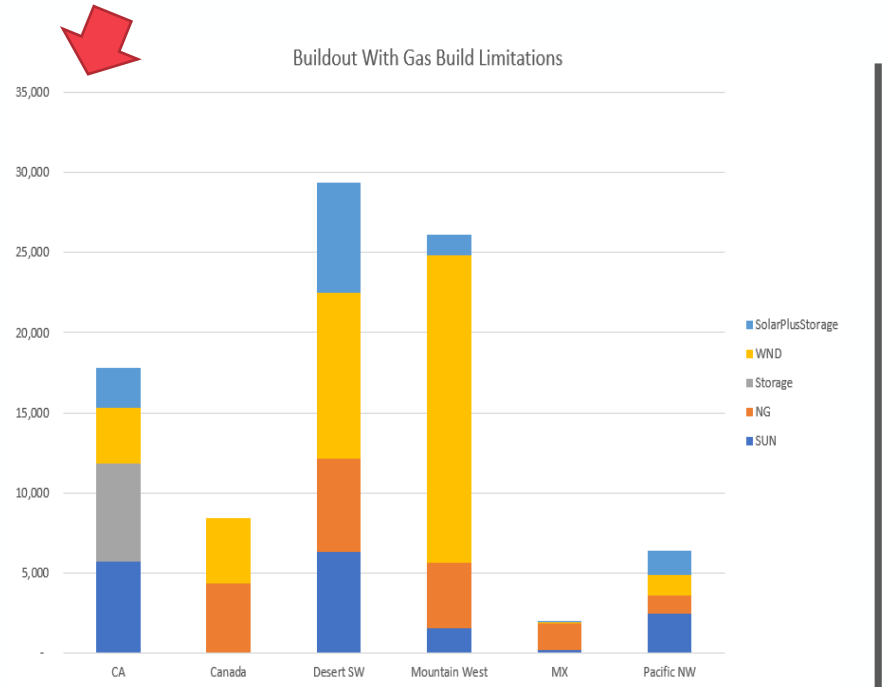


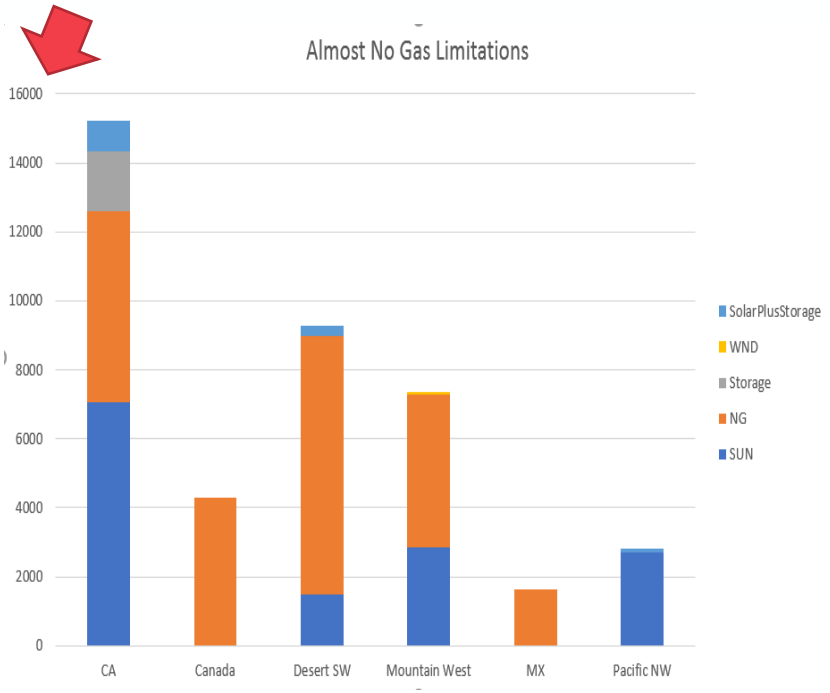
Comparison of Buildout by Scenario – *Cumulative Buildout in Nameplate MWs by Year*

Limited Gas per Regulatory and Policy Climate						
Year	Single Axis Solar	Natural Gas	4 Hour Battery	Wind	Solar with Battery	Geothermal
2025	16,050	17,082	6,100	38,600	12,300	0
2030	30,900	19,362	8,100	68,800	18,500	0
2035	39,000	20,220	8,100	91,400	22,100	546
2040	42,150	20,649	8,100	100,900	22,700	858
2045	46,350	20,649	8,100	102,400	22,800	1,170

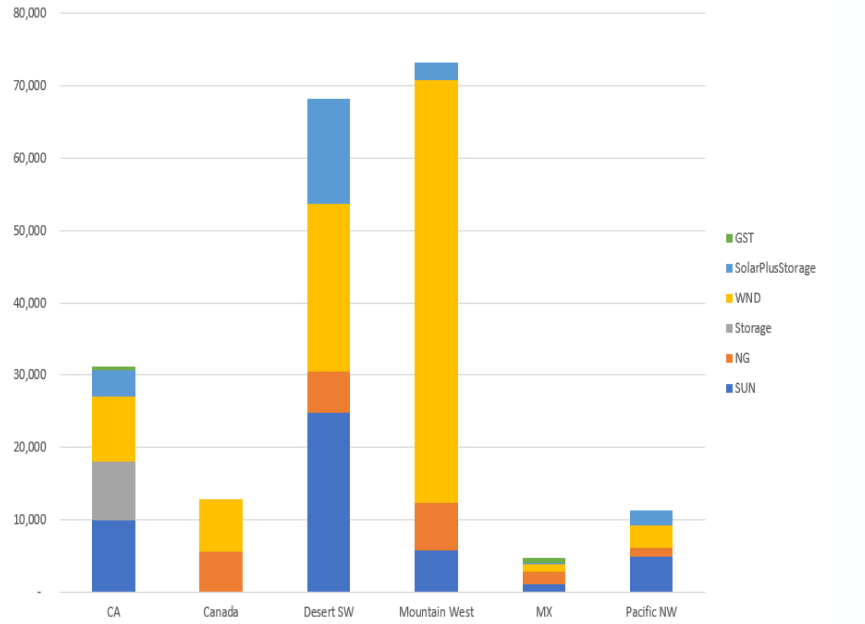
Minimal Gas Limitation						
Year	Single Axis Solar	Natural Gas	4 Hour Battery	Wind	Solar with Battery	Geothermal
2025	15,900	27,591	1,700	100	1,300	0
2030	22,650	35,052	1,700	100	1,300	0
2035	35,250	42,317	1,700	100	1,500	0
2040	56,850	50,354	1,700	400	1,500	0
2045	74,100	56,438	1,700	3,500	1,900	0

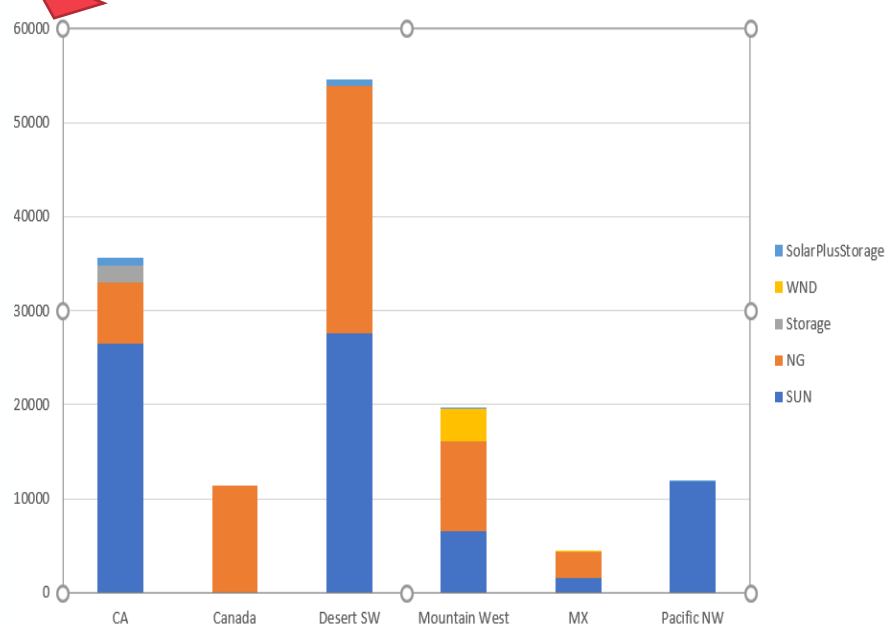
Where and what new resources are built by 2025?

