Integrated Resource Planning

Roundtable Meeting #20-5

August 19, 2020

MEETING LOGISTICS

- Electronic version of presentation:
  - https://www.portlandgeneral.com/our-company/energy-strategy/resource-planning/integrated-resource-planning/irp-public-meetings
- Teams Meeting
  - Please click the meeting link sent to your email or here:
    - Join Microsoft Teams Meeting
    - +1 971-277-2317 (dial this number into your phone for best results)
    - PW: 318 142 008#
  - Please use Microsoft Edge or Google Chrome with Teams as it will give you the best experience
  - During the presentation, all attendees will be muted; to unmute yourself via computer, click on the microphone that appears on the screen when you move your mouse
  - To unmute yourself over the phone, press *6
  - If you call in using your phone in addition to joining via the online link, please make sure to mute your computer audio
  - There is now a meeting chat feature rather than a Q&A feature. Pull this up on the menu bar when you move your mouse and look for the little message icon

AGENDA

- Welcome
- Price Futures
  - 30 minutes
  - Informational and participants' feedback
- Capacity Assessment Baseline
  - 45 minutes
  - Informational
- Supply-Side Options
  - 30 minutes
  - Informational and participants' feedback

PGE

SAFETY MOMENT

- The importance of Water
  - Lack of water is the #1 trigger for **daytime fatigue**.
  - A 2% drop in water level of the body can spur problems with short term memory.
  - Water naturally cleanses the body of toxins.
  - Water regulates the body's cooling system.
- It is recommended to drink at least 50oz to 64oz of water a day depending on what source you refer to. That is about three to four regular sized water bottles a day.

https://www.safetytalkideas.com/safetytalks/hydration/

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Price Futures

Nora Xu

IRP Price Forecasting Process

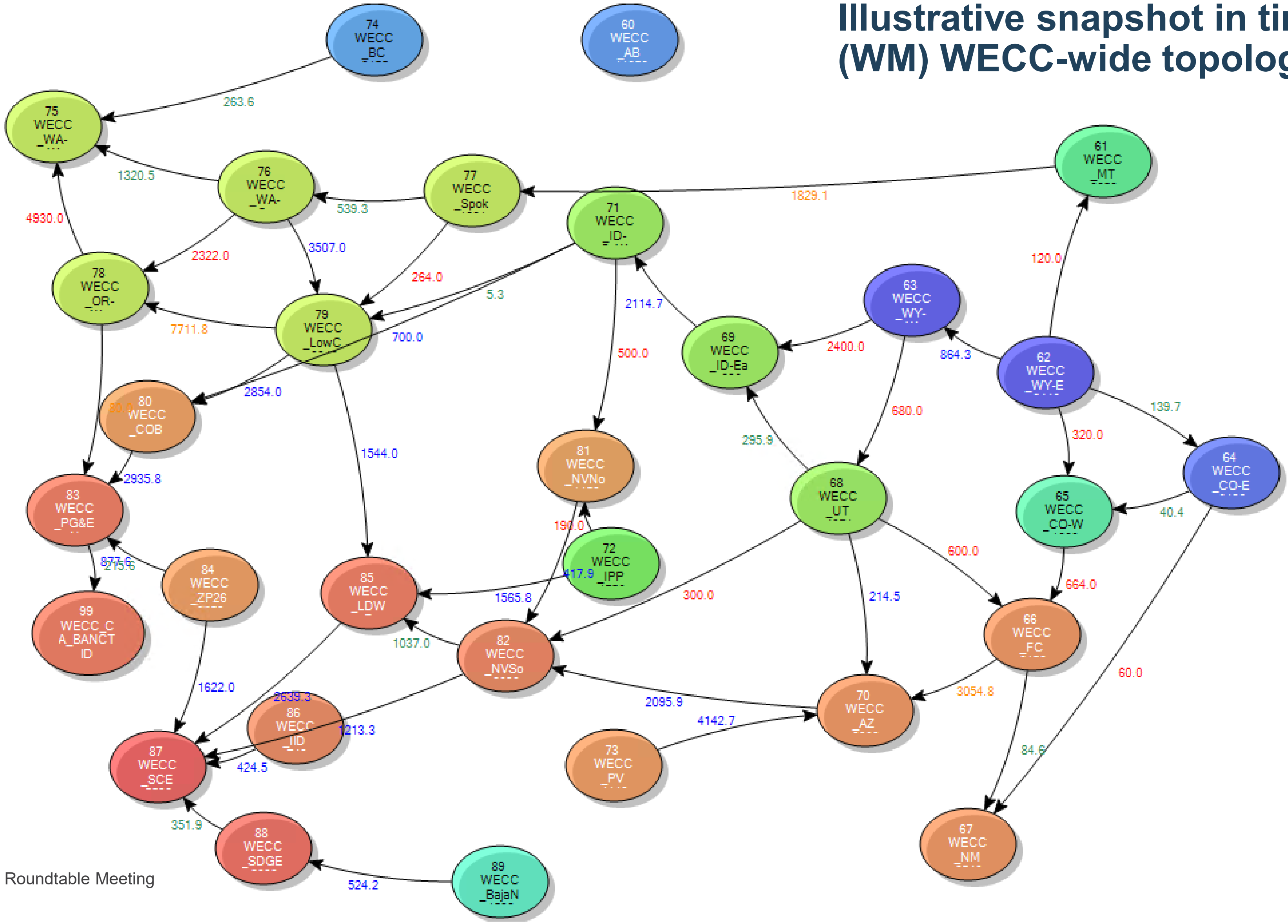
- One of the first steps in our long-term planning process is to simulate long-term wholesale electricity prices under a variety of conditions (Price Futures) for the WECC-wide region
- We use production cost models as a tool to produce long-term wholesale electricity prices forecasts
- Production cost models generally simulate a system by meeting required load and reserves with available resources while minimizing system cost subject to system operating constraints
  - Example inputs: regional loads, resource parameters, transmission parameters, fuel prices, emission rates
  - Example outputs: hourly zonal electricity prices, resource dispatch, emissions
- Please refer to the 2019 IRP Appendix I.4 for additional detail

IRP Price Forecasting Process

- We use a “WECC-wide” model to simulate long-term wholesale electricity prices under a variety of conditions (Price Futures)
- “WECC” can refer to two definitions:
  - The regional organization that develops and reviews reliability standards and promotes and plans for system reliability
  - The resources, transmission lines, other facilities and loads that comprise the Western Interconnection electrical grid, which is a NERC region
- When discussing the “WECC-wide” models for electricity price simulation, we are referring to the second bullet point above.

Source: https://www.wecc.org/Administrative/=INTRO_MOD_1-IntroSysOps=rev2016.pdf

IRP Price Forecasting Process



Illustrative snapshot in time of the WoodMackenzie (WM) WECC-wide topology as seen in Aurora

- WM, a research and consultancy firm, provides a starting database of resources, loads, constraints for the WECC
- Regions are described as zones containing resources, demand and with aggregated links for import and export to connected zones

IRP Price Forecasting Process

AURORA
BY ENERGY EXEMPLAR

WECC-wide Model

Base WECC-wide Aurora buildout
Wood Mackenzie 2020 H1*

PGE updates the following:

- Carbon prices
- Gas prices
- Additional renewable build out
- Hydro sensitivities

Price Futures

PGE Zone Model (PZM)

- Existing resource dispatch
- Candidate new resource dispatch
- Portfolio summary

*Wood Mackenzie typically releases two Aurora databases each year (e.g. 2019 H1 and 2019 H2).

2019 IRP: Four key factors determined Price Futures

Renewable Buildout

Carbon

Natural Gas

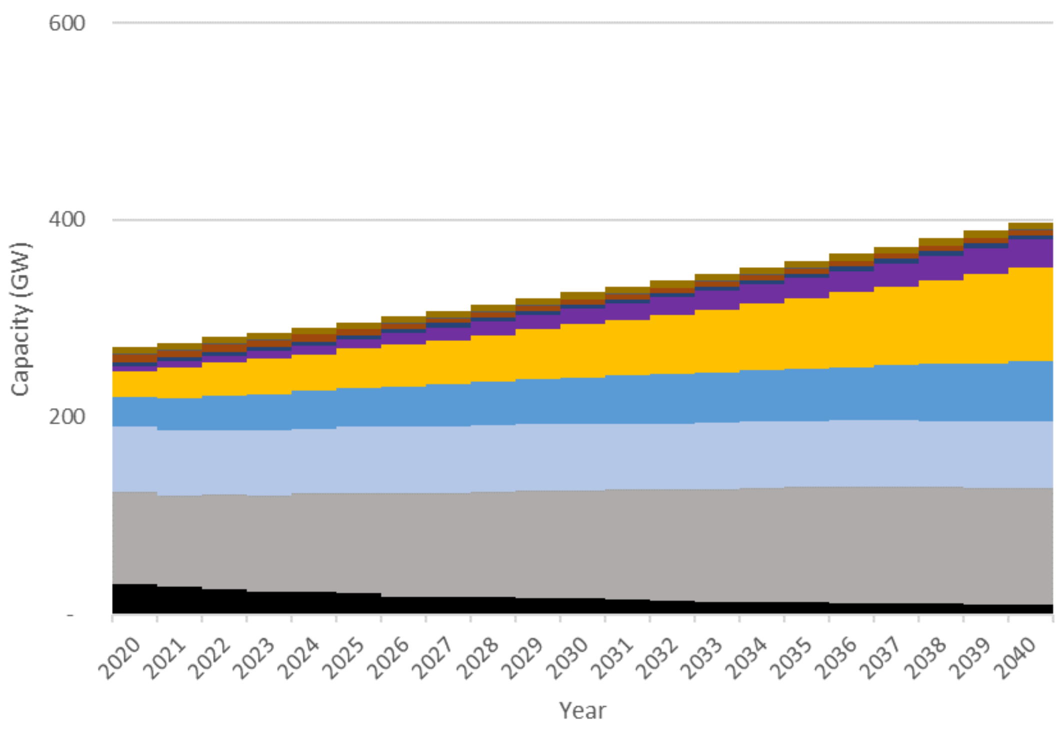
Hydro

Renewable Buildout

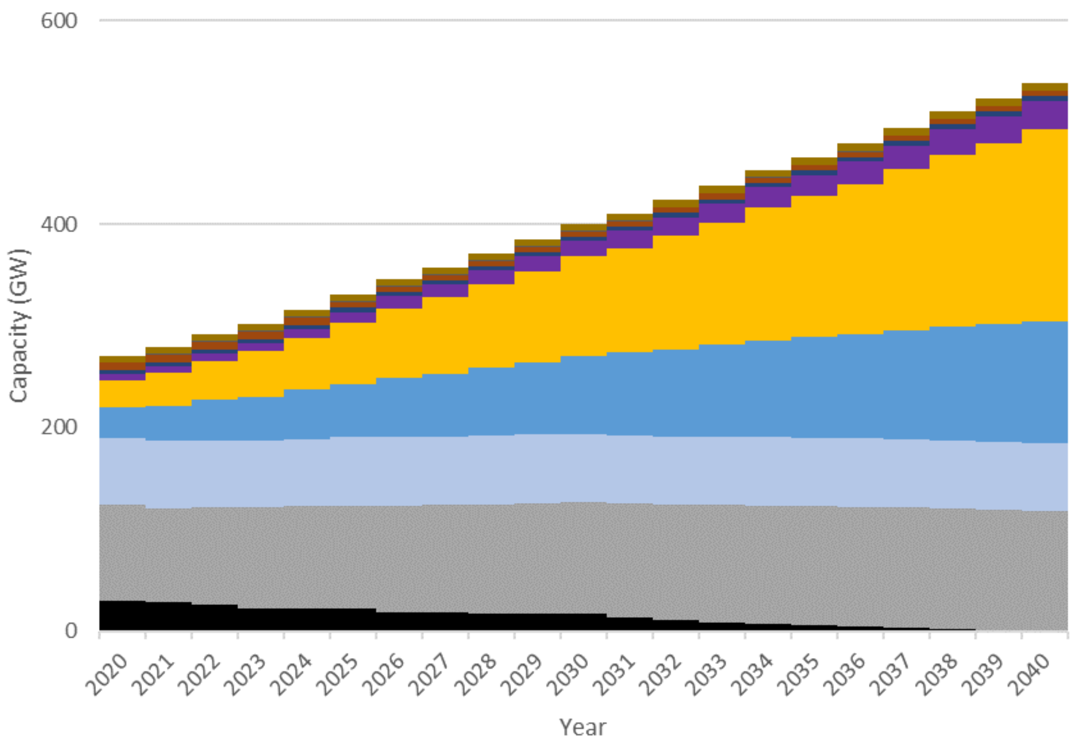
- Future renewable buildout in the WECC is an important source of uncertainty
  - Policy and voluntary renewable goals can result in increasing penetration of renewables across the WECC
  - By how much can renewable buildouts exceed current stated policies?
- The WECC-wide base renewable buildout uses as a starting point, a third-party Aurora database from Wood Mackenzie (WM)
- In the 2019 IRP, we also included a High Renewable Buildout that sought to approximate a world with high penetration of renewables across the WECC at levels exceeding current RPS planning standards
  - Assumed linear decline of WECC coal capacity to zero from 2030 to 2040
  - Added renewable resources by sub-region until the available carbon-free generation was equal to 100 percent of load by 2040 using WM regional new wind-to-solar ratios.
  - What was the effect on prices? It reduced prices on an annual average level but resulted in significantly higher volatility