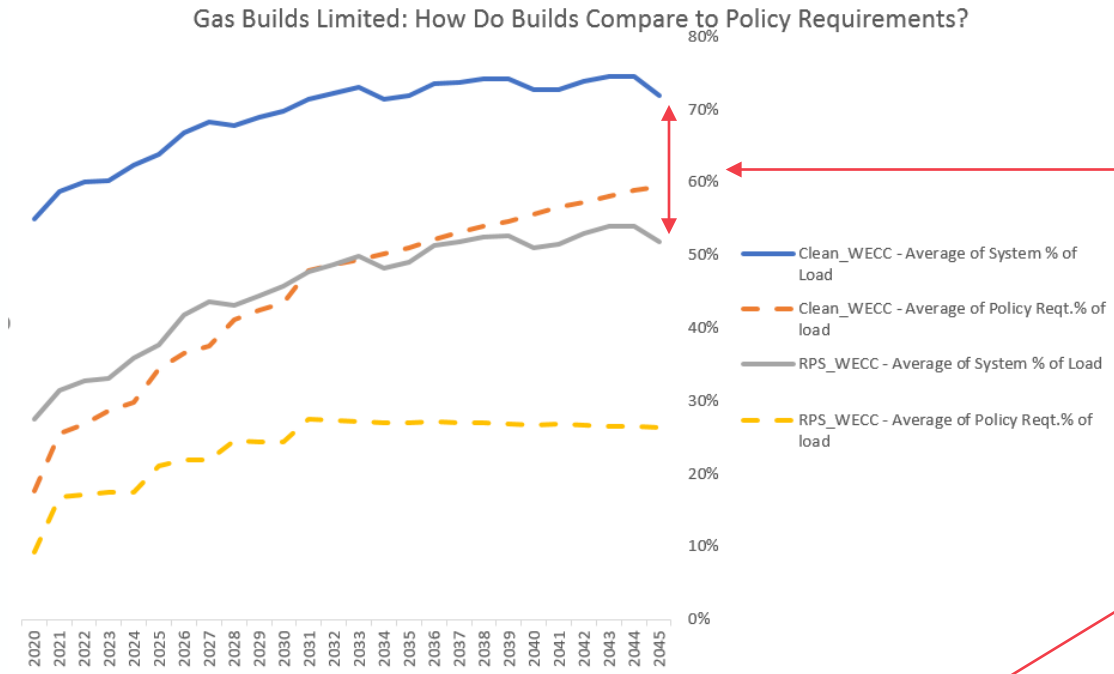


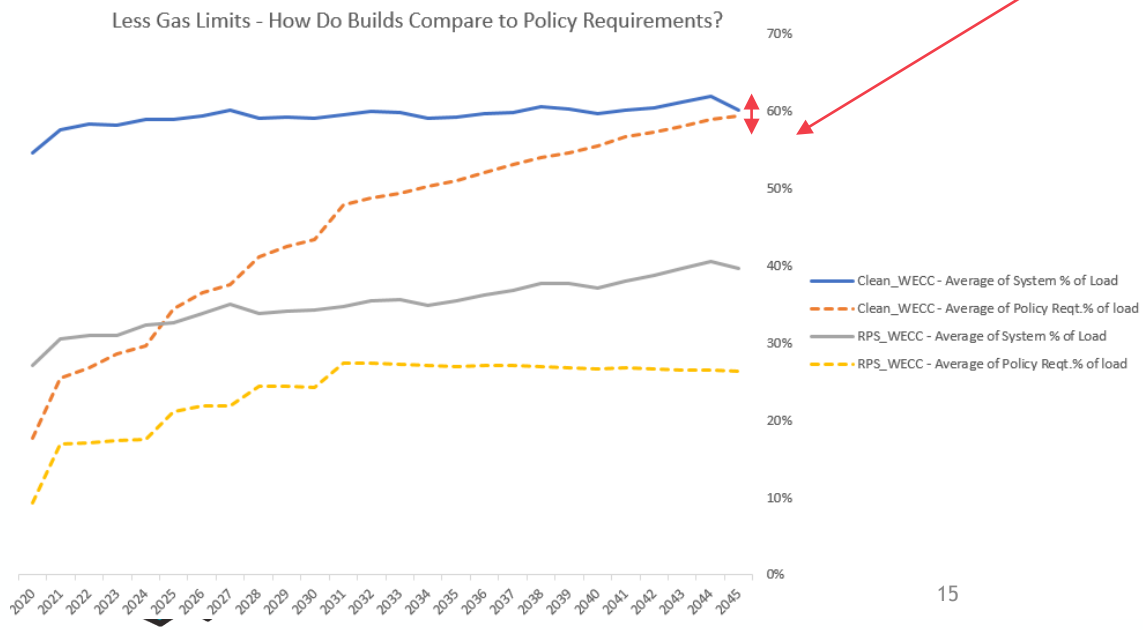


Where and what new resources are built by 2045?





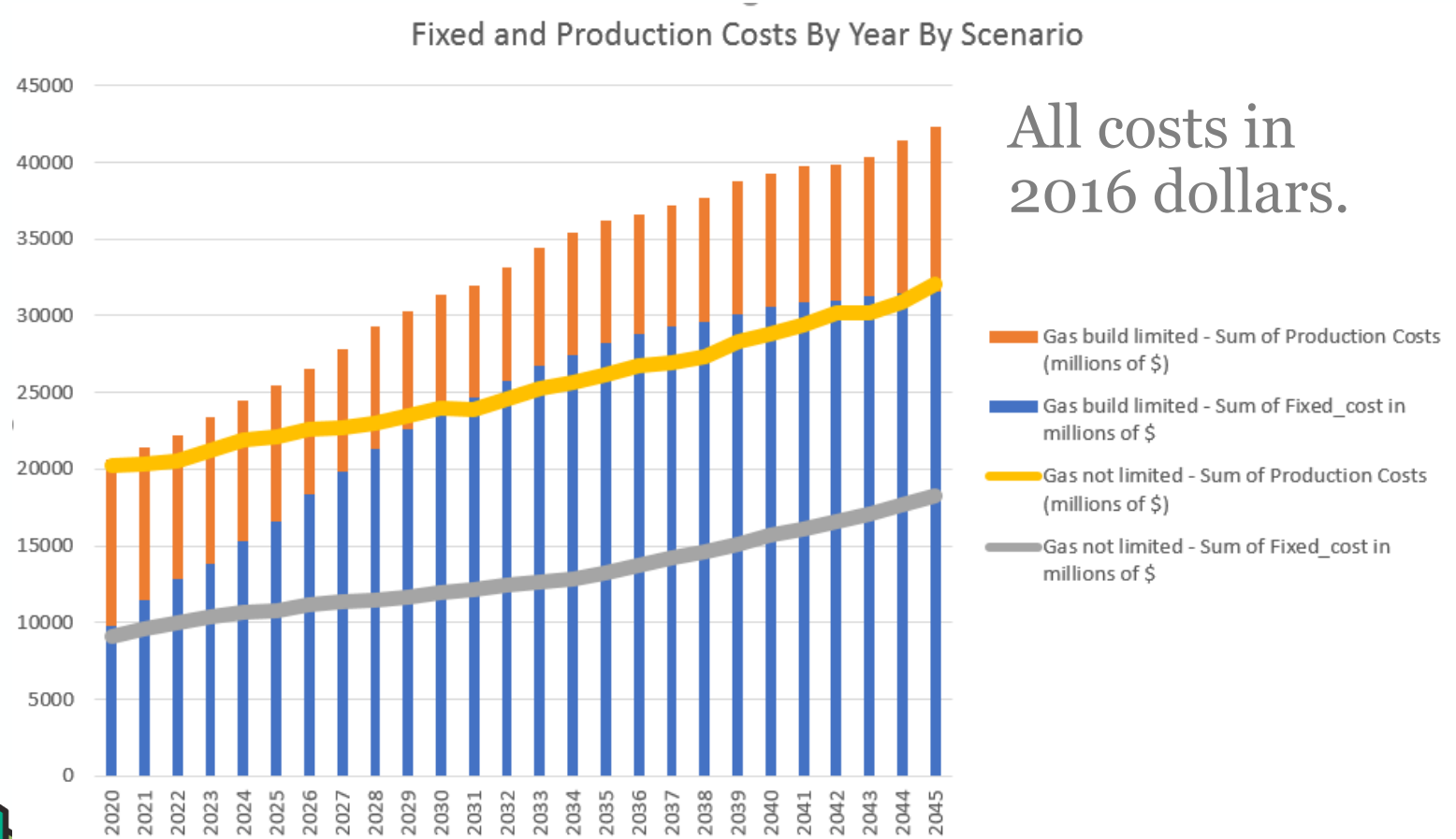




Limited gas case renewable builds are more than the clean policy requirements to maintain reserve margins

State policies are not the only thing driving renewable builds in the limited gas scenario…

Limiting Gas Builds Lowers Production Costs but Raises Fixed Costs…



All costs in 2016 dollars.

Buildout Summary

- Moving from higher production costs to higher fixed costs with more renewable buildout.
  - Total costs slightly more expensive with limits on gas.
- Coal retirements is filled in by a kitchen sink approach, but more wind and solar with storage than just single axis solar on its own (unless more gas builds are allowed).
- State policy drives significant renewable buildout, clean buildout is already bolstered by significant hydro but needs augmentation from renewables to meet state targets.

Wholesale Power Price Study Update

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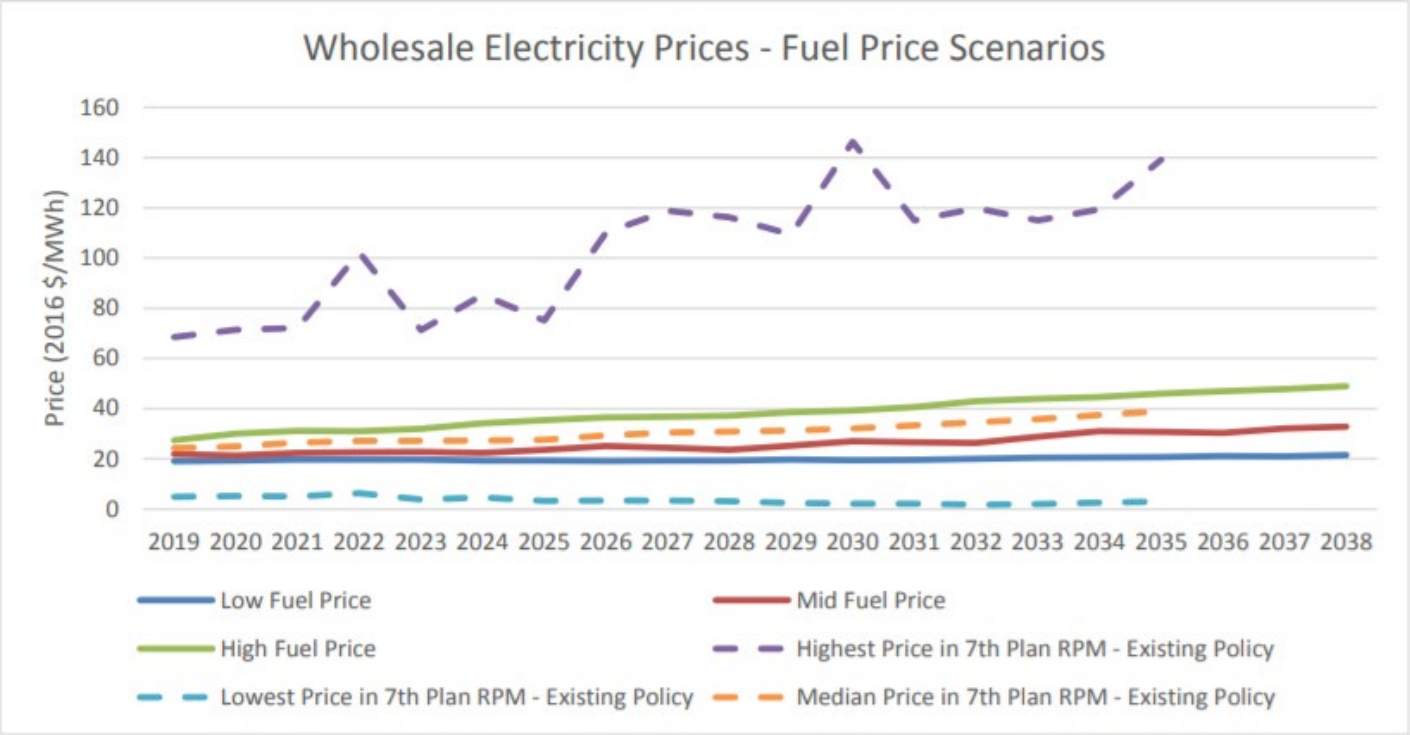
Discussion Topics

- Previous study pricing for context
- Mid-C Prices versus prices throughout WECC
- Hydro effect on Mid-C pricing
- Daily price shape change throughout time

Note: All prices are in 2016 dollars per MWh.