2019 IRP: Base and High Renewable Buildouts

2019 IRP Base Buildout

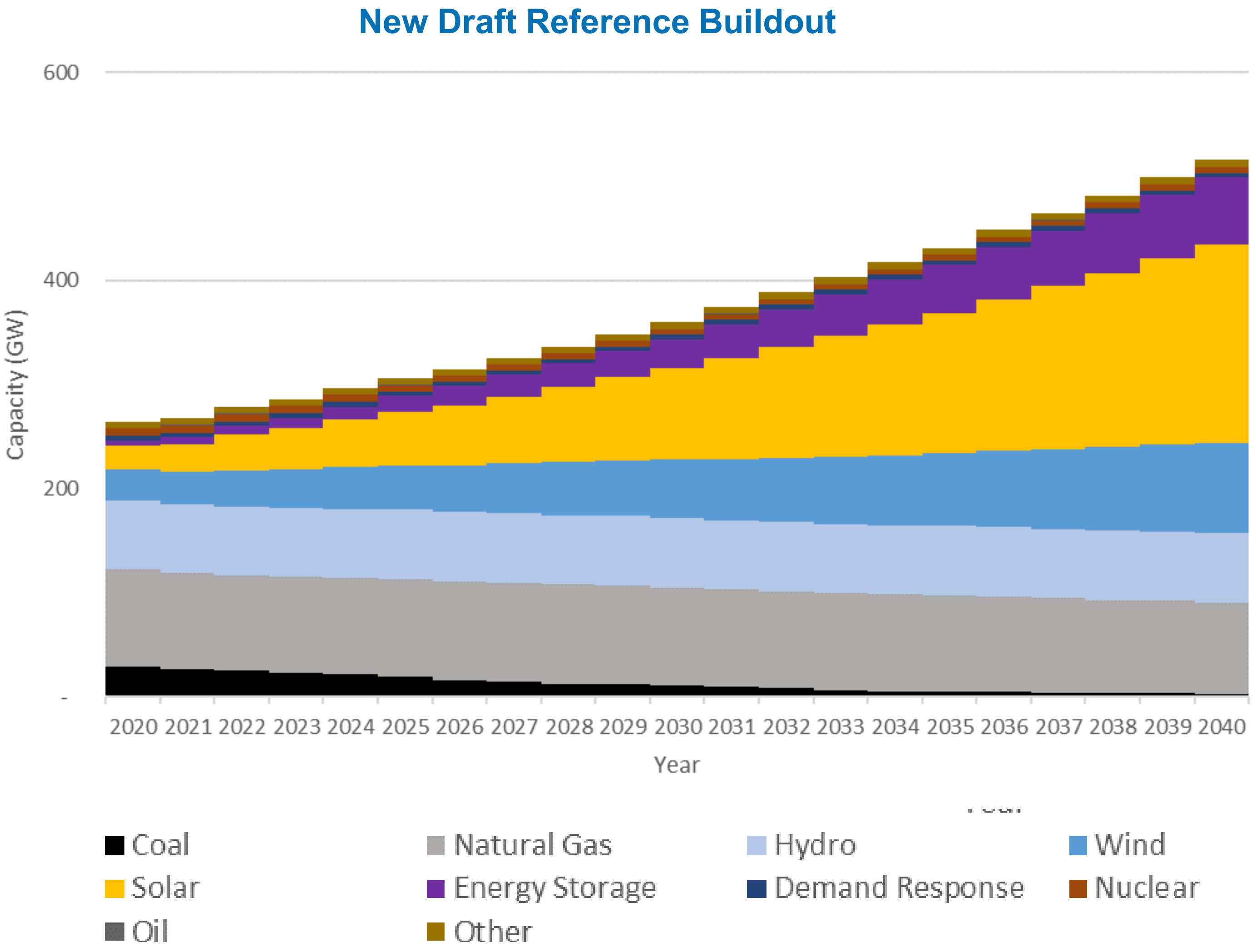


2019 IRP High Renewable Buildout



Coal
Natural Gas
Hydro
Wind
Solar
Energy Storage
Demand Response
Nuclear
Oil
Other

Next IRP: Draft Base WECC-wide Buildout

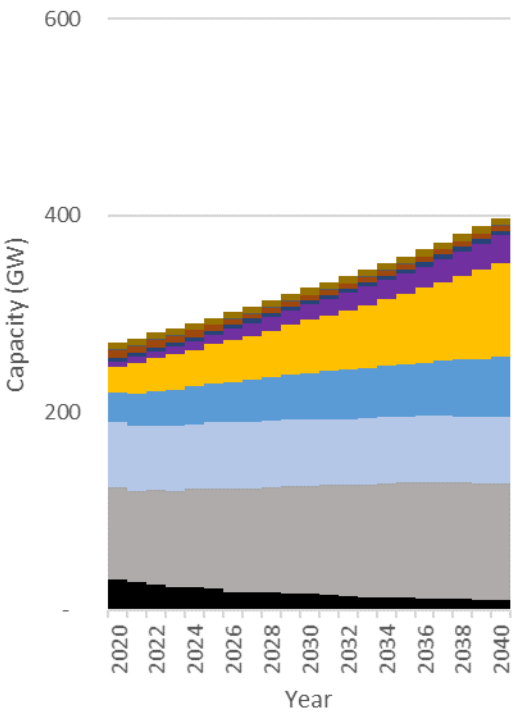


- We start from a draft Reference WECC-wide buildout database from Wood Mackenzie
  - Renewables are generally higher across the WECC in compared to the 2019 IRP Base buildout
  - Continued reduction of coal in system
  - In OR/WA: new resources consist of renewables and storage

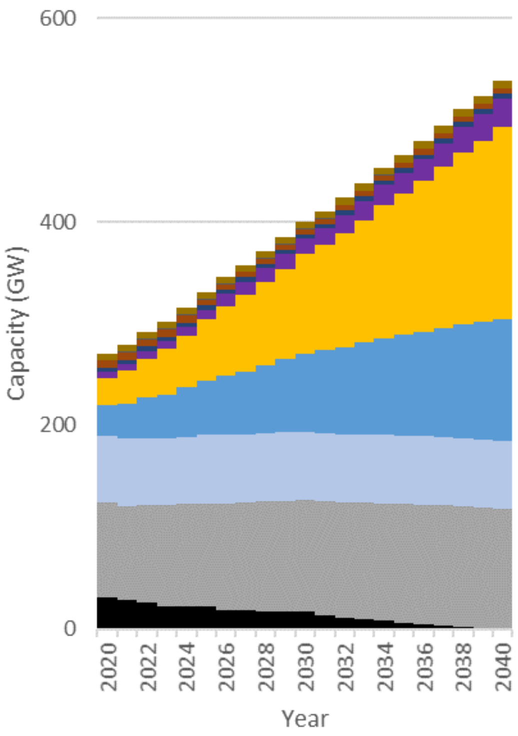
Next IRP: Draft Base WECC-wide Buildout

Our starting point is different compared to last time. We are seeking your input. Questions? Comments?

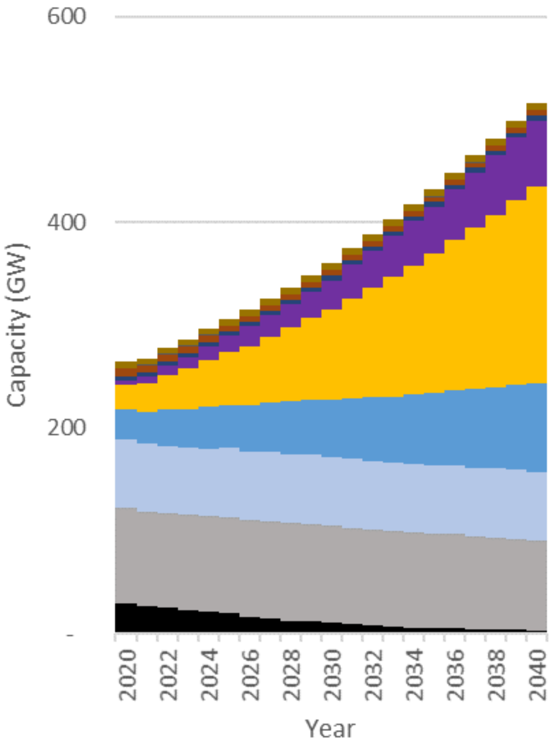
2019 IRP Base Buildout



2019 IRP High Renewable Buildout



New Draft Reference Buildout

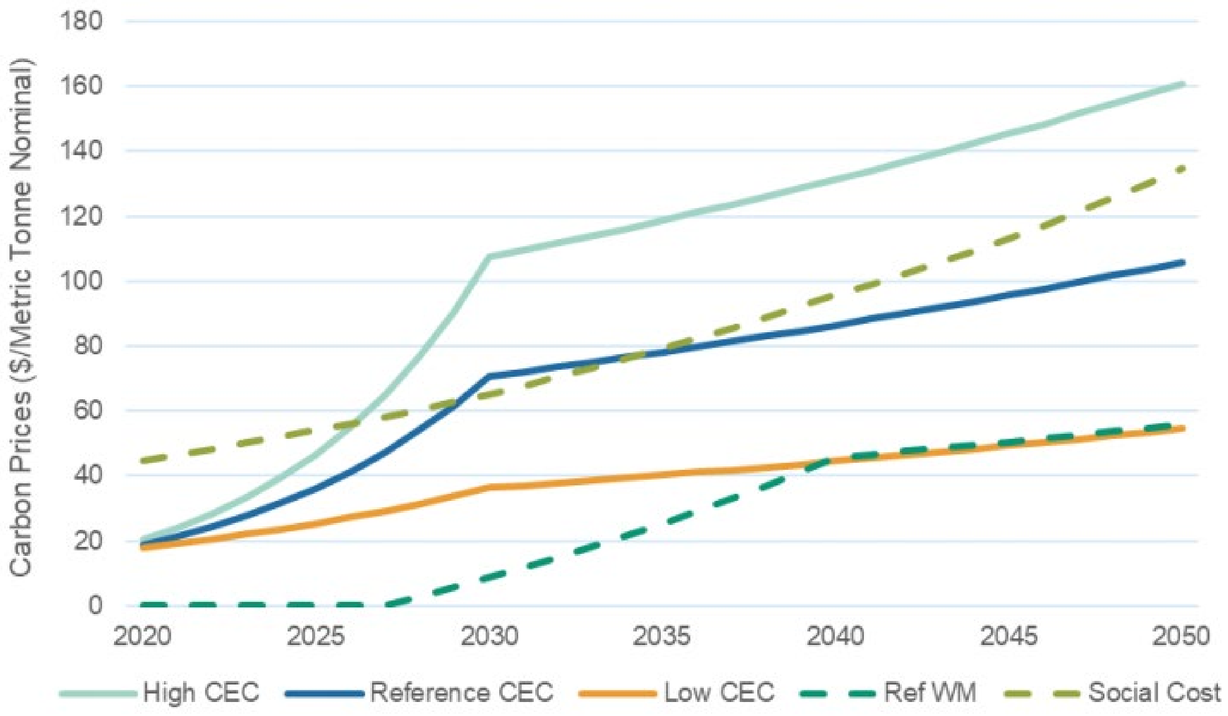


Coal | Natural Gas | Hydro | Wind
Solar | Energy Storage | Demand Response | Nuclear
Oil | Other