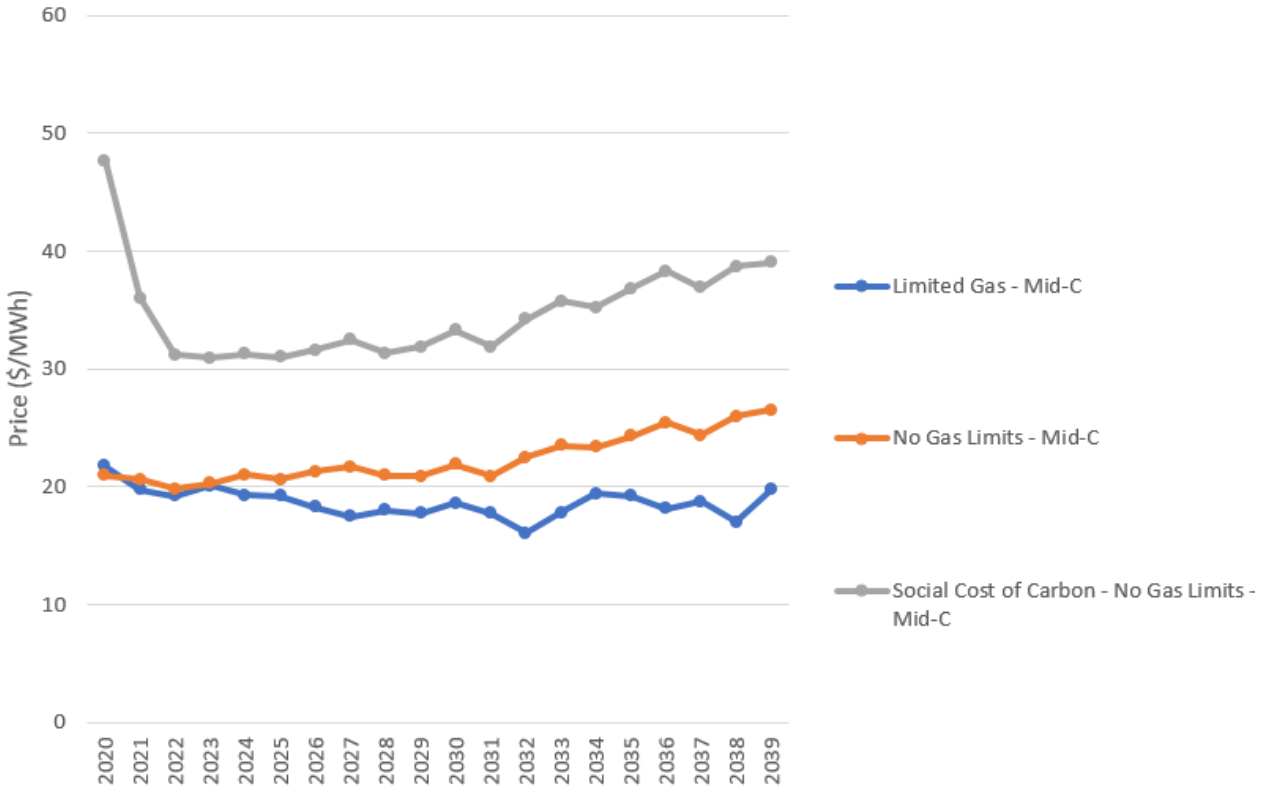
Price Ranges in Midterm and Seventh Power Plan

Figure 3 - 7: Annual Wholesale Electricity Prices Under Different Natural Gas Price Forecasts



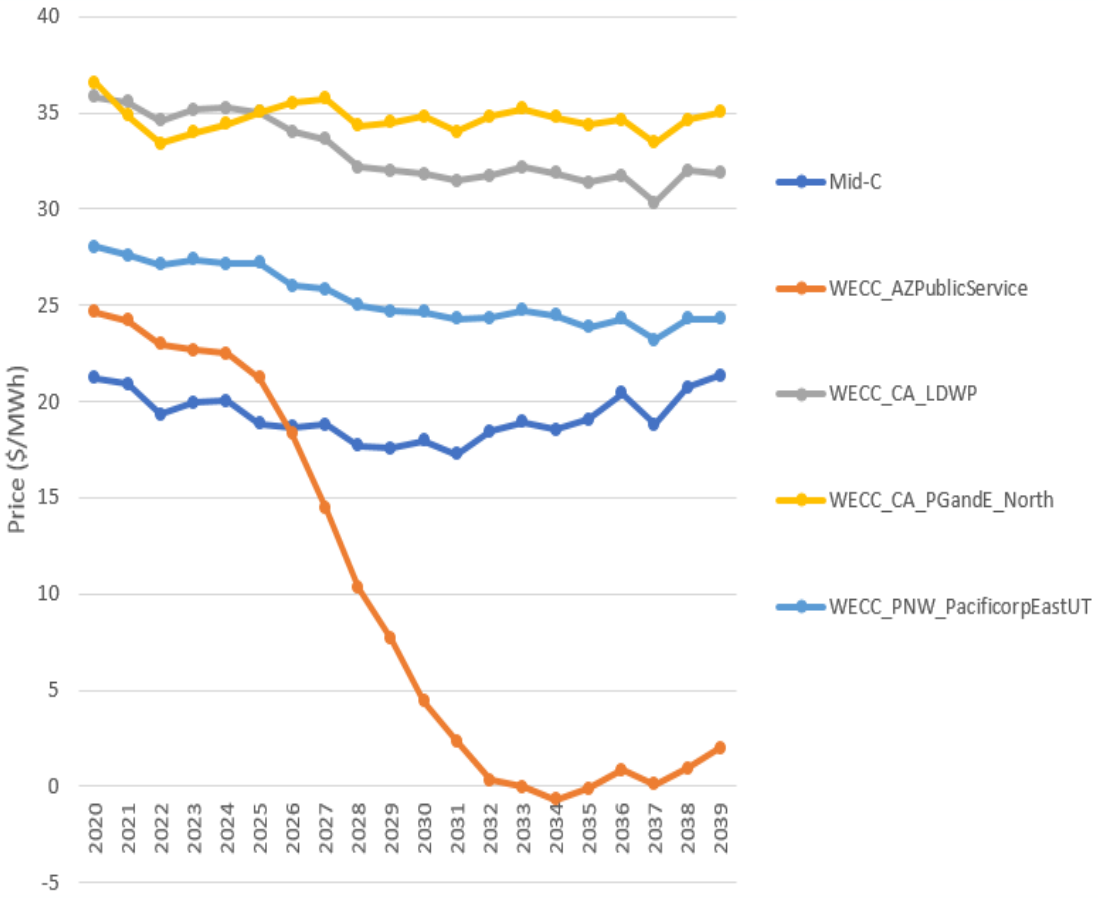
Annual Mid-C Price: Scenario Comparison, Mid Gas Prices

- Expected annual Mid-C Prices stay fairly flat in the limited gas case, but creep up slightly in the no gas limit build.
- The Social Cost of Carbon scenario sees a huge initial decline in prices as the existing coal is pushed off the margin in almost all hours.

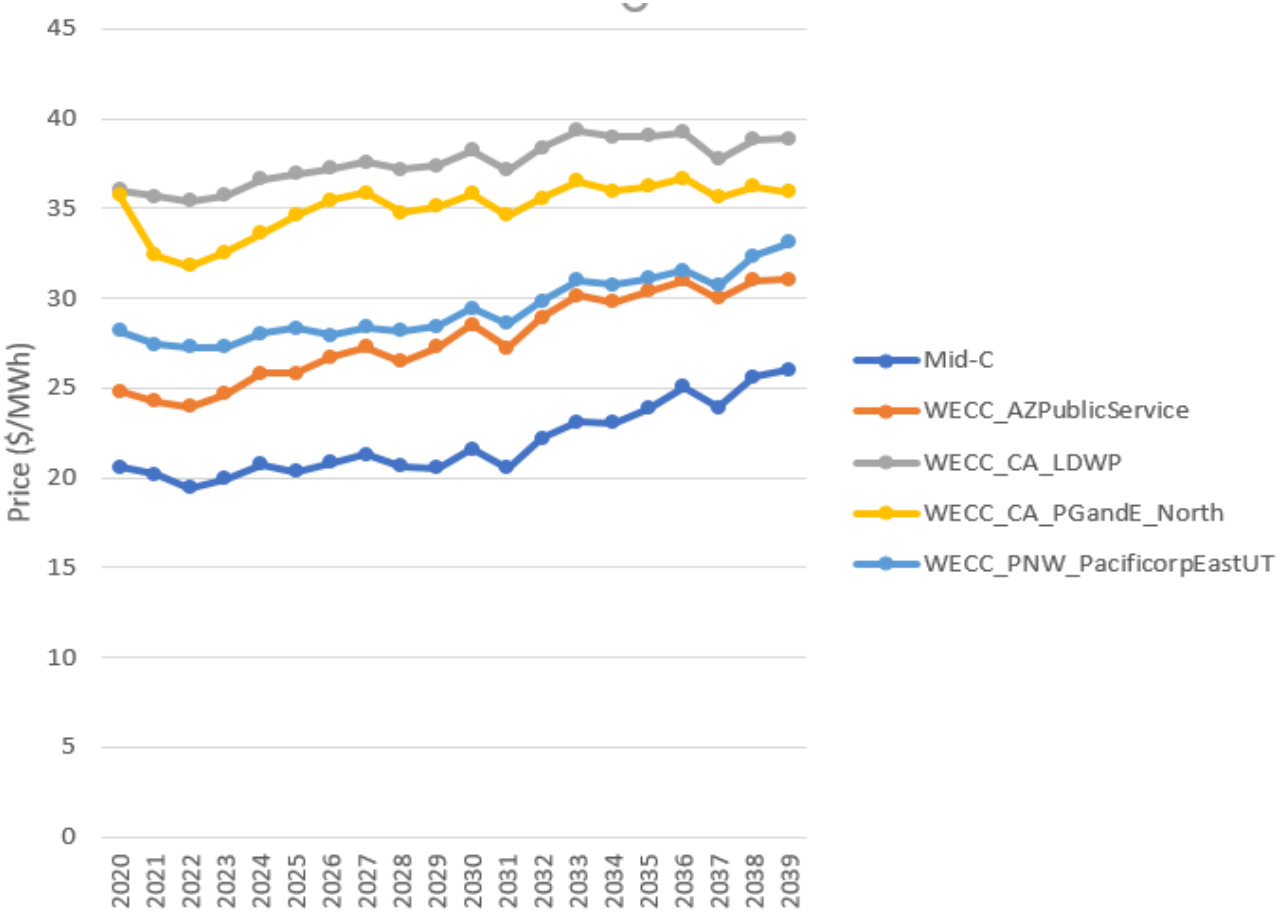


Annual Mid-C Prices versus other Regional Prices – Limited Gas

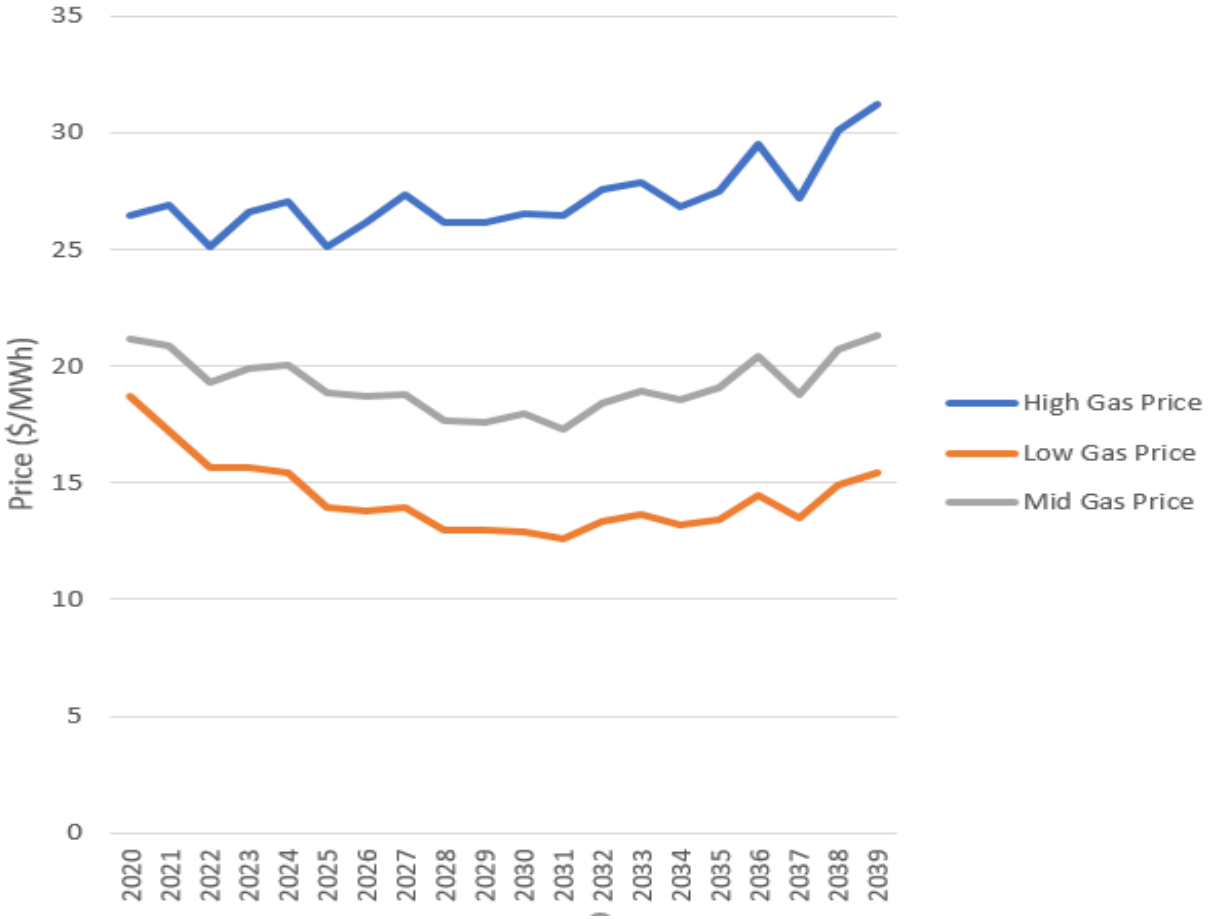
- Traditional hub price differentials are maintained with California hubs demanding higher prices than Mid-C, Mountain West and Desert SW hubs
- The huge influx of renewables in the Desert SW drops prices to around zero on an annual average basis!



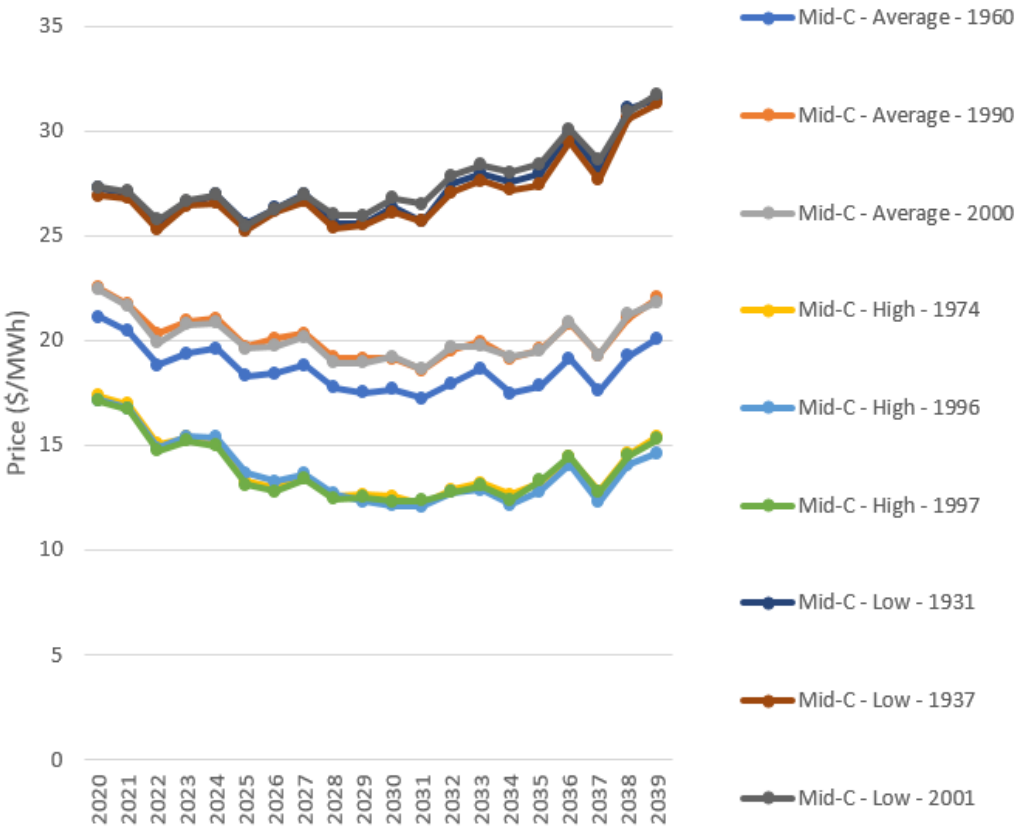
Annual Mid-C Prices versus other Regional Prices – No Gas Limits



Mid-C Prices Still Vary Significantly Depending on Natural Gas Prices – Limited Gas Builds

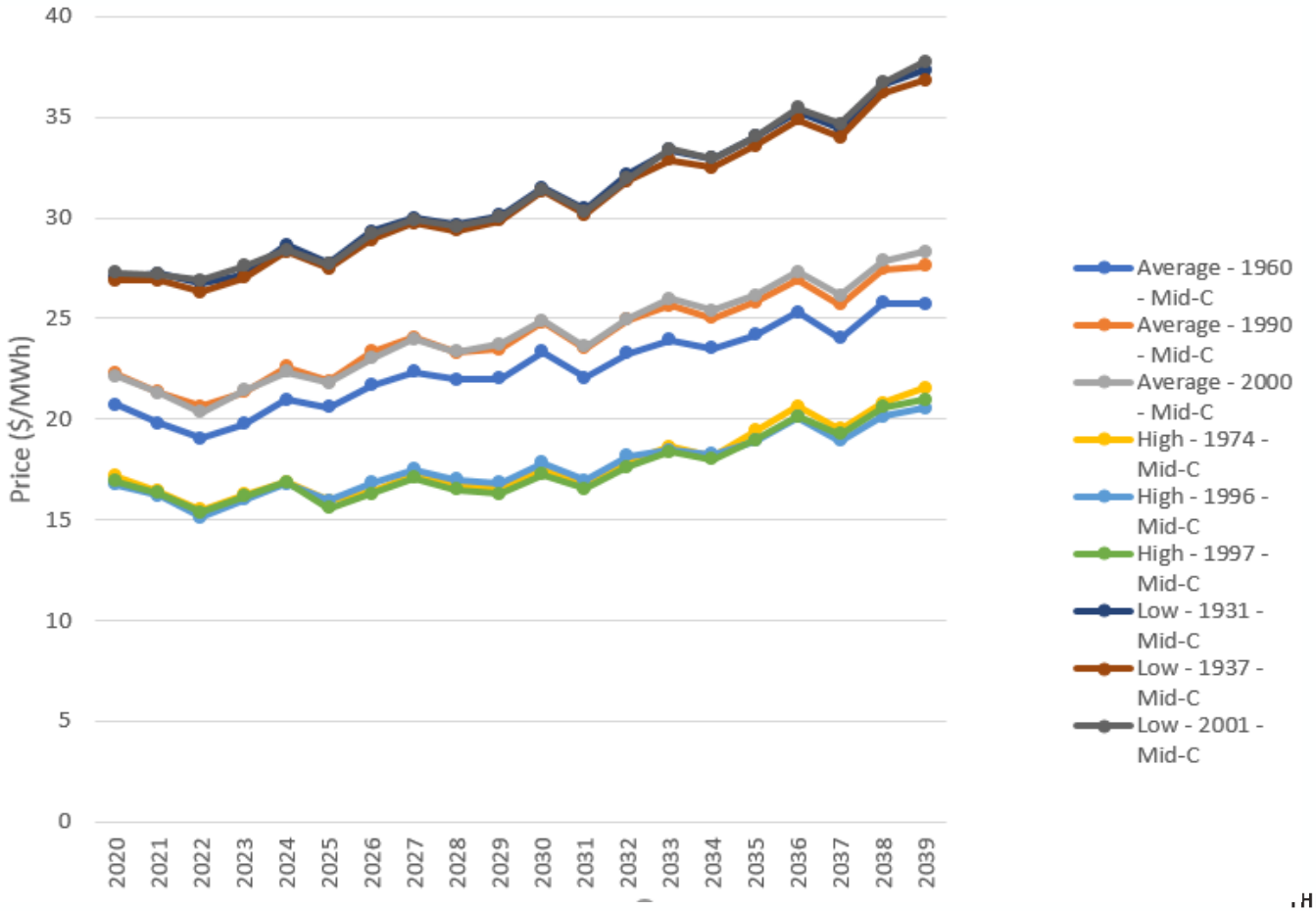


Hydro Conditions Effect on Mid-C Pricing – Limited Gas Builds

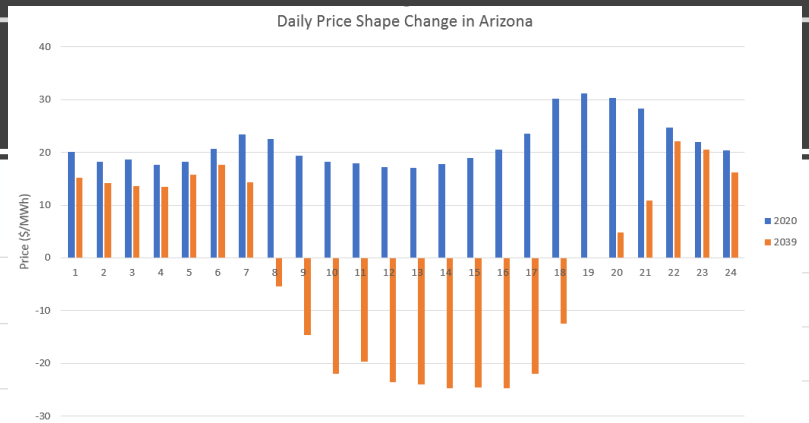


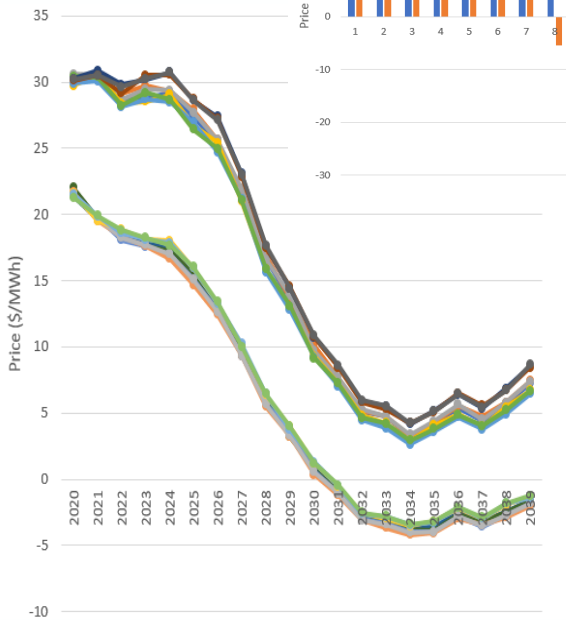
- High hydro conditions still result in low prices, and low hydro results in higher Prices.