Carbon pricing

- We have included carbon pricing in IRP analysis since 2008, consistent with Order No. 08-339
- While working on the 2019 IRP, OR legislature was considering the introduction of a cap and trade program
- The 2019 IRP used California Energy Commission (CEC) carbon price forecasts (low, reference, high) to capture the potential impacts of future climate policies
- Climate Executive Order No. 20-04 issued March 10, 2020
- **We are continuing to think about how to best consider carbon in our analysis and seeking your input! Thoughts? Questions?**

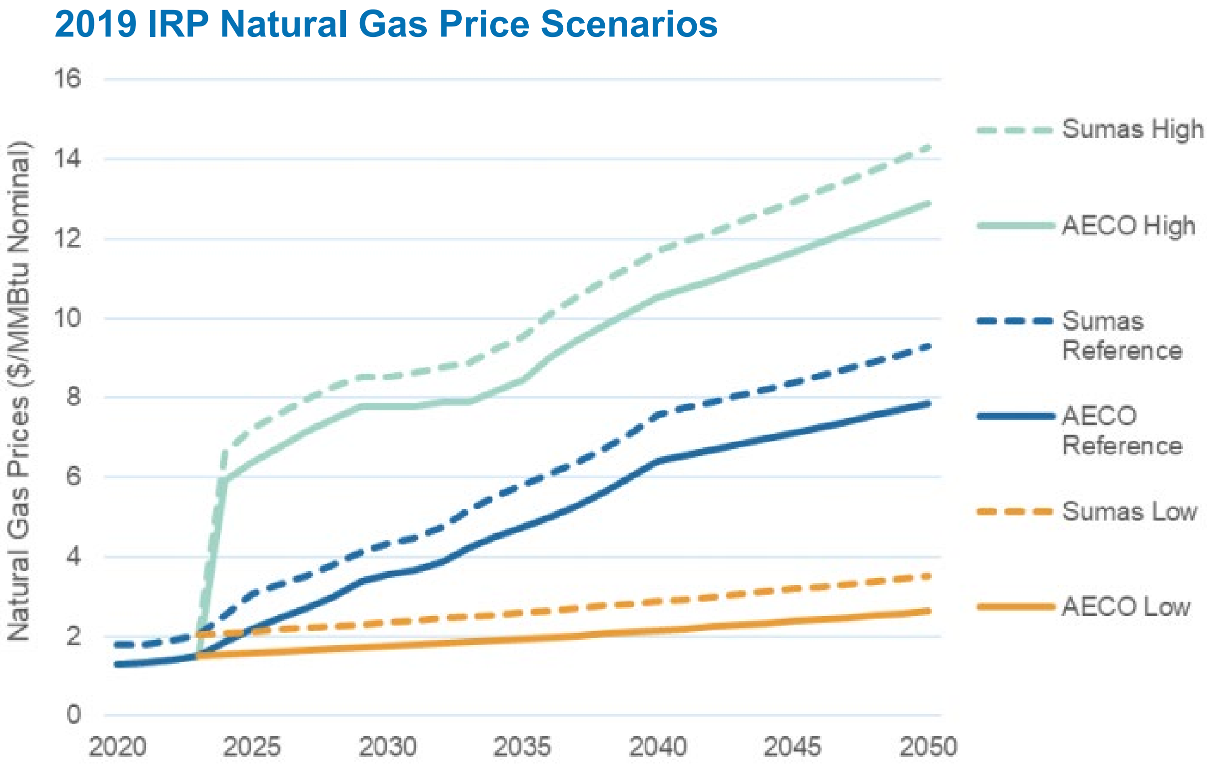
2019 IRP Carbon Prices*



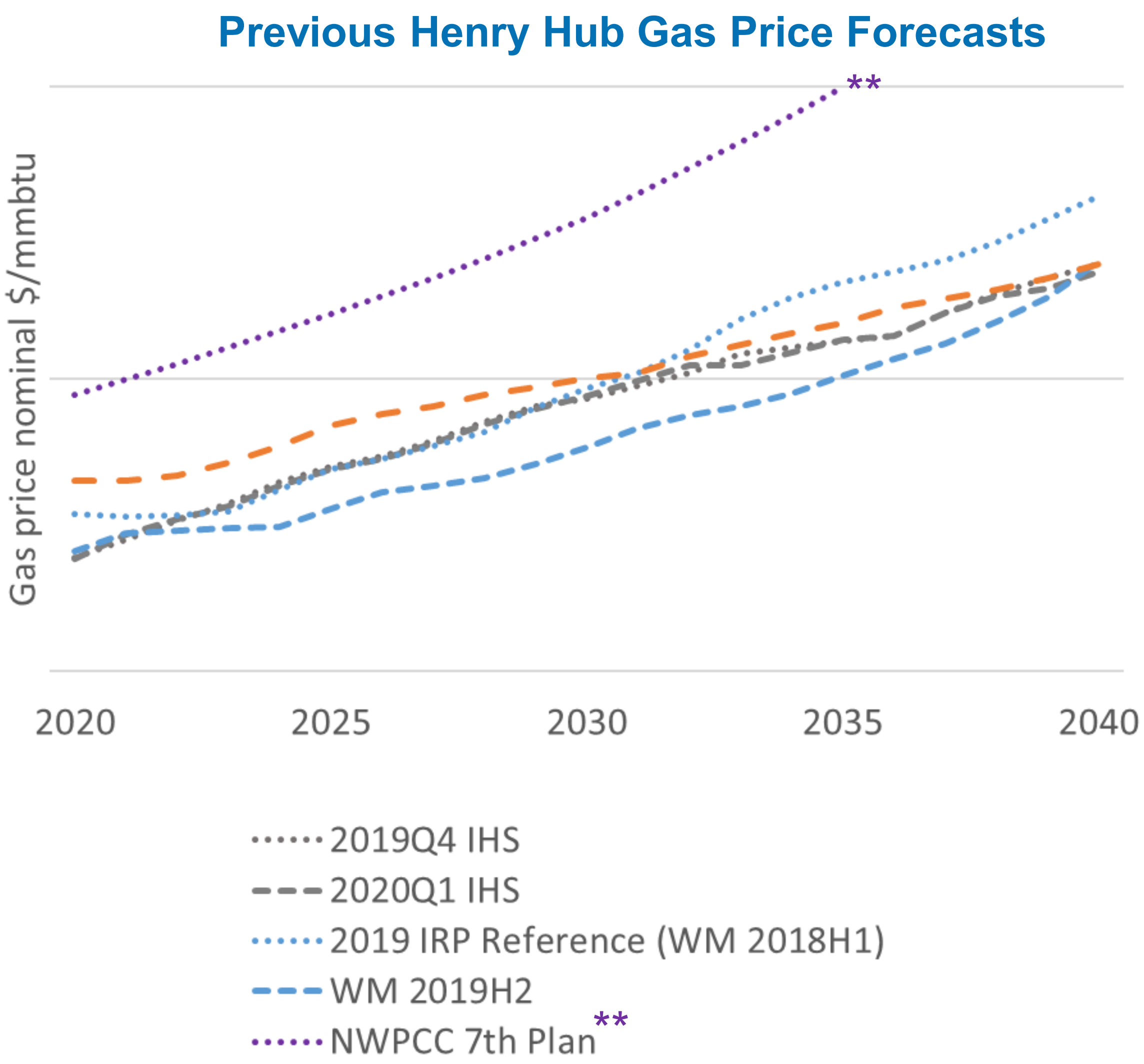
* Social cost of carbon used for analysis from EPA (August 2016) with 3% average discount rate

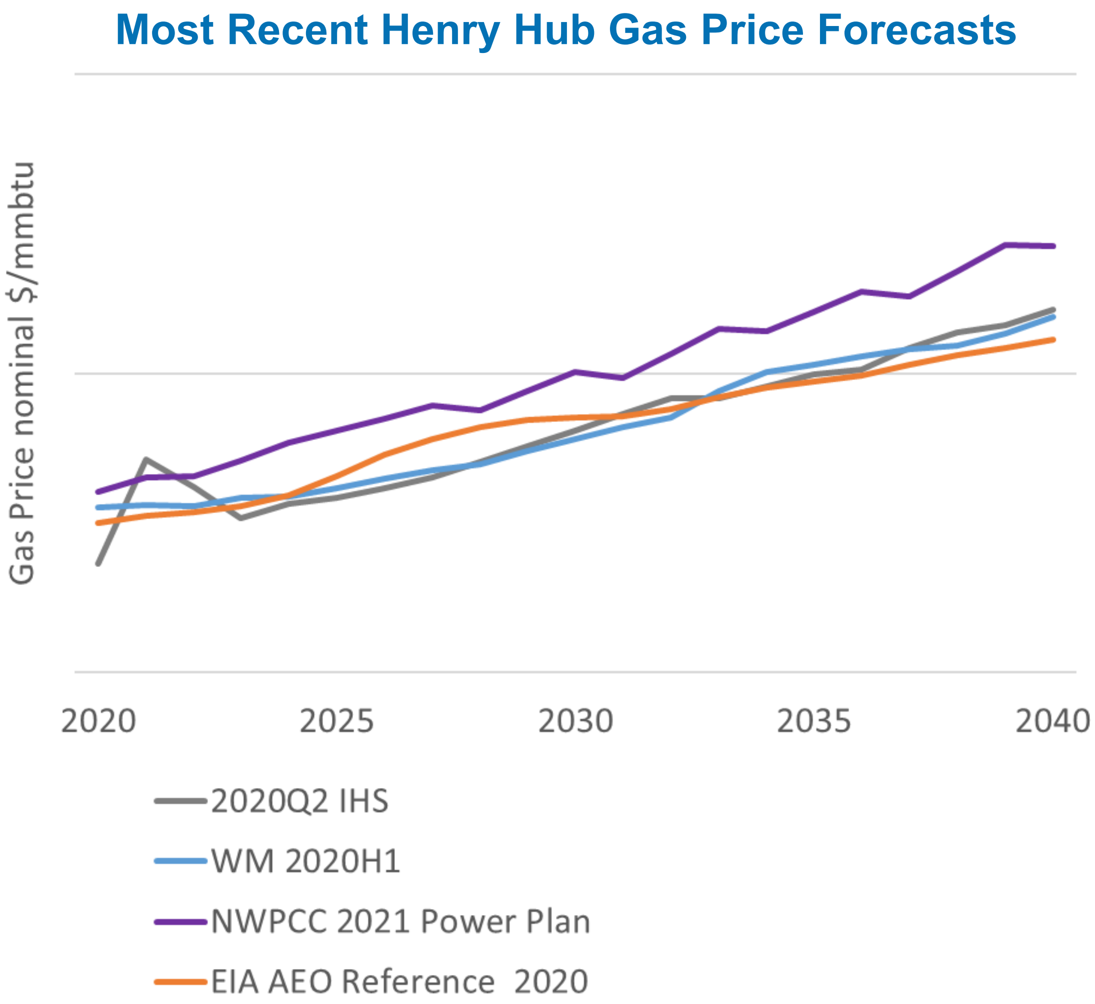
Natural gas

- Future gas prices are a key driver of uncertainty in forecasting electricity prices. It's important to consider actions across a range of potential gas price scenarios
- In the 2019 IRP, we modeled low, reference, and high gas price scenarios
- Data sources and forecasts we have used and/or considered in the past:
  - PGE near-term forward trading curve
  - Wood Mackenzie gas price forecast
  - EIA Annual Energy Outlook gas forecasts
  - Other forecasts such as IHS, Northwest Power Conservation Council (NWPCC)
- **We will be continuing this discussion in future roundtables and are seeking your input! Thoughts? Questions? Comments?**