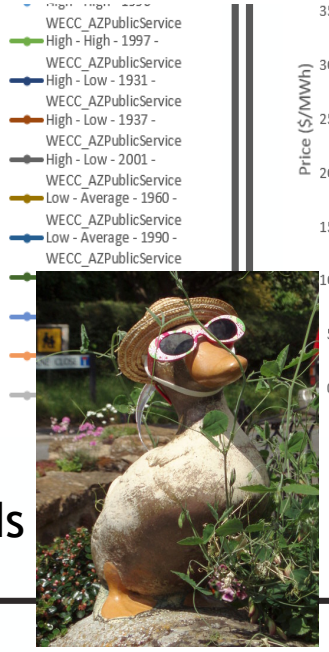
Hydro Conditions Effect on Mid-C Pricing – No Limits on Gas

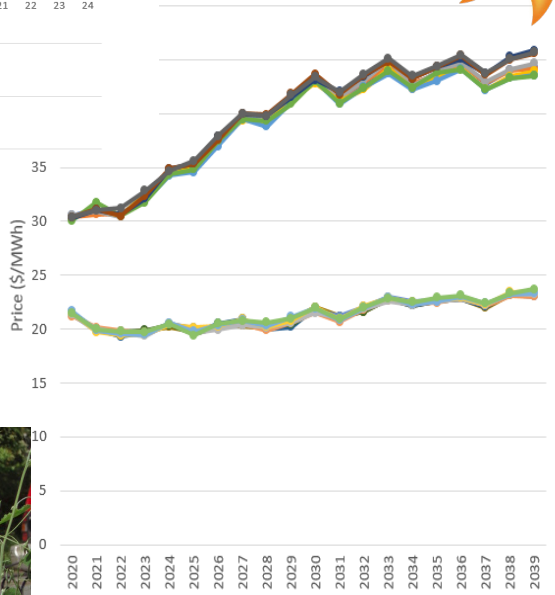


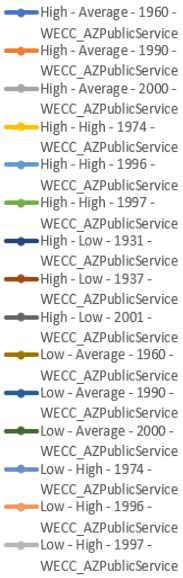
High and Low Gas Prices and Assumptions on Gas Buildout Change Prices in Desert SW considerably, NW Hydro Conditions hardly change them at all…











Limited Gas Builds

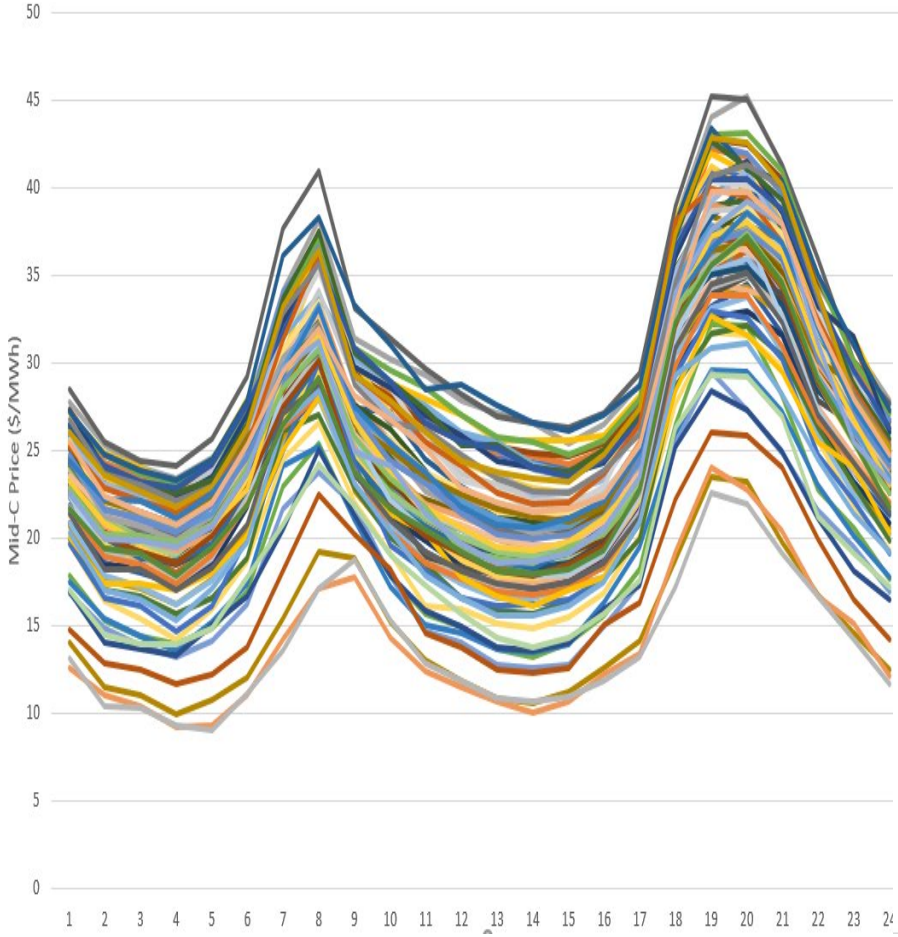
No Limits on Gas Builds

Daily Price Shape Graphs – All 80 Hydro Conditions

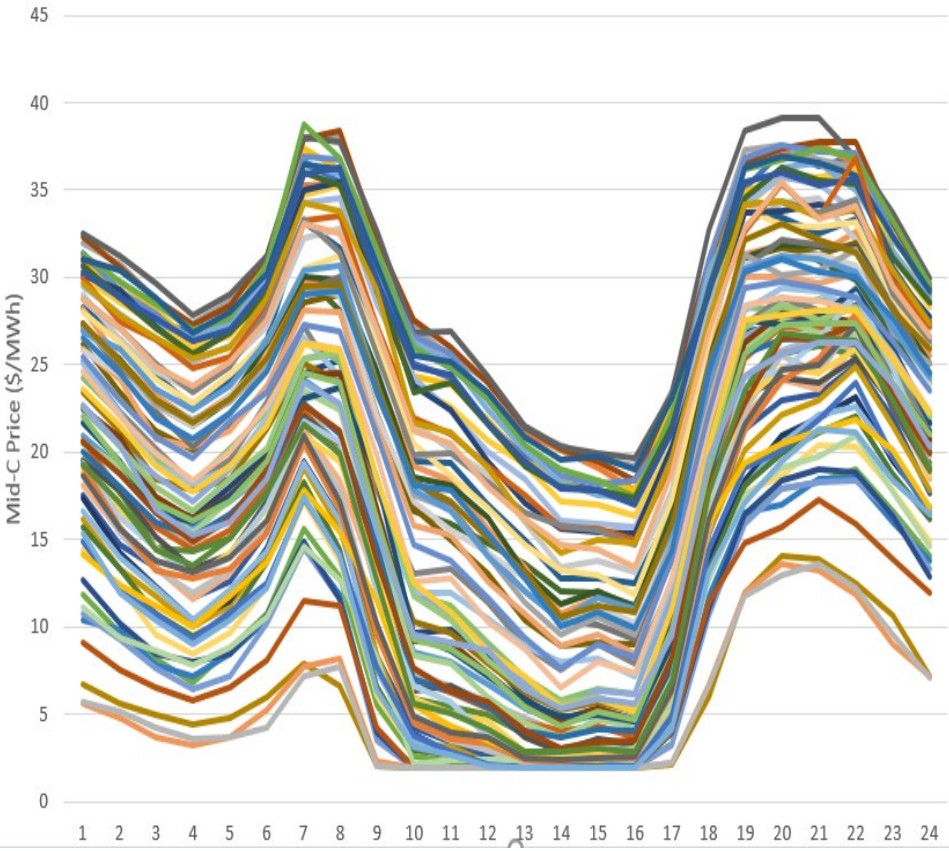
- Graph on left is 2020 and graph on right is 2035.
- Average daily prices display more variability by hydro condition in all seasons.
- Hydro is on the margin in many hours in the spring and in the middle of the day in the winter by the end of the study
- Focused on limited gas build studies as daily price shape is similar to previous studies (although still different than historic) when there are no limits on gas builds.