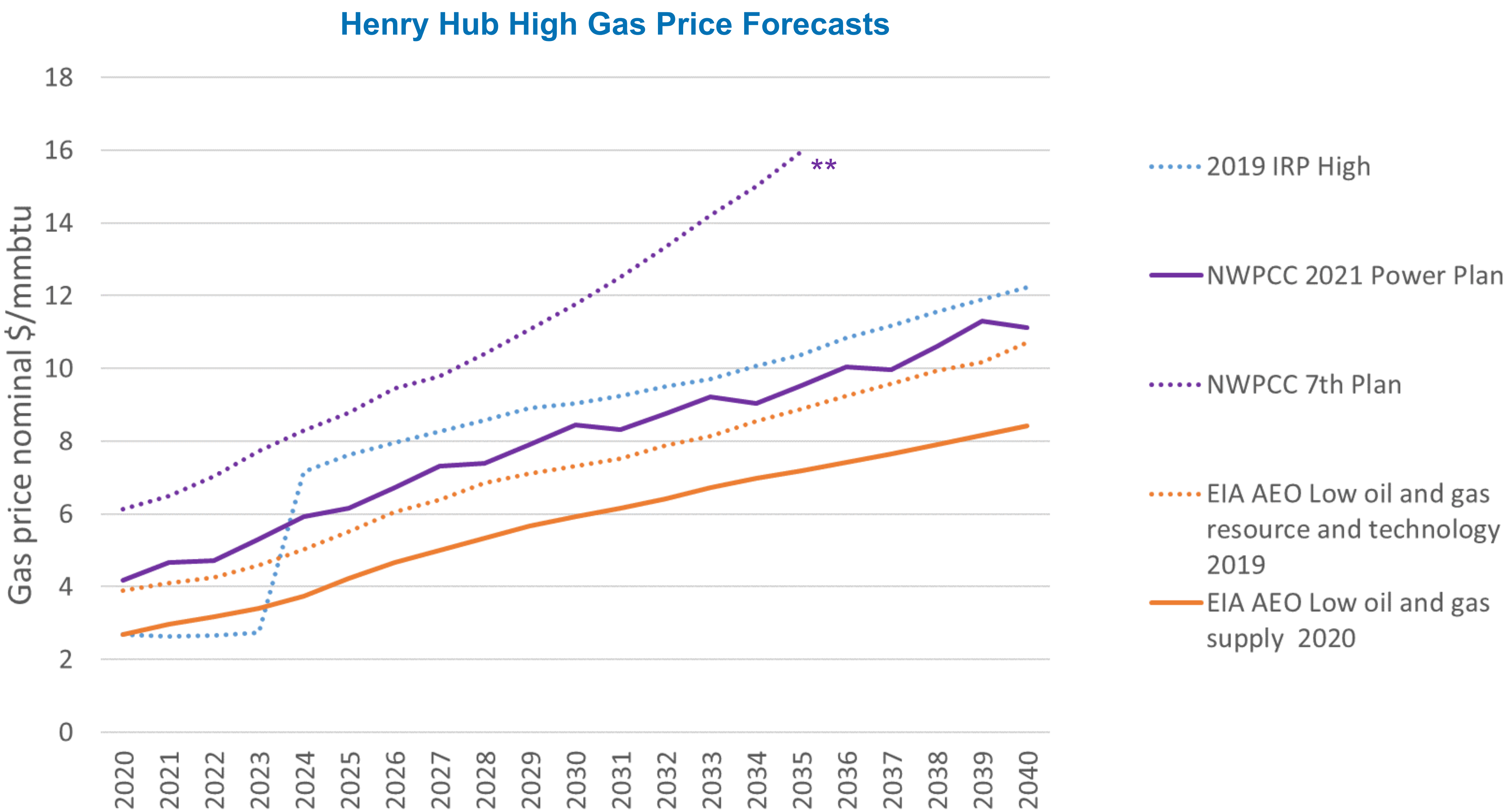
Natural Gas Reference Case Forecast Comparisons





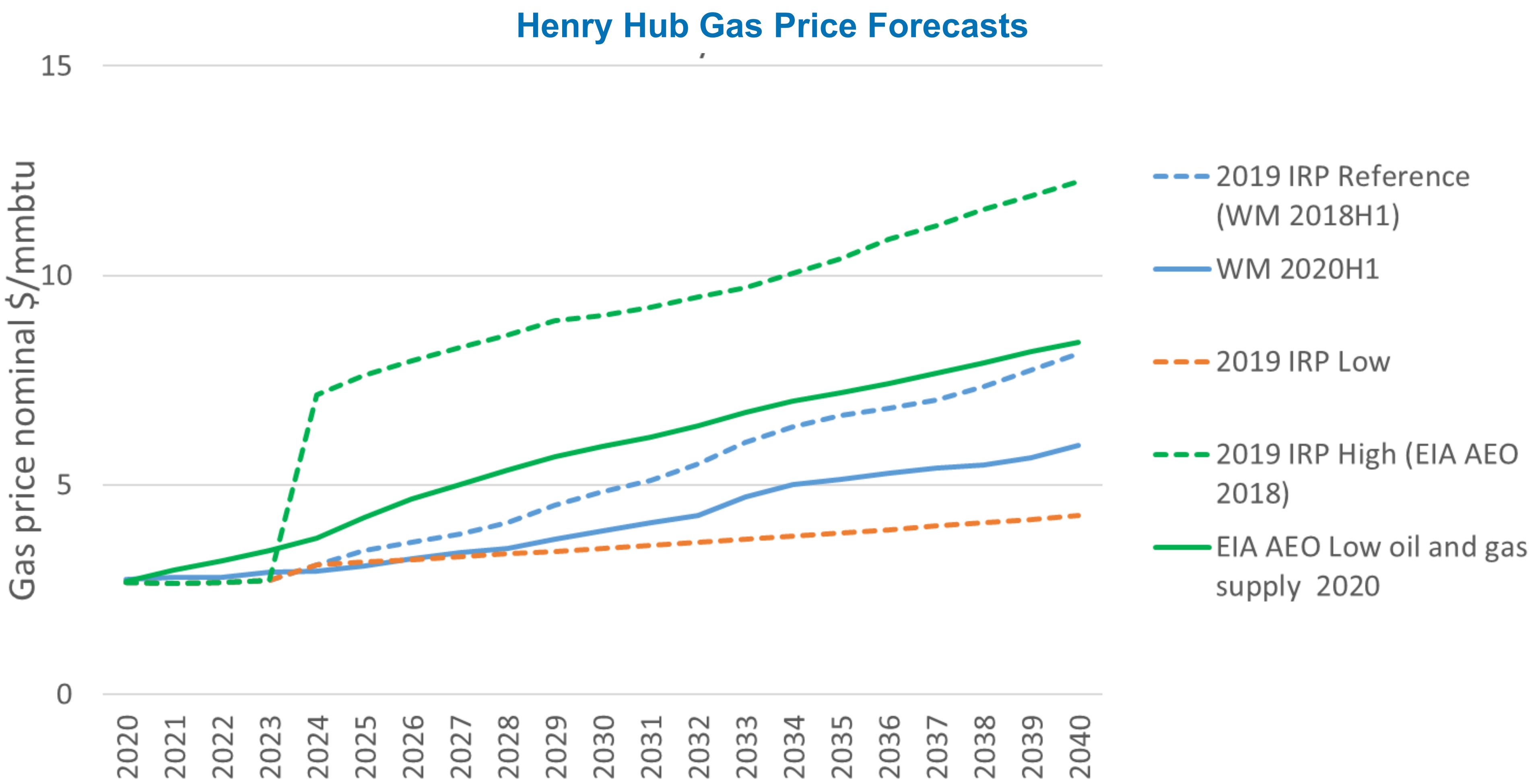
**NWPCC 7th Plan was published in 2016, so this vintage of forecasts came out prior to comparable forecasts on this plot

Natural Gas High Case Forecast Comparisons



NWPCC 7th Plan was published in 2016, so this vintage of forecasts came out prior to comparable forecasts on this plot

Natural Gas Forecast Comparisons



Regional hydro conditions

- Hydro generation in the PNW can strongly influence electricity prices
- We model an “average” hydro year in Aurora modeling
- In the 2019 IRP, we considered three sets of hydro conditions
  - Low and High hydro conditions were modeled as +/- 10 percent (approximately one standard deviation) of annual Pacific Northwest energy production
  - Low and High hydro conditions were included in the analysis of portfolio performance across risk metrics, but not in portfolio construction
- **We are continuing to seek your input on this topic! Questions? Comments?**

ADDITIONAL QUESTIONS/ DISCUSSION?

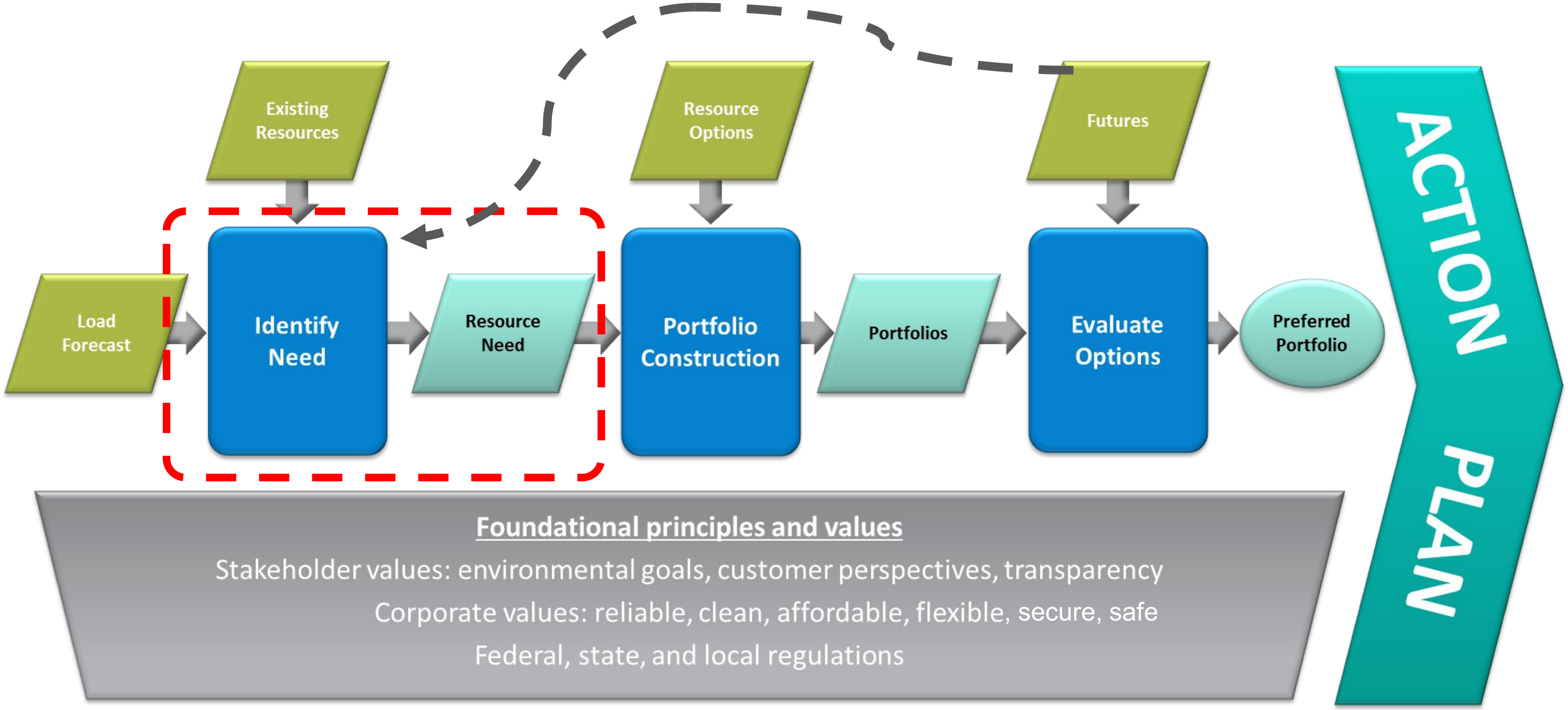
AGENDA

- Capacity Assessment Baseline
  - 45 minutes
  - Informational
- Supply-Side Options
  - 30 minutes
  - Informational and participants' feedback

Capacity Assessment Baseline

Kate von Reis Baron

Need Assessment Analysis



Roundtable Review – Capacity Assessment, Sequoia

- RT 20-1 included a high-level introduction to capacity assessments and the Sequoia model.
- RT 20-3 provided additional details about Sequoia's structure and dispatch logic.
- The slides from earlier Roundtables are available at:

https://portlandgeneral.com/our-company/energy-strategy/resource-planning/integrated-resource-planning/irp-public-meetings

Sequoia

A Monte Carlo time-sequential capacity assessment model that calculates capacity need and capacity contribution of incremental resources.

Key objectives for developing the model:

- Improved treatment of energy-limited resources
- Improved process efficiency

#1 Input Data → #2 Monte Carlo Module → #3 Dispatch Module → #4 Output Metrics

Baselining Exercise Overview

To better understand the drivers of the changes to the capacity need assessment from RECAP to Sequoia, we undertook a preliminary baselining exercise

Baselining exercise

- Investigate 2025 capacity needs in both RECAP and Sequoia using input assumptions consistent with the 2019 IRP Updated Needs Assessment*
- Analysis does not incorporate more recent information about loads and resources
- Analysis is draft and subject to change
- Information is presented for comparison only and does not reflect PGE's resource needs at this time

The following slides will cover:

1. Capacity need reporting convention
2. Impacts of switching to a time-sequential model
3. Impacts of implementing additional operational rigor with Sequoia
    - Energy-limited dispatchable resources (hydro, storage, and hybrid resources)
    - Contingency reserve obligations and provisions

*For the baseline exercise, Sequoia's objective function minimized the sum of the maximum capacity shortage and the average energy shortage across each week; capacity need was assessed based on a reliability standard of a loss-of-load expectation of no more than 2.4 hr/yr

Capacity Accounting Convention

What does 1 MW of capacity need mean?

RECAP model

RECAP calculates capacity need in MW of generic capacity.

2016 & 2019 IRPs:

- Generic capacity was a 100 MW unit with a 5% forced outage rate
- Capacity contributions were defined as relative to the generic capacity unit, so a 100 MW thermal unit with 5% forced outage rate had ELCC = 100%

Sequoia model

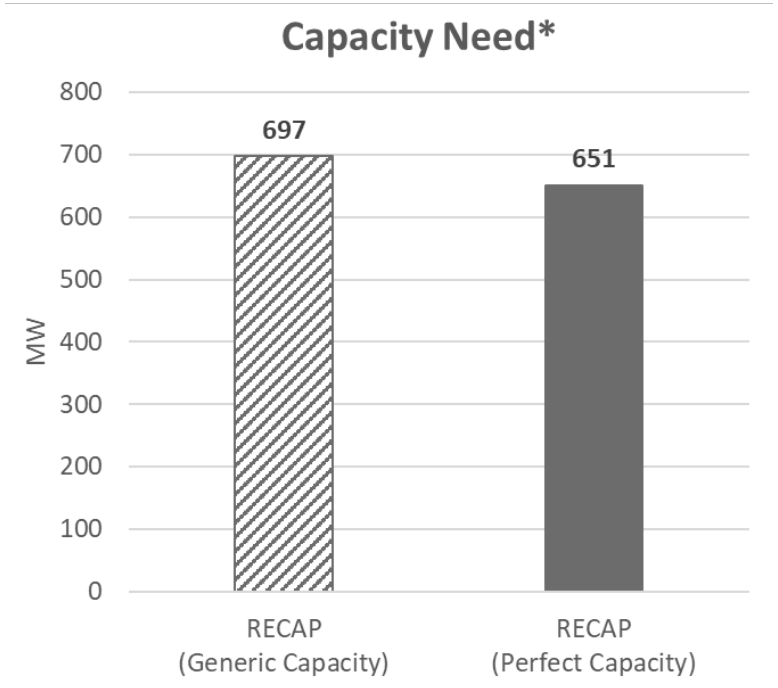
Sequoia calculates capacity need in MW of perfect capacity.

- Perfect capacity is available all hours of every day
- Capacity contributions will be defined as relative to perfect capacity, so a 100 MW thermal unit with 5% forced outage rate would have ELCC < 100%
- Why? Technology-agnostic, easier to calculate, consistent with other jurisdictions

ELCC = Effective Load Carrying Capability

Impact of converting to perfect capacity convention

Step 1. Calculate capacity need in RECAP with perfect capacity convention to ensure apples-to-apples comparisons with Sequoia



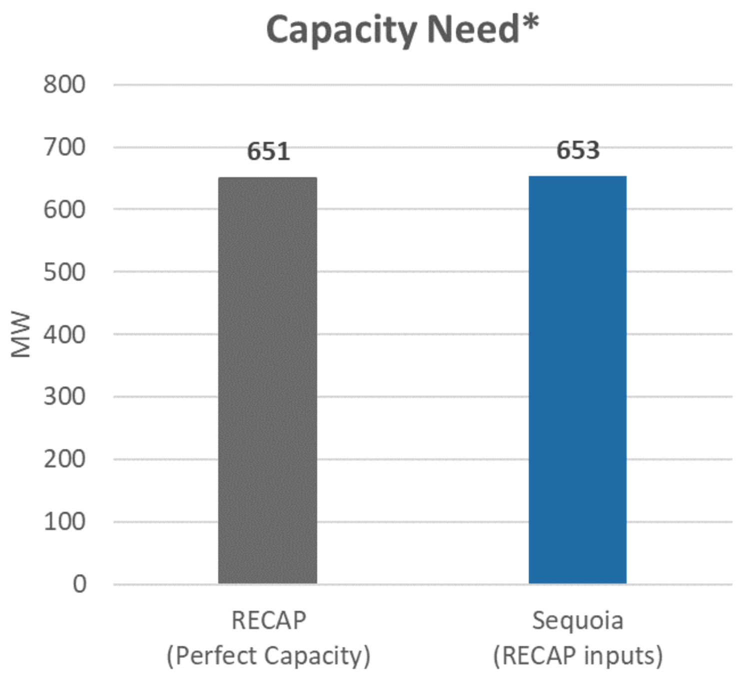
*2025 capacity needs with input assumptions consistent with PGE's 2019 IRP Needs Assessment Update (i.e., not updated for more recent load forecast or contract information)

- Switching from generic capacity to perfect capacity reduces total capacity needs, in this draft test by 46 MW (7%)
- This change in convention would also:
  - Have a corresponding impact (reduction) to all capacity contributions so there is no change in the amount of infrastructure required to meet a given reliability target, all else equal
  - Have a corresponding impact (increase) to the net cost of capacity so that total capacity value for each resource remains unchanged

Draft analysis – subject to change

Impact of switching to time-sequential modeling

Step 2. Run the RECAP case in Sequoia using the same input assumptions



- Switching from RECAP to Sequoia slightly increases the capacity need, in this draft test by 2 MW (0.3%)

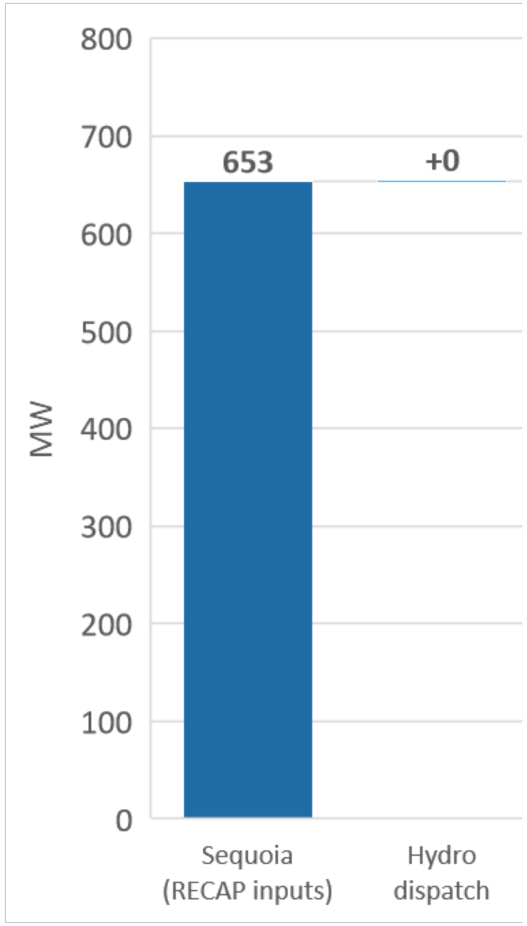
- Magnitude of change falls well within our high-level sense of the uncertainty inherent to LOLP modeling

*2025 capacity needs with input assumptions consistent with PGE's 2019 IRP Needs Assessment Update (i.e., not updated for more recent load forecast or contract information)

Draft analysis – subject to change

Impact of implementing additional operational rigor

Step 3. Layer in more sophisticated treatments of resource operations in Sequoia



Hydro treatment

Simple treatment: hydro units are modeled with monthly dependable capacity and outage distributions that approximate impacts of historical hydro conditions

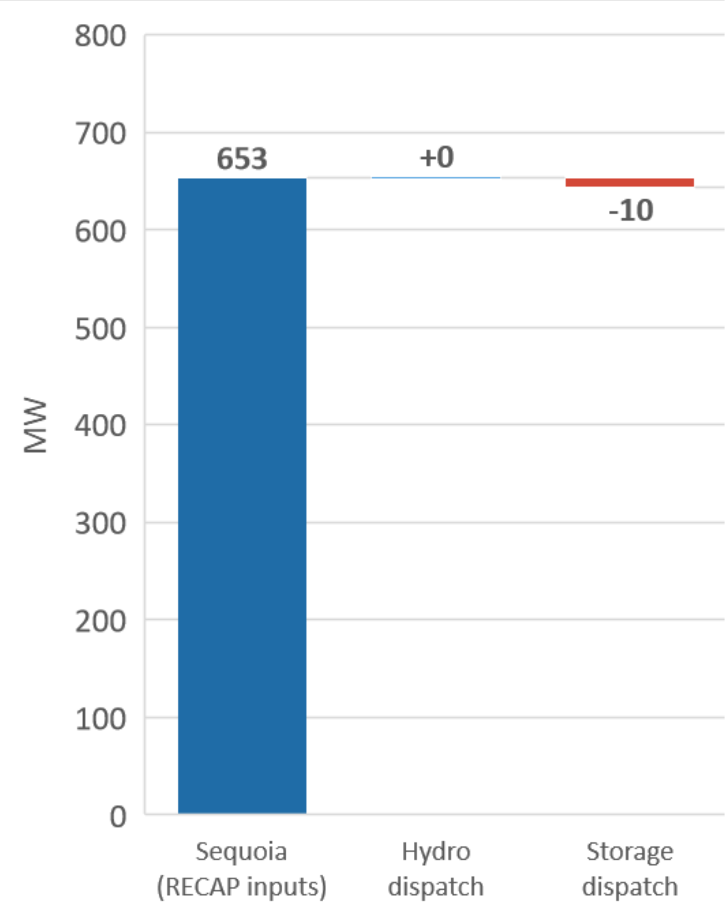
Sequoia hydro dispatch: randomly draws hydro years and available weekly energy and capacity associated with those hydro years; dispatches hydro subject to those capacity and energy constraints

Impact: Explicitly modeling hydro conditions and energy constraints had negligible net impact on capacity needs in draft test

Draft analysis – subject to change

Impact of implementing additional operational rigor

Step 3. Layer in more sophisticated treatments of resource operations in Sequoia



Storage treatment

Simple treatment: storage modeled with fixed month-hour shapes that are informed by expected timing of loss of load events

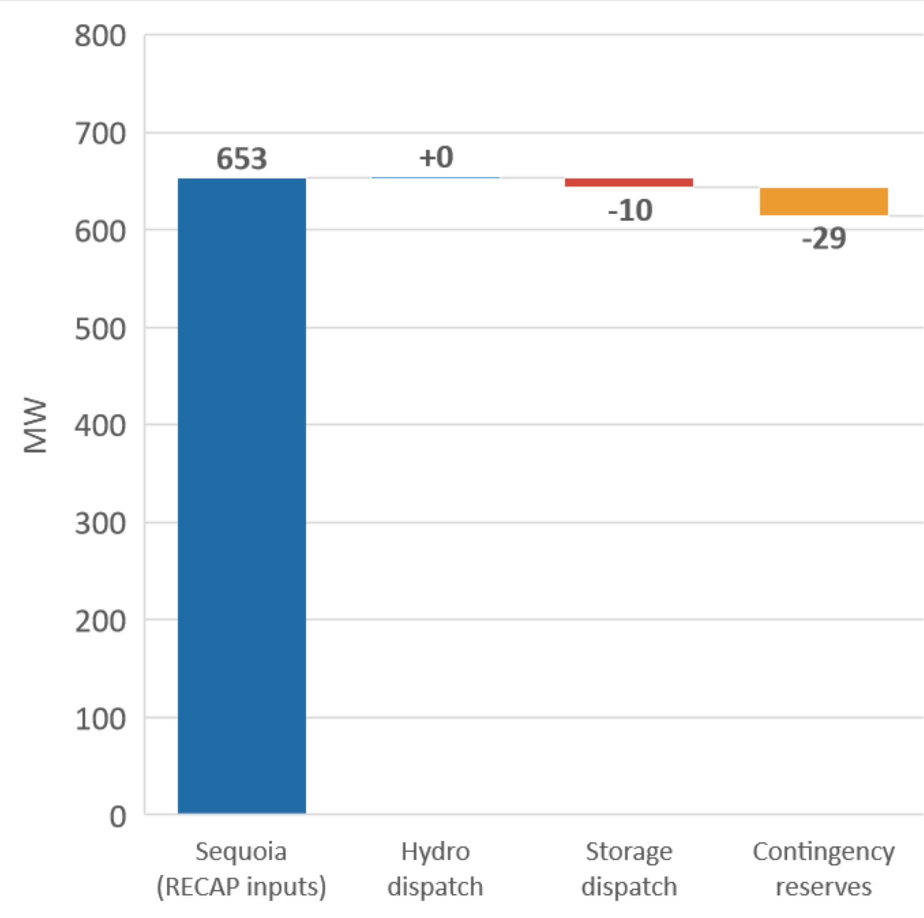
Sequoia storage dispatch: optimizes storage portfolio hourly dispatch in each week based on the conditions in that week; storage not limited to one cycle per day