Daily Price Shape: *Winter* Limited Gas in 2020 and 2035

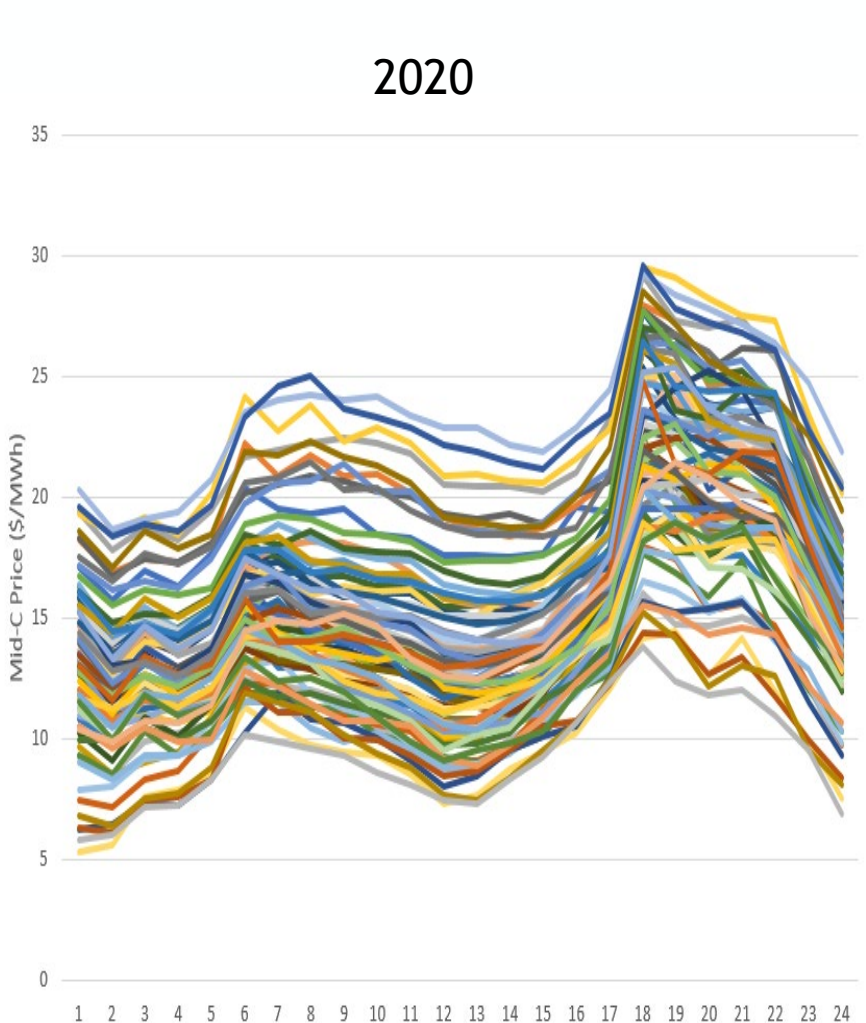
2020

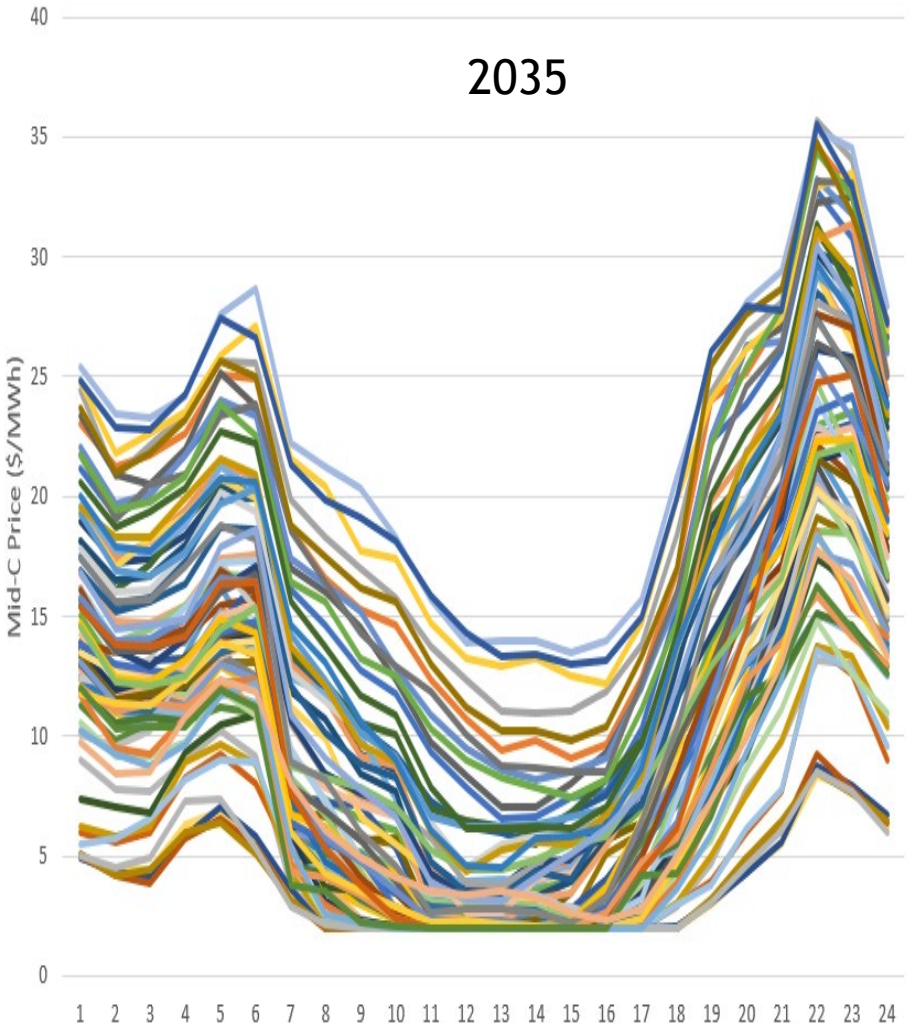


2035

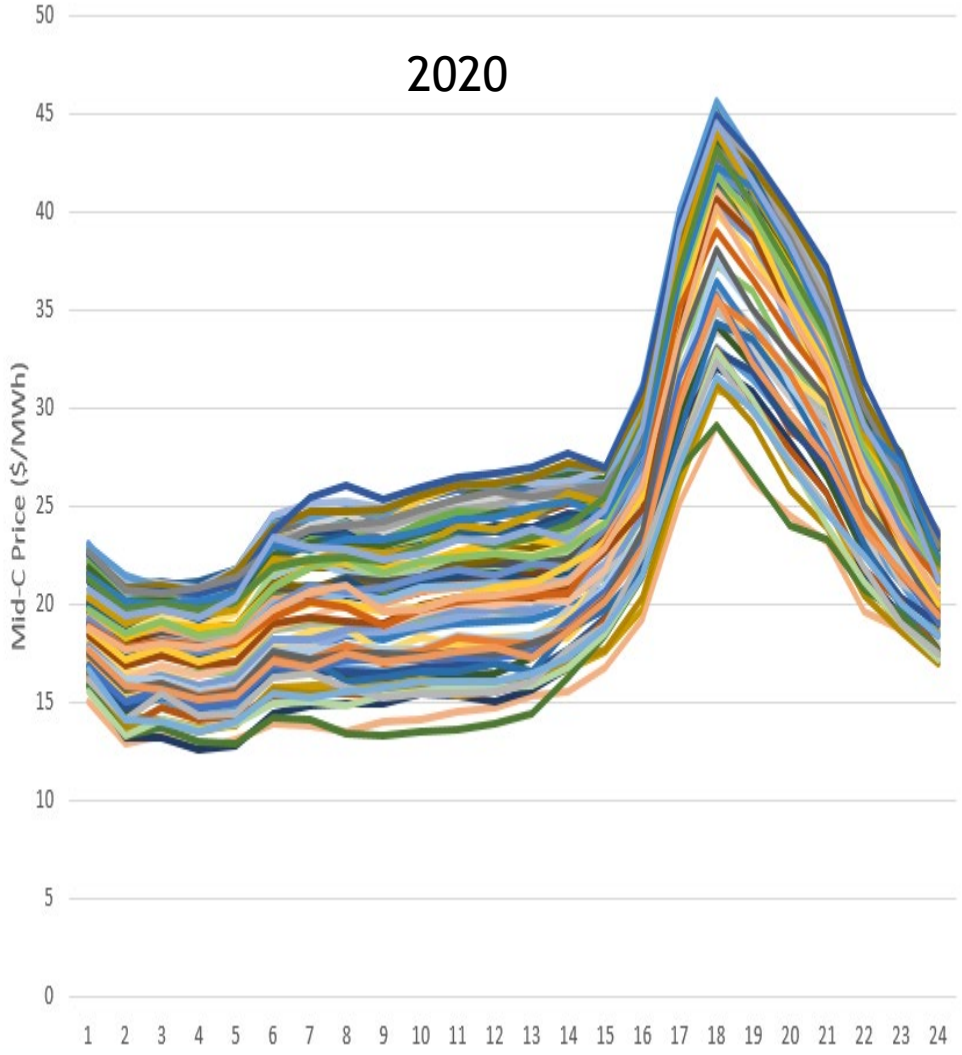


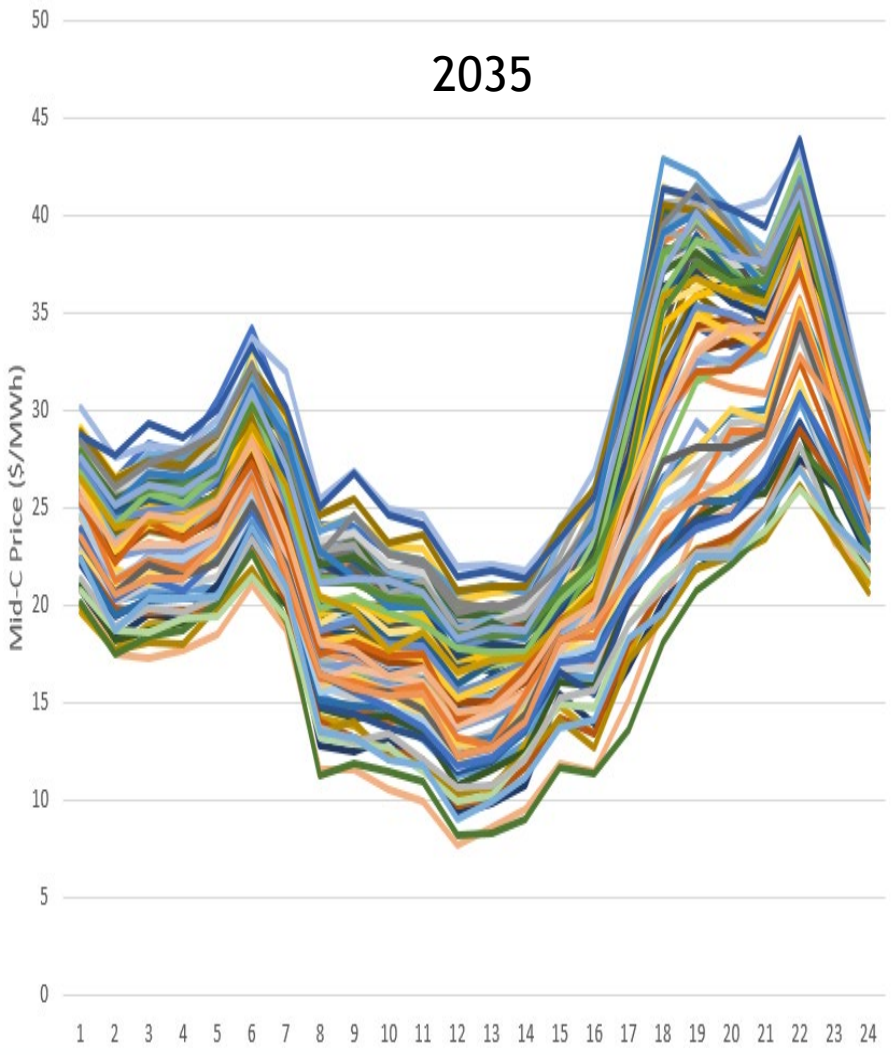
Daily Price Shape: *Spring* Limited Gas in 2020 and 2035





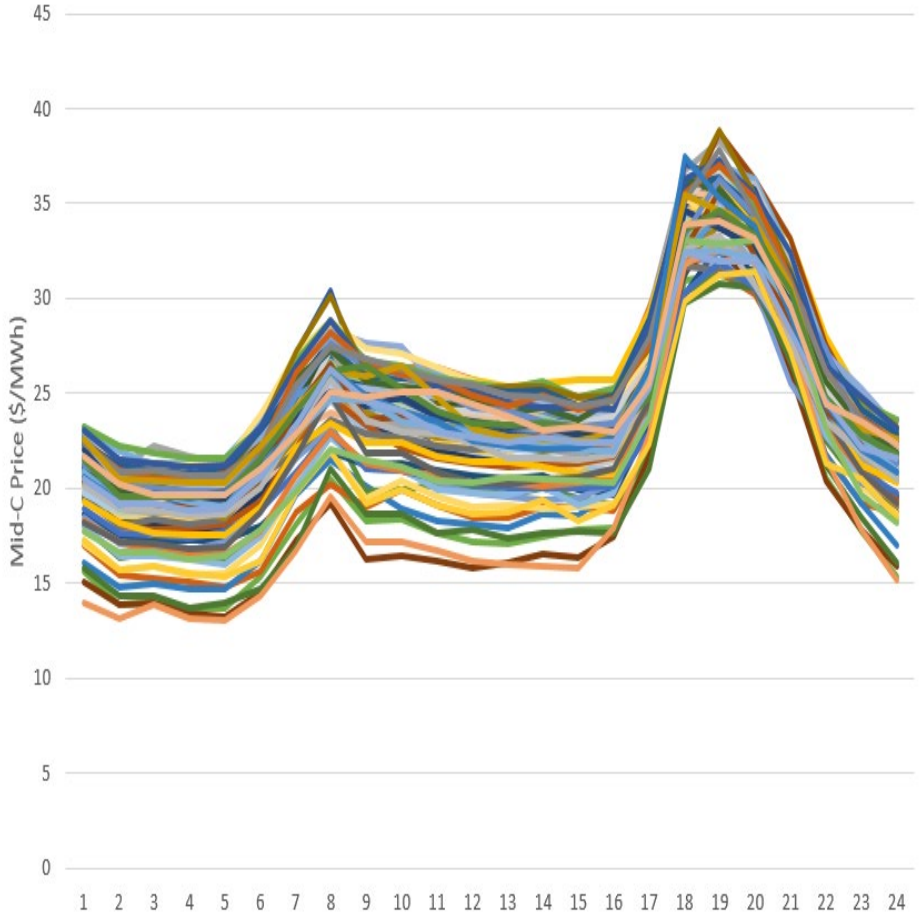
Daily Price Shape: *Summer* Limited Gas in 2020 and 2035