Impact: Optimizing storage dispatch decreases capacity needs slightly (-10 MW). This is small relative to total capacity needs, but significant relative to the size of the storage portfolio (28 MW)

Draft analysis – subject to change

Impact of implementing additional operational rigor

Step 3. Layer in more sophisticated treatments of resource operations in Sequoia



Contingency reserve treatment

Simple treatment: Contingency reserve obligation equal to 6% of load; all resources able to contribute to meeting combined load + contingency reserve obligation

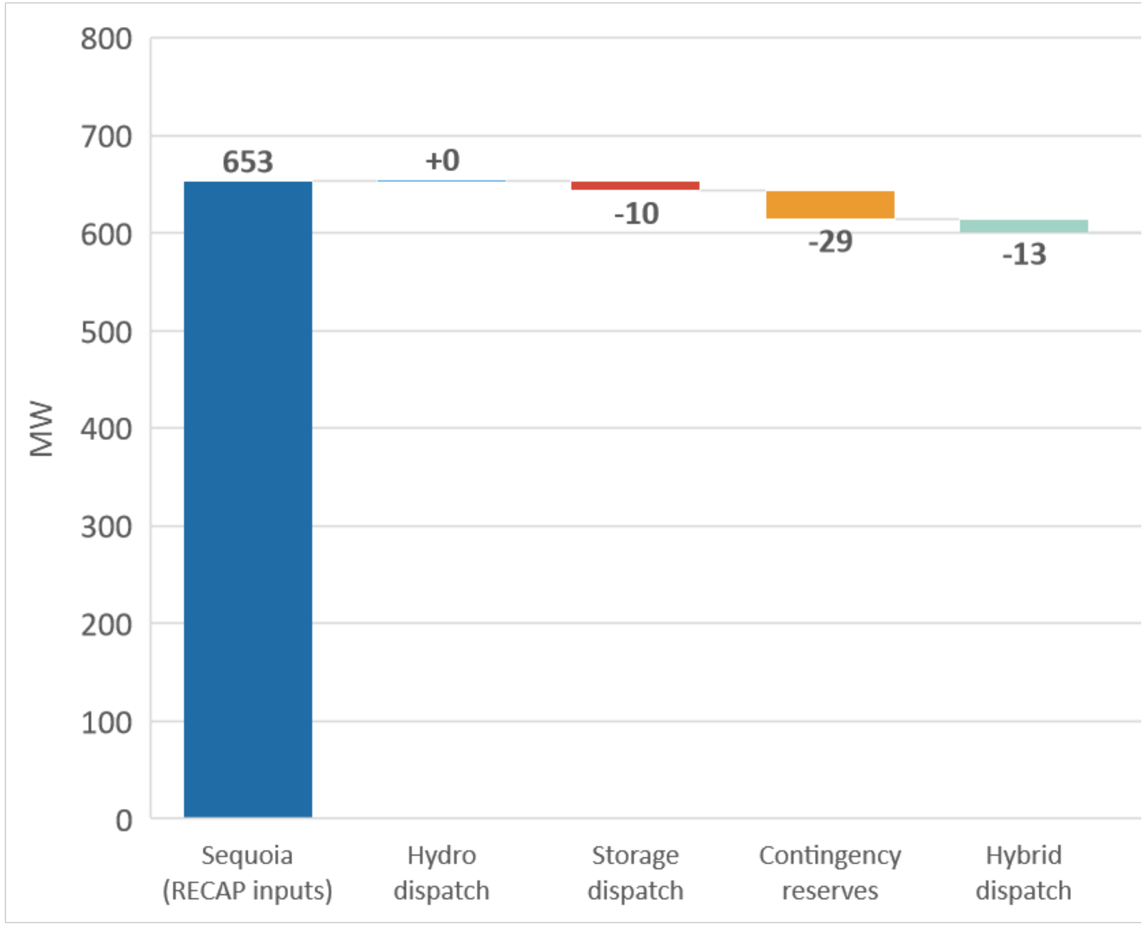
Sequoia contingency reserves: explicit accounting of contingency obligation for all loads and resources; explicit hourly representation of spin and non-spin provisions by resource based on capability

Impact: Explicit treatment of contingency reserve obligations and spin and non-spin provisions reduces capacity needs (-29 MW)

Draft analysis – subject to change

Impact of implementing additional operational rigor

Step 3. Layer in more sophisticated treatments of resource operations in Sequoia



Hybrid resource treatment

Simple treatment: hybrid resources modeled with fixed shapes that are informed by expected timing of loss of load events

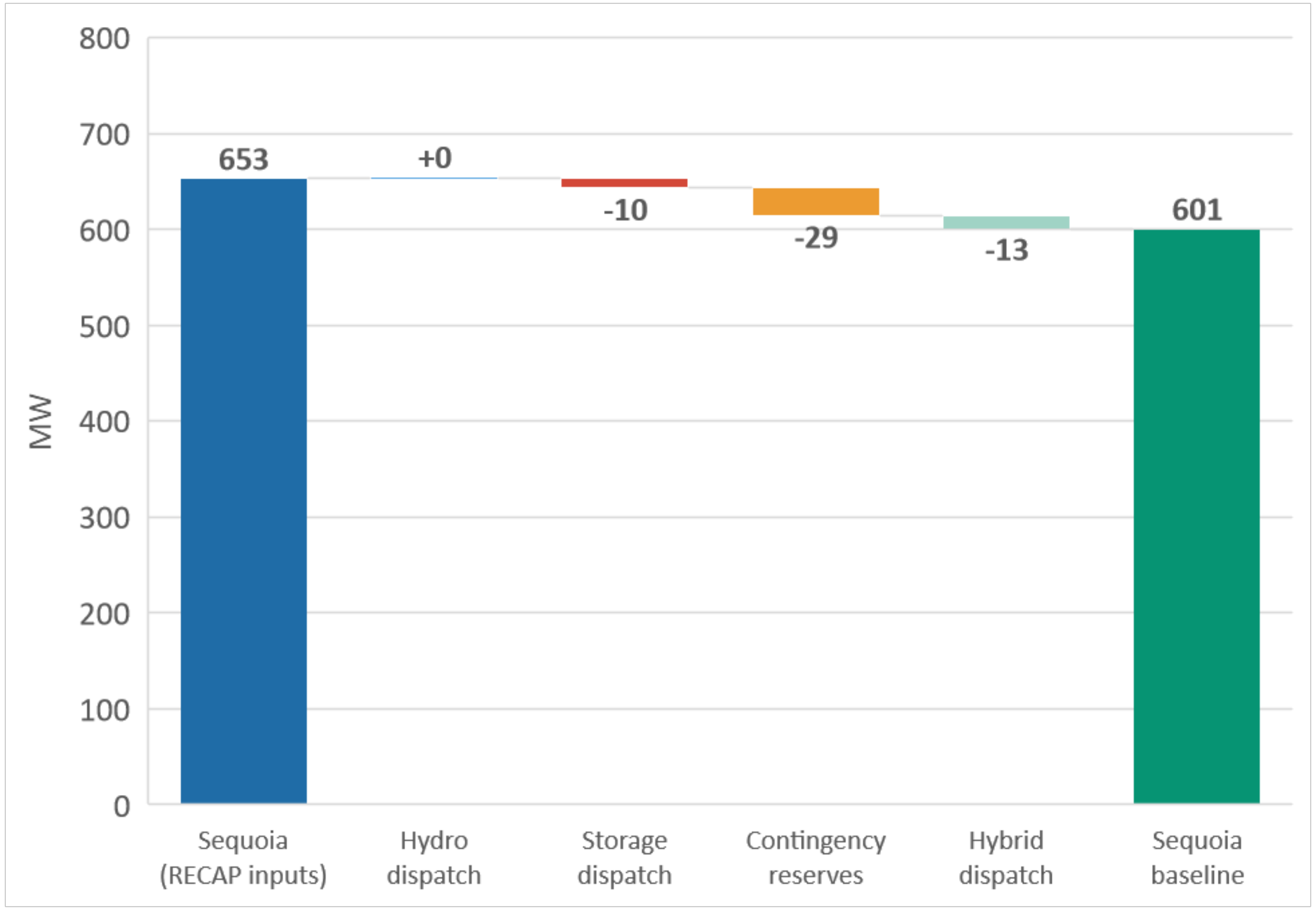
Sequoia hybrid dispatch: optimizes hourly dispatch in each week based on the conditions in that week

Impact: Optimizing hybrid dispatch decreases capacity needs slightly (-13 MW). This is similar in relation to the size of hybrid storage capacity (approx. 30 MW) as the change for Storage

Draft analysis – subject to change

Impact of implementing additional operational rigor

Step 3. Layer in more sophisticated treatments of resource operations in Sequoia

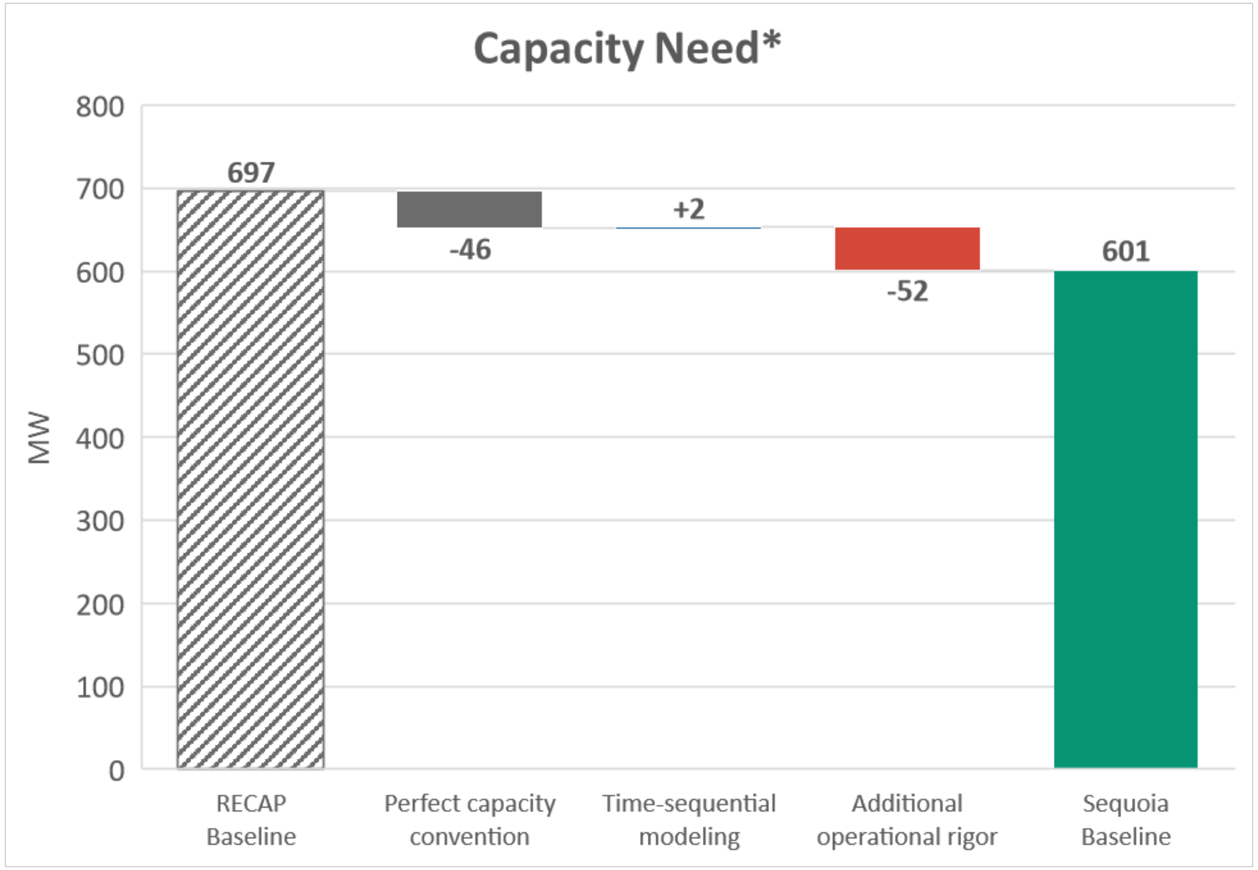


More sophisticated treatment of energy-limited dispatchable resources (hydro, storage, and hybrid resources) and contingency reserves have a net impact of reducing quantified capacity needs in this draft test by 52 MW (8%)