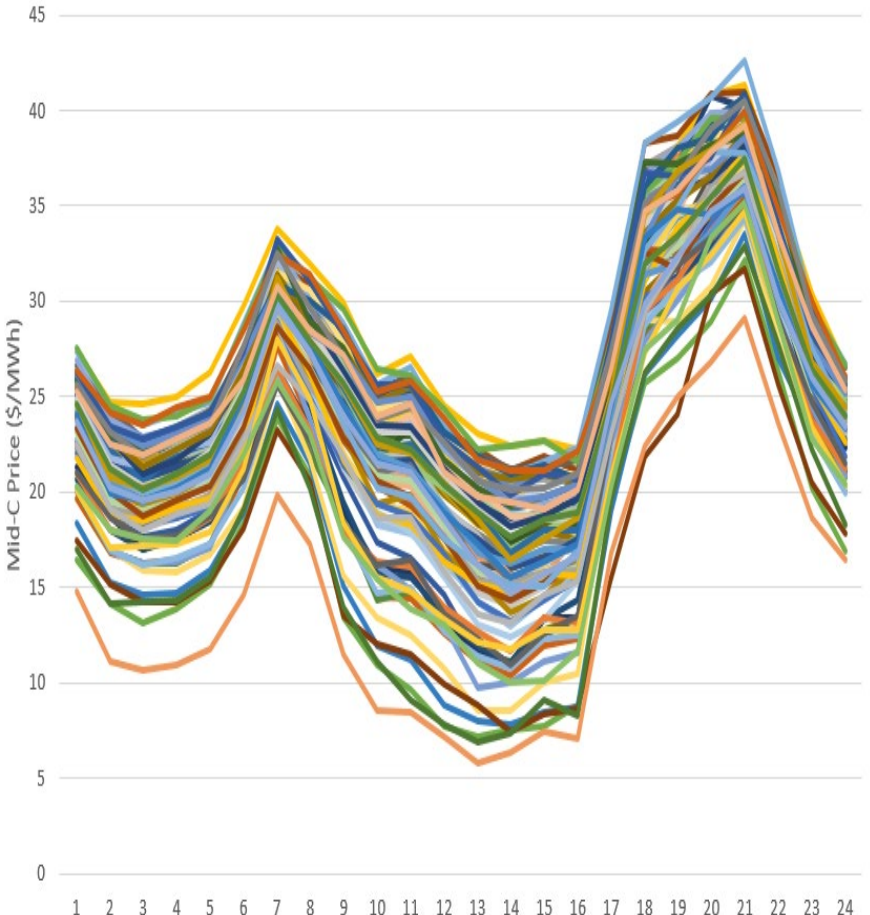


Daily Price Shape: *Fall* Limited Gas in 2020 and 2035

2020

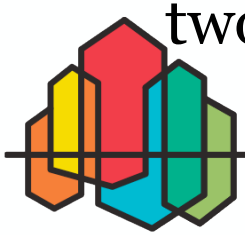


2035



Wholesale Electricity Price-Conclusions

- No gas build limit scenario results are consistent with previous 2018 study, limited gas build studies has some differences.
  - State policies effect prices on limited gas build studies more.
  - Limited gas build scenarios add enough low fuel cost renewables to keep Mid-C prices virtually flat on an annual basis, but introduce more daily variation.
  - No gas build limit scenarios maintain similar market price differentials throughout the WECC, however, in limited gas build studies some areas (like the Arizona, Colorado, Wyoming) build so many renewables annual average market prices fall precipitously later in the study.
- Fuel price and hydro condition variability are still the two biggest drivers in annual Mid-C price variation.



Avoided Emissions Rate Update

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Avoided Emissions Rate Summary

- Review methodology and previous study results for context.
- Avoided Carbon Dioxide Emissions Rate annual and monthly for the following years:
  - 2020
  - 2025
  - 2030
  - 2035
- Average emissions rate versus marginal emissions rate
- Daily shape of emissions
  - Changing daily shape of coal and gas dispatch

WECC Avoided Carbon Emissions Rate Methodology

The *avoided emissions rate* over the output changed in the WECC from the flat drop of 100 MW is

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

Variable Defn:

1. $Emissions_{100}$ is the emissions in the WECC with 100 MW less load run
2. $Emissions_0$ is the emissions in the WECC in the base run
3. $Output_{100}$ is the output in the WECC with 100 MW less load run
4. $Output_0$ is the emissions in the WECC in the base run

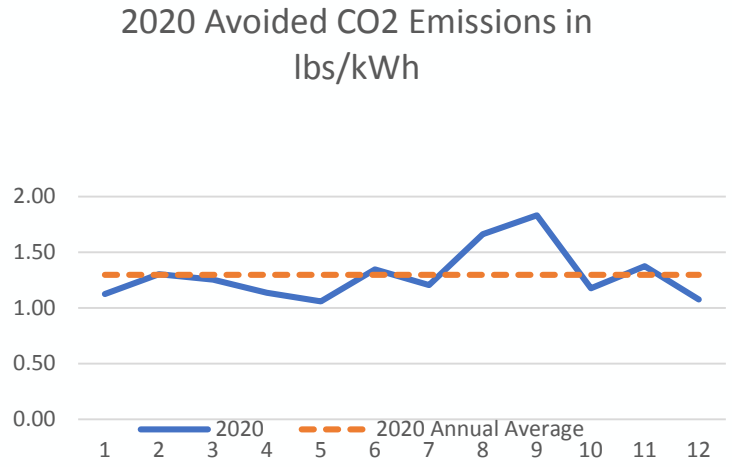
Avoided Emissions Rate: Context and 2018 Study Review

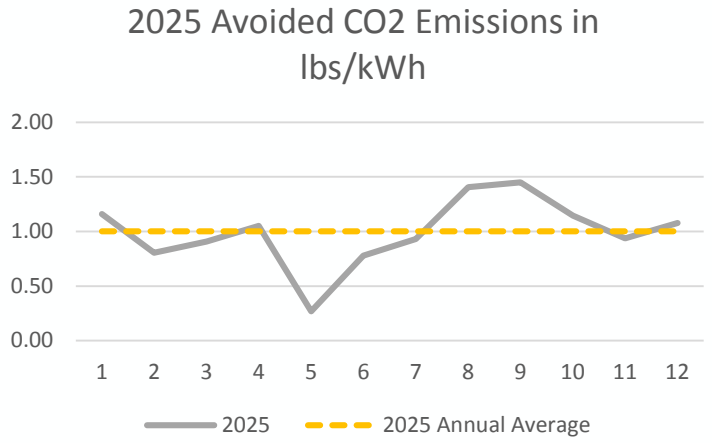
1. Contemporary natural gas-fired combined cycle unit emits roughly 0.8 to 0.9 pounds (lbs.) of CO_2 per kilowatt-hour.
2. A typical conventional coal-fired steam unit emits roughly 2.1 to 2.4 lbs. of CO_2 per kilowatt-hour.
3. Peaker gas units have a larger range of emissions rates 1.1 to 1.7 lbs. of CO_2 per kilowatt-hour.

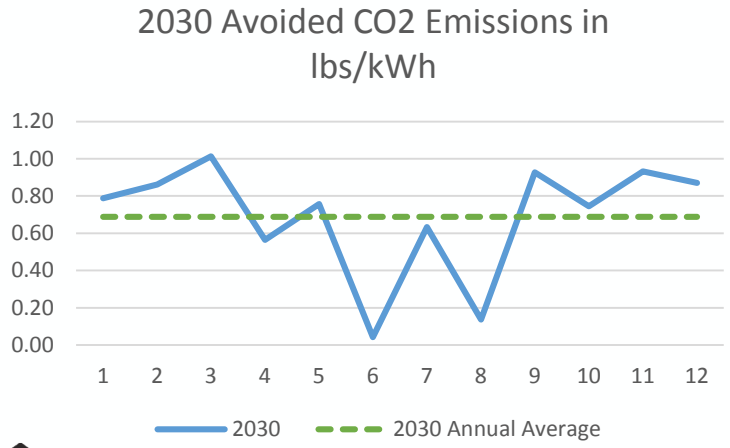
Table 1: Annual Average Avoided CO_2 Emissions Rate

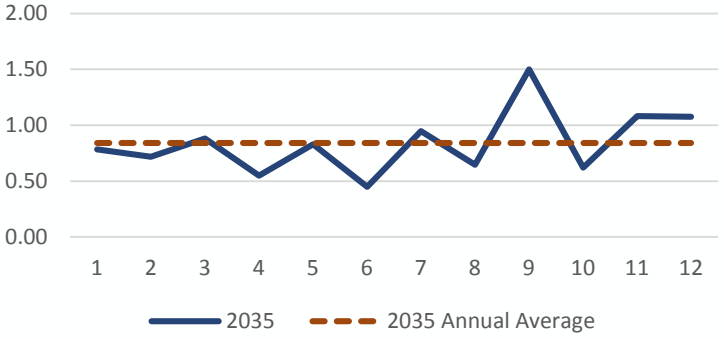
Scenario	Annual Average Avoided Emissions Rate (lbs. of CO2 per kWh)
2016	1.83
2021	0.91
2026	0.93
2031	0.97

Avoided CO_2 Emissions Rate Monthly in 2020, 2025, 2030 and 2035









Avoided CO_2 Emissions Rate (lbs/kWh) Summary

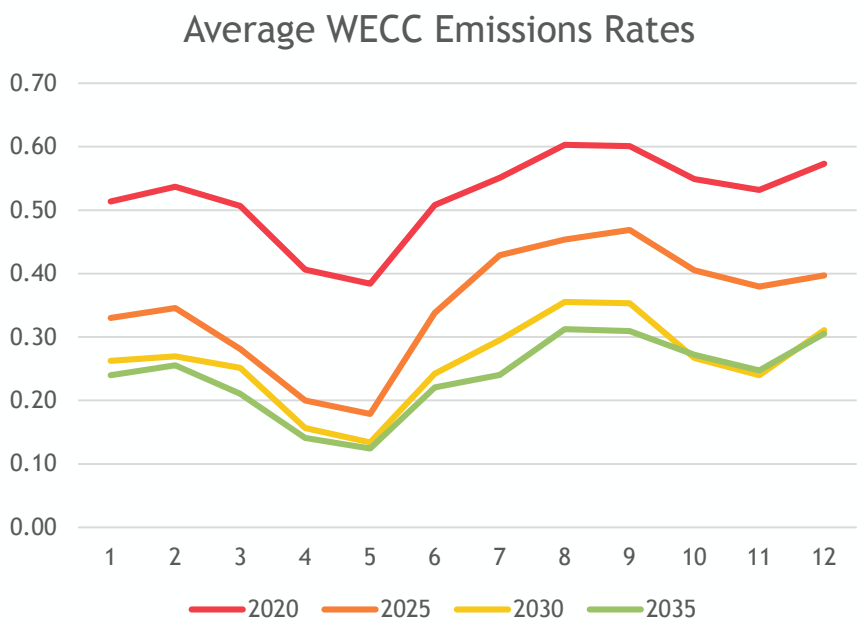
A few observations:

1. The annual averages decrease throughout time.
   - Coal retirements early
   - Load growth late
2. Annual average rate close to the rate of a combined cycle gas unit, but….
   - Actually indicates change in coal, combined cycle and simple cycle gas combustion turbines production throughout the WECC

Month	2020	2025	2030	2035
1	1.13	1.16	0.79	0.79
2	1.30	0.81	0.86	0.72
3	1.25	0.91	1.01	0.88
4	1.14	1.05	0.57	0.55
5	1.06	0.27	0.76	0.83
6	1.35	0.78	0.04	0.45
7	1.20	0.93	0.63	0.95
8	1.66	1.41	0.14	0.65
9	1.83	1.45	0.93	1.50
10	1.18	1.14	0.74	0.62
11	1.37	0.94	0.93	1.08
12	1.07	1.08	0.87	1.08
Annual	**1.30**	**1.00**	**0.69**	**0.84**

Average Emissions Rates Summary

- More defined seasonal shape.
    1. Lower average emission rate in the spring with hydro runoff and lower loads.
    2. Higher average emission rate in the summer, when WECC has peak loads.
- Decreased average emissions rate over time as state policy targets for clean/RPS resources increase.
- Because zero fuel cost resources tend to have zero emissions, average emissions rates will always be lower than marginal emissions rates.