Draft analysis – subject to change

Summary of baselining exercise

Methodological changes result in a net reduction in quantified capacity needs, 52 MW of which represents an actual change in expected needs and 46 MW of which is due only to a change in reporting convention

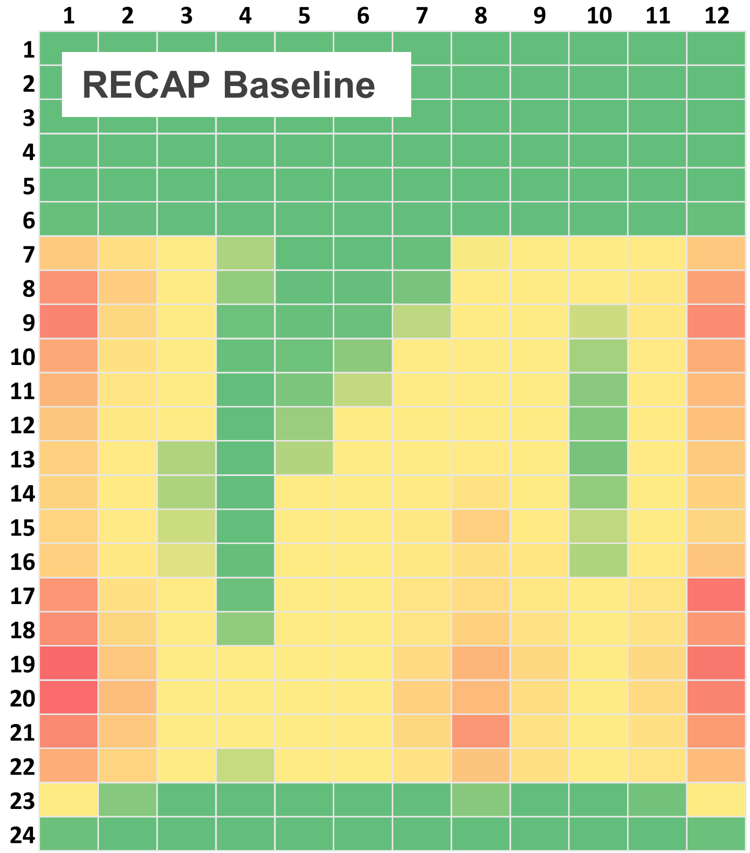


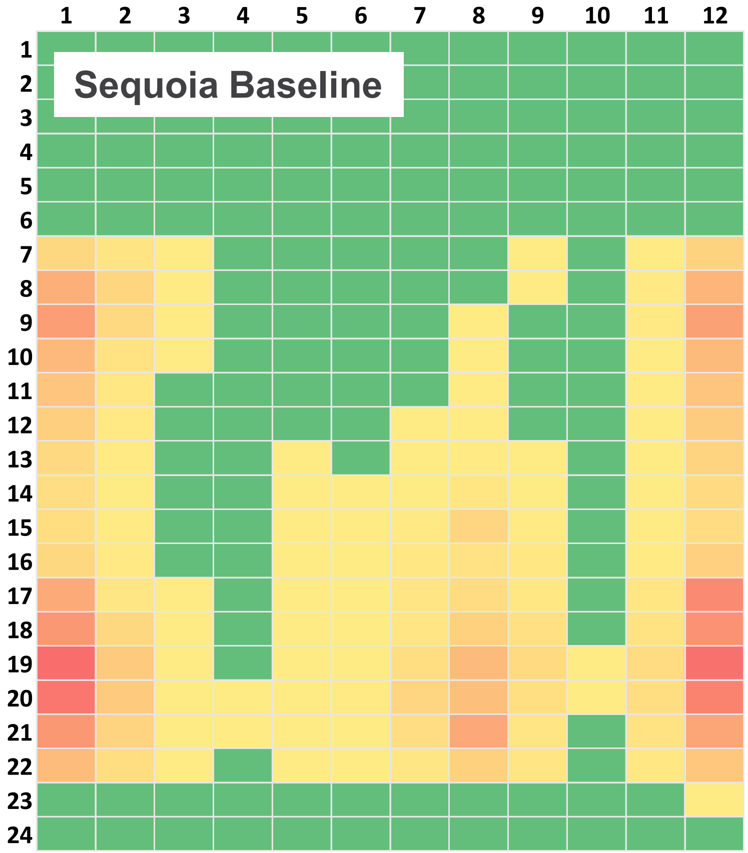
*2025 capacity needs with input assumptions consistent with PGE's 2019 IRP Needs Assessment Update (i.e., not updated for more recent load forecast or contract information)

Draft analysis – subject to change

Loss of load probabilities

Constrained seasons and times of day are similar between RECAP and Sequoia

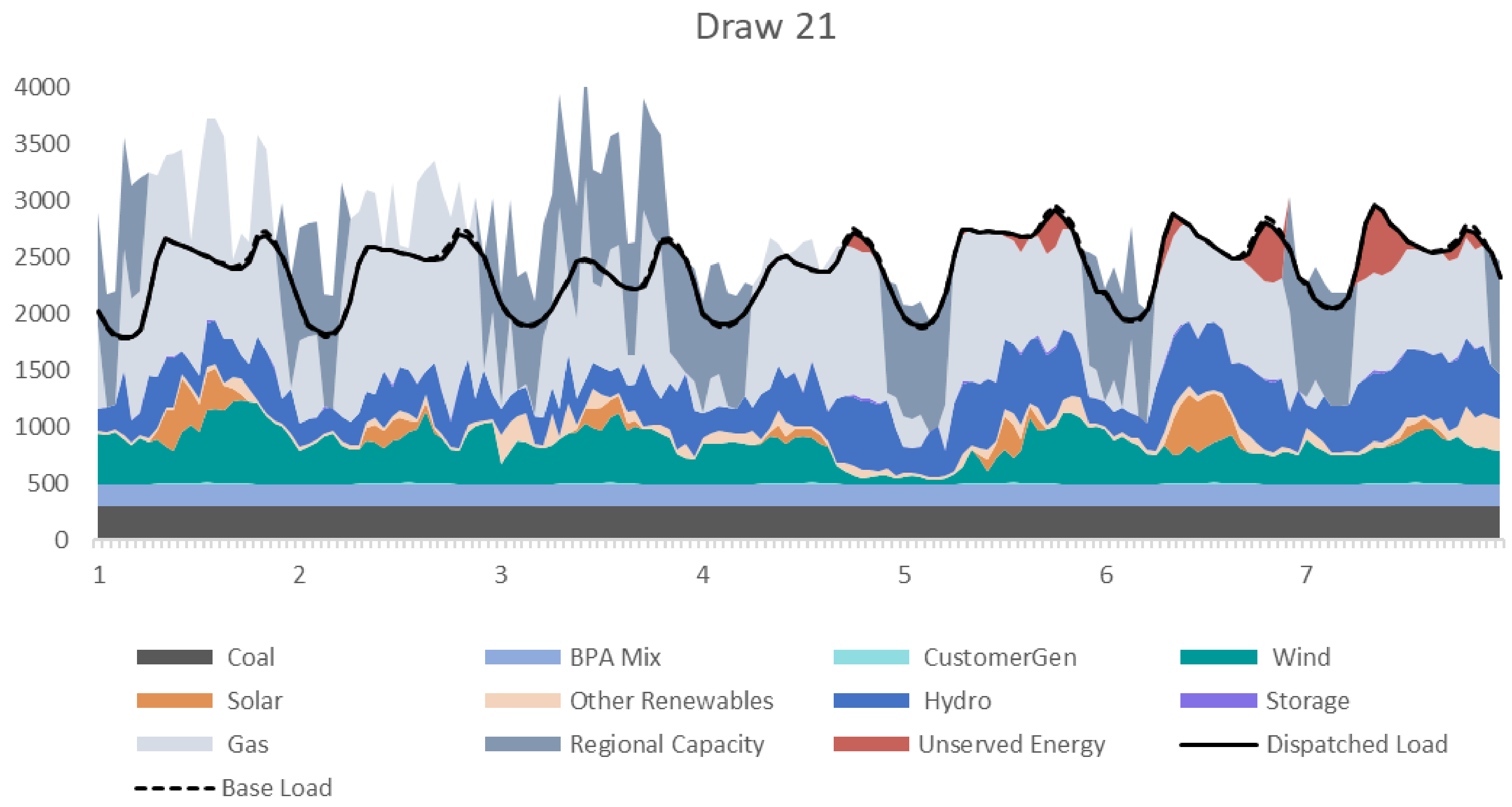




Draft analysis – subject to change

Example week with loss of load

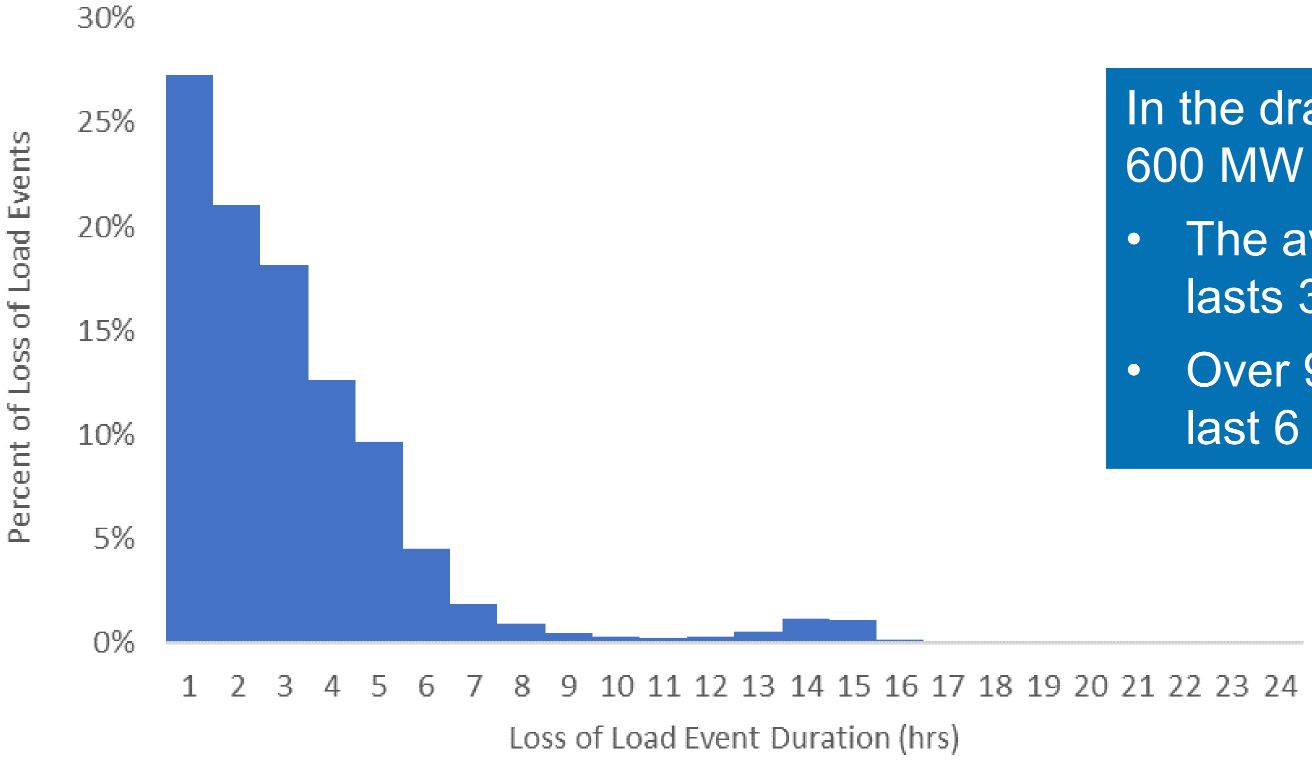
Sequoia provides additional information about the conditions in which loss of load events may arise



Draft analysis – subject to change

Loss of load events

Examining loss of load events can provide helpful information to understand the nature of capacity needs and the potential solutions to fill capacity needs



In the draft baseline case, even with a 600 MW capacity shortage:

- The average loss of load event lasts 3.3 hours
- Over 90% of loss of load events last 6 hours or less

Draft analysis – subject to change

Sequoia Next Steps

Sequoia Phase 1 Goals

- **Improve treatment of energy-limited resources**
- **Improve process efficiency**

- Continue code review and validation
- Update resources and loads
- Continue development of output reports and documentation
- Schedule Technical Workshop to share additional model detail and draft capacity contribution values

QUESTIONS/ DISCUSSION?

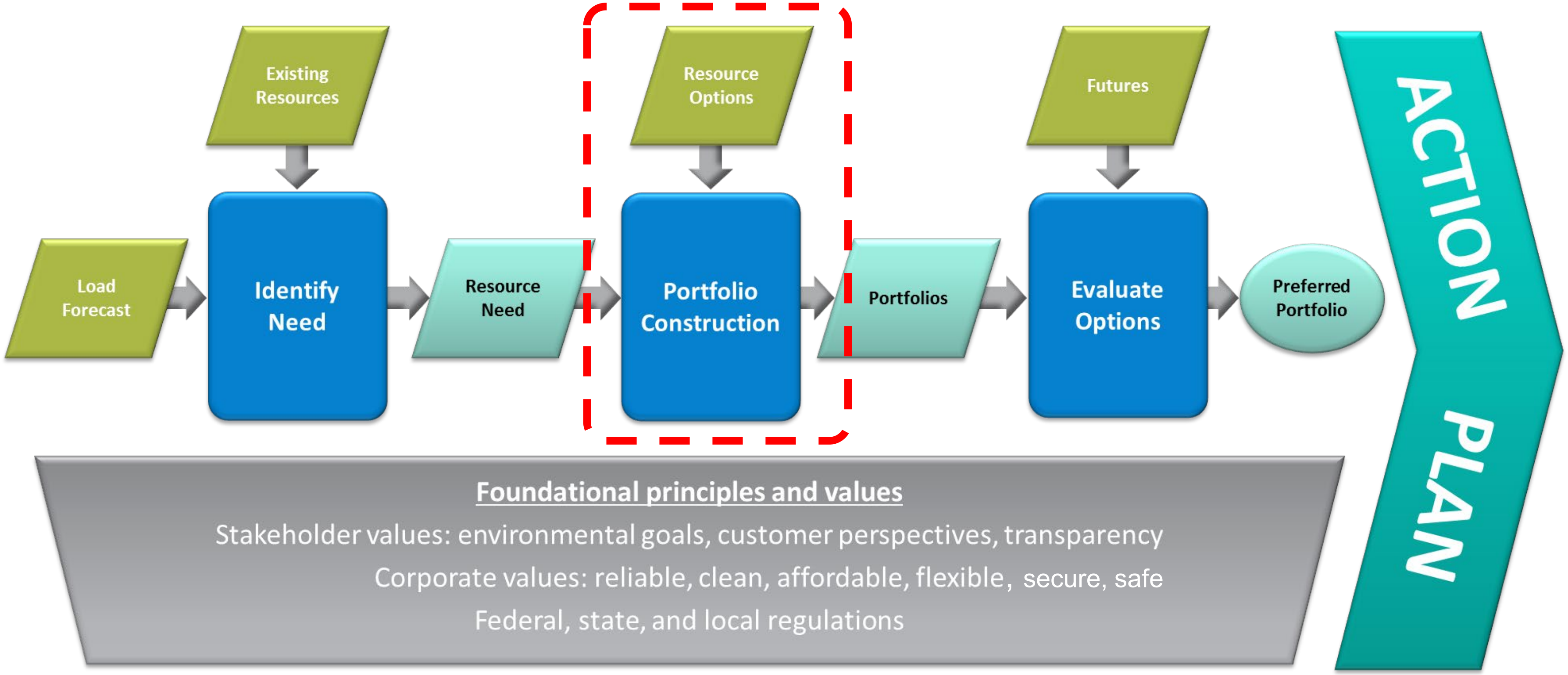
AGENDA

- Supply-Side Options
  - 30 minutes
  - Informational and participants' feedback

Supply-Side Options

Robert Brown & Seth Wiggins

Supply-Side Options



Resource Options

Resource needs may arise in the future due to a variety of factors (e.g., growth in demand, contract expirations or retirements, regulatory compliance)

We consider a variety of options to meet future resource needs

- Distributed resources
  - Typically located at or close to the customer site
  - Energy efficiency, flexible load and demand response, rooftop solar, customer storage
  - Will be considered within a Distributed Energy Resources (DER Study), to be discussed at a future roundtable meeting
- Supply-side resources
  - Typically larger in size and interconnected at higher voltages to utilize transmission and distribution infrastructure to meet load

This presentation will focus on the purpose and selection of supply-side options in the next IRP

Supply-Side Options: Decision Criteria

There are **four** main considerations when selecting supply-side options:

1. **Realism**: Will the generation technology be competitive relative to other resource in the IRP planning horizon? Will it be practical?
2. **Data**: Is there quality cost and benefit data for the resource?
3. **Transmission**: is the energy generated able to serve PGE's load?
4. **Performance**: What are the costs and benefits the resource would bring to our system?

There are **three** categories of analysis for a technology, with increasing evaluation:

1. Emerging technologies[1,2]	2. Resource Economics[3]	3. Full portfolio analysis[4]
2016 IRP – Hydrokinetic 2019 IRP – Hydrokinetic, hydrogen, SMR	Calculating LCOE, capacity value, etc.	ROSE-E considers resource for evaluation

1. 2016 IRP pg. 220
2. 2019 IRP pg. 148
3. Chapter 6 - 2019 IRP, pg. 155
4. Chapter 6 - 2019 IRP, pg. 175

Supply-Side Options: Data Sources

In previous IRPs, we engaged third-party consultants to prepare cost and operating characteristic reports for supply-side resources

- HDR in 2019, Black & Veatch and DNV GL in 2016

Regardless of data source, we evaluate the projections in two ways:

1. Data sources (data vintage, reputation, and reliability)
2. Specific estimates (cohesion with previous estimates, other IRPs, etc.)

In this IRP, we decided to utilize publicly available sources of supply-side resource costs and operating characteristics

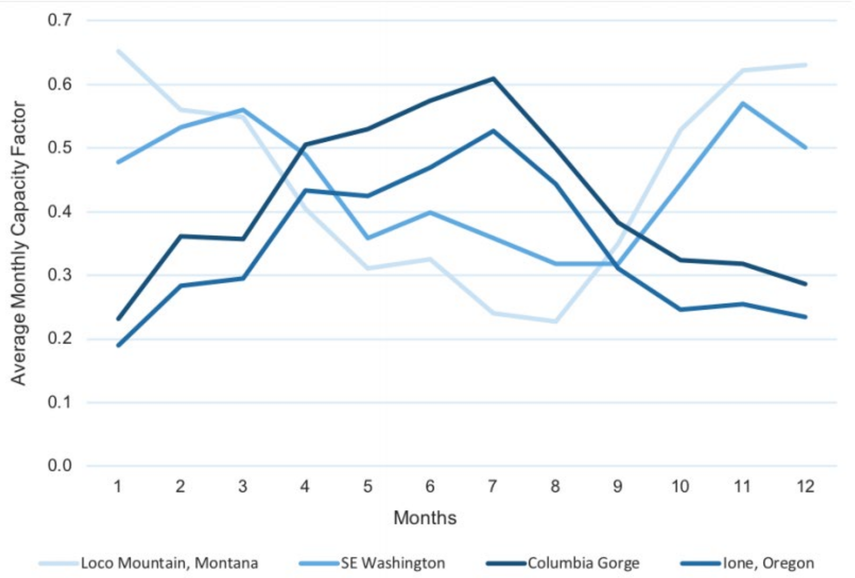
- We are currently evaluating NREL and EIA data
- Are open to consider other data sources

Supply-Side Options: Other Considerations

Geographic diversity:

- The contributions of variable resources can differ by geography
- To value the benefits of resource diversity, it is useful to model resources at multiple locations

FIGURE 5-4: Average monthly wind capacity factors by location



However, the set of resources considered presents an important trade-off:

- ***Too few*** resources could generate a resource expansion path which provides less useful learnings about the possibility for cost and risk reductions
- ***Too many*** resources considered would lead to longer run times, limiting the number of modeling questions we can investigate

Supply-Side Options: Previous IRPs

The 2016 and 2019 IRPs included the following resources in their portfolio analysis

Fuel Type	Resource	2019 IRP	2016 IRP
Wind	Gorge	x	x
	Montana	x	x
	Ione	x	
	SE Washington	x	
Solar	Solar	x	x
Hybrid	Solar + Storage	x	
Geothermal	Geothermal	x	x
Biomass	Biomass	x	x
Pumped Storage	Pumped Storage	x	
Li-Ion Battery Storage	2-hour	x	
	4-hour	x	
	6-hour	x	
Natural Gas	Combined-cycle (CCCT)	x	x
	Simple-cycle (SCCT)	x	x
	Reciprocating Engines	x	x
	Aeroderivative (LMS100)	x	

Supply-Side Options: Current IRP

In the upcoming IRP, we are currently considering these additional resources to evaluate:

Fuel Type	Resource
Hybrid	Wind + storage
Storage	Vanadium flow batteries
Hydrogen	Solid-oxide fuel cell
	Electrolysis
Renewable	Hydrokinetic (wave or tidal) energy
	Multiple solar locations
Additional	Small modular nuclear
	Waste-to-energy (Municipal solid waste)
	Hydrogen co-fire (at new natural gas facilities)

Supply-Side Options: Current IRP

Fuel Type	Resource
Wind	Multiple Locations
Solar	Multiple Locations
Hybrid	Solar + Storage
	Wind + Storage
Geothermal	Geothermal
Biomass	Biomass
Pumped Storage	Pumped Storage
Battery Storage	Multiple durations
	Vanadium flow batteries
Hydrogen	Solid-oxide fuel cell
	Electrolysis
Natural Gas	Combined-cycle (CCCT)
	Simple-cycle (SCCT)
	Reciprocating Engines
	Aeroderivative (LMS100)
Renewables	Hydrokinetic (wave or tidal) energy
	Waste-to-energy (Municipal solid waste)
Additional	Small modular nuclear
	Hydrogen co-fire (at new natural gas facilities)

Participant feedback:

- Are there any options omitted from this list?
- Are there any options here that shouldn't be?
- Are there any other aspects of this choice we should be considering?
- Please provide any additional feedback by September 9th, 2020 here:

https://www.portlandgeneral.com/forms/pge-stakeholder-feedback

QUESTIONS/ DISCUSSION?

THANK YOU

Contact us at:

IRP@pgn.com

Attachment A: Acronyms

- PCM: Production Cost model
- WECC-wide: Western Interconnection (Today - The generators, transmission lines, and other facilities that comprise the Western Interconnection electrical grid, which is a NERC region)
- WM: WoodMackenzie
- PZM: PGE zone model
- RPS: renewable portfolio standard
- CEC: California Energy Commission
- EIA: Energy Information Administration
- AEO: Annual Energy outlook
- NWPCC: Northwest Power and Conservation Council
- NREL: National Renewable Energy Laboratory
- PNW: Pacific Northwest
- RT: roundtable
- MW: megawatt
- GW: gigawatt
- ELCC: effective load carrying capability
- LOLP: loss of load probability
- DER: distributed energy resources
- SMR: small modular reactor
- LCOE: levelized cost of energy
- ROSE-E, RECAP, and Sequoia: models PGE uses or used for IRP analysis (see Appendix I: 2019 IRP Modeling Details from the 2019 IRP)