Avoided CO_2 Emissions Rate - Conclusions

- Results are consistent with previous 2018 study.
  - Studies are over different years and have different vintages of coal retirement data, which is the biggest driver of reduction of the marginal emissions rate.
  - Both studies show increase of the rate over time due to load growth requiring more dispatch of less efficient and higher emitting resources.
- Clean/Renewable state policies seem to lower average CO_2 emissions rates and temporarily lower marginal CO_2 emissions rates over time.
  - Massive renewable buildout in the beginning of the study limits emissions that can be avoided on the margin in some hours due to hydro or efficient gas being on the margin.
  - Load growth leads to the likelihood of the necessity of more higher emitting fossil fuel resources on the margin, and thus emissions rates rise slightly at the end of the study.

System Analysis Advisory Committee Discussion of Results

- Buildouts
  - Some thought gas limited buildout more likely and closer to what is happening than the no limits on gas buildout scenario.
  - Some thought these two scenarios were good bookends.
- Daily shape changing traditional view of "peak" pricing
  - Prices are very volatile from hour to hour
  - Even more influenced by solar shape
  - Follow-up discussion in future SAAC.
- Pricing clean/RPS attributes
  - Long-term REC pricing will require some follow-up discussion

Final Thoughts/Questions

- If we as a region believe that 56 GW of new gas power plants will not be built in the next 20 years and closer to 20 GW will be built, then we will begin to see significant seasonal changes in intraday pricing throughout the WECC.
  - Additionally, limited gas builds seems to push out price increase to end of study.
- Clean and RPS policies are leading to significant solar builds that continue to depress mid-day pricing and create higher prices in the evening ramp hours.
  - The policies currently modeled are just the state policies. Utilities, municipality, and state goals will likely drive more renewable build, which will cause more of the above behavior?
- Will other regions actually build to their reserve margins to keep prices this low?

Additional Slides

Brief Methodology Review

Use same load, EE solar and wind. Hydro and thermal dispatch aligned using multiple models.

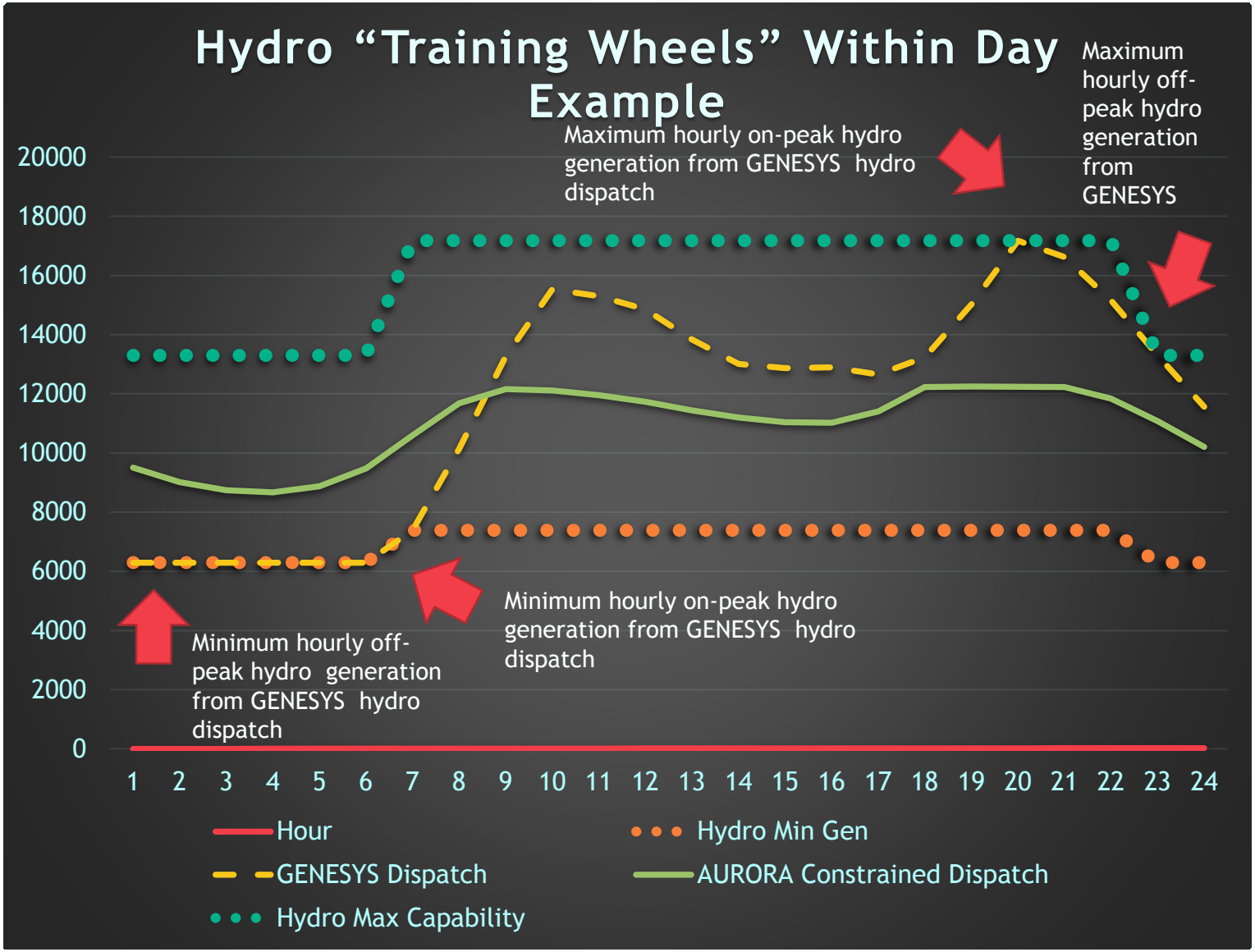
GENESYS
Hydro-Thermal Dispatch Under Constraints

WECC-wide hydro and thermal plant dispatch

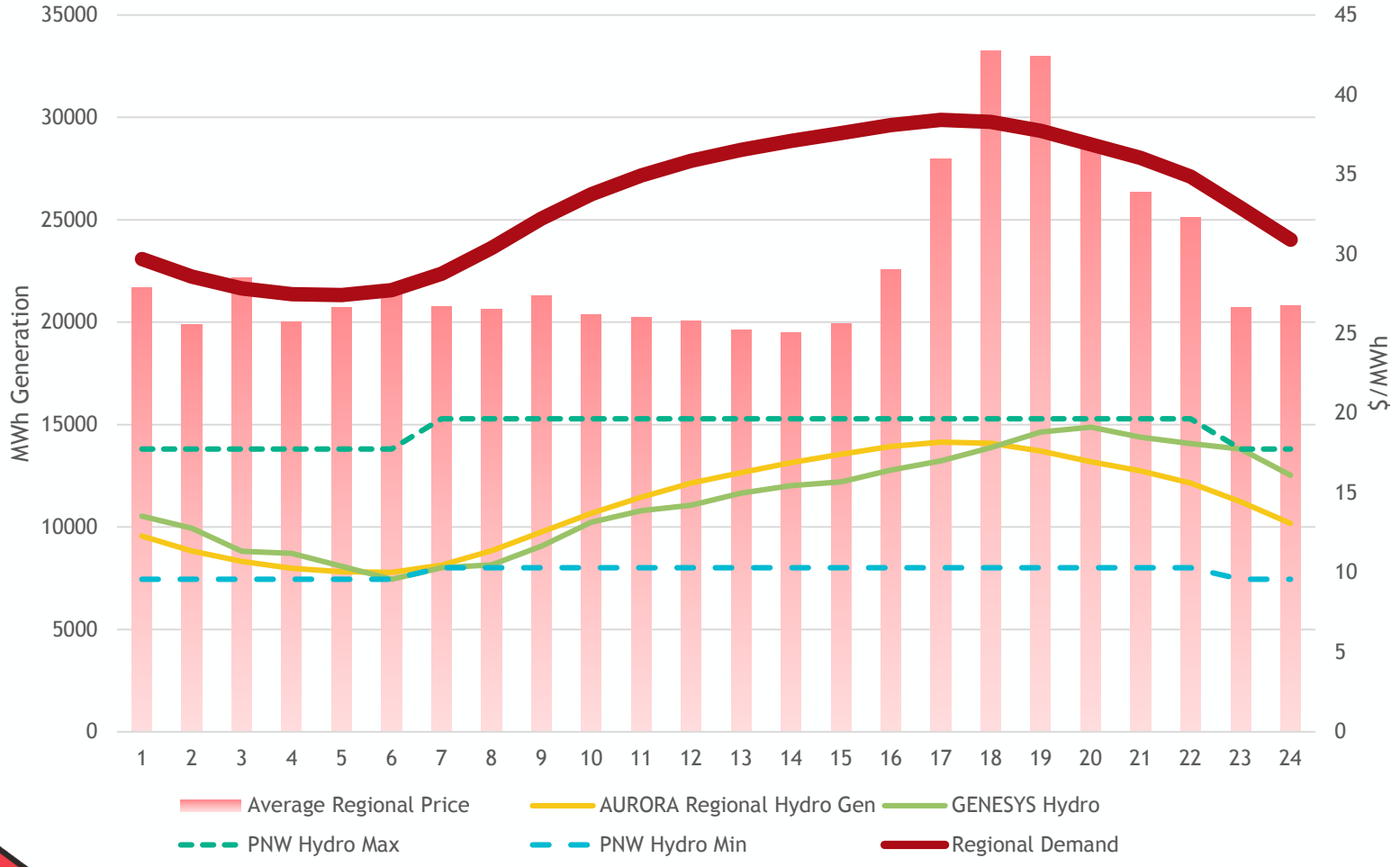
AuroraXMP
Production Cost Model for WECC

- *Monthly hydro generation from GENESYS is used to create monthly energy budget for each hydro condition.*
- *For each day within the month, on-peak minimum generation and maximum capability are calculated to pass as hourly operation constraints for AURORA. The same methodology is used to calculate off-peak constraints.*

Hydro "Training Wheels" Within Day Example



Hydro “Training Wheels” Within Day Example Summer



Data Presentation: 9 Representative Hydro Conditions

Table Key: **Year** (**Rank**, **% of Normal Flow**)

High	Mid	Low
1974 (2, 154%)	1990 (30, 102%)	1937(Critical)
1996 (5, 138%)	2000 (31, 99%)	2001 (57, 59%)
1997 (1, 157%)	1960 (suggested by BPA)	1931 (suggested by BPA)

Period ranking and **percent of normal** of inflow into the Dalles from NOAA's website. The ranking listed is for January – July from 1960 to 2018. These years were also consistently in the high, mid and low rankings even for Oct-Sep, Apr-Sep and Apr-Aug