PGE CEP & IRP Roundtable 24-4

August 7th 2024

August 7th, 2024 – Agenda

9:00 – 9:05	Welcome | Meeting Logistics
9:05 – 10:05	Brattle Study: Clean Energy Availability
10:05 – 10:55	Capacity Need
10:55 – 11:00	Closing Remarks | Next Steps

Meeting Details

1

Electronic version of presentation

https://portlandgeneral.com/about/who-we-are/resource-planning/combined-cep-and-irp/combined-cep-irp-public-meetings

2

Zoom meeting details

- Join Zoom Meeting https://us06web.zoom.us/j/84391255924?pwd=RDQ2VFpUZERVSEcraU5CZWw3VDhQZz09
- Meeting ID: 843 9125 5924
  Passcode: 108198

3

Participation

- Use the raise hand feature to let us know you have a question
- Unmute with microphone icon or *6 on phones

Meeting Logistics

Focus on Learning & Understanding

- There will be no chat feature during the meeting to streamline taking feedback
- Team members will take clarifying questions during the presentation, substantive questions will be saved for the end (time permitting)
- Attendees are encouraged to ‘raise’ their hand to ask questions

Follow Up

If we don’t have time to cover all questions, we will rely on the CEP/IRP feedback form

Brattle Study: Clean Energy Availability

Chris White, PGE

Market Non-Emitting Generation

The annual Intermediate GHG model in the 2023 CEP/IRP assumed that PGE was able to buy and sell non-emitting generation at times in which PGE was short and long.

- PGE did not apply emissions factors to the market purchases required to balance short hours (and vice versa for market sales). The analysis focused on whether PGE's average annual position under the preferred portfolio was sufficient.
- However, if PGE was not able to access adequate non-emitting generation from the market during hours of need, the emissions resulting from the Company's preferred portfolio could fall outside of the Company's 1.62 mmtCO2e target.

In the analysis provided by PGE in the response to LC80 Round 2 Comments, PGE assumed no market availability for non-emitting energy.

- All market purchases above those allocated by the IGHG model were treated as unspecified and assigned the default emission factor, consistent with current Oregon DEQ GHG reporting requirements.
- However, if PGE were able to access non-emitting generation from the market when it is needed, diversity of regional non-emitting generation could help PGE serve Oregon retail customers with clean energy.

Market Non-Emitting Generation

Solution for 2023 CEP/IRP Update

- Estimates of market availability for clean energy and the corresponding price premium will be provided by The Brattle Group.
- That availability will be modeled as a resource available to augment PGE's aggregate supply.
- The price premium will be used to represent the non-emitting market resource cost such that the model can choose between this non-emitting market resource and other PGE supply to meet load when the non-emitting market resource is available.

Clean Energy Availability in the WECC

AN HOURLY APPROACH TO ESTIMATING WECC-WIDE AND REGIONAL CLEAN ENERGY SURPLUSES AND ASSOCIATED PRICE PREMIUMS

PRESENTED BY

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Oleksandr Kuzura

John Tsoukalis

PRESENTED FOR

PGE IRP Team

PGE

JULY 2024

Brattle

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Background & Motivation

OPUC asked PGE to enhance its IRP GHG emissions modeling

The Oregon Public Utility Commission (OPUC) directed PGE to include an accounting of its forecasted hourly clean energy position and the associated GHG emissions implications in its 2023 CEP/IRP Update

In the LC 80 docket acknowledging PGE's 2023 Integrated Resource Plan (IRP), OPUC Staff expressed concern about PGE's assumptions about their ability to procure non-emitting energy ("clean energy") from the market

- PGE's portfolio was forecasted to be long during shoulder seasons and short during peak hours, matching regional supply trends
- PGE assumed an equivalent market for clean energy throughout the year
- Staff and stakeholders expressed concern about market availability and premium costs associated with buying clean energy
- The OPUC directed PGE to update its modeling to incorporate an hourly analysis of its clean energy position, the additional premium costs of clean energy purchases, and the GHG emissions implications of the former

PGE engaged our team to develop a high-level framework for estimating WECC-wide & regional hourly clean energy surplus and associated potential premium *to use as an input* to ongoing analysis of the projected PGE GHG position in the IRP

An hourly clean energy availability accounting framework

Addressing the OPUC’s request for an hourly accounting of the availability and the cost of purchasing clean energy will involve answering the following questions:

- In each hour, how much clean energy is available after accounting for resources that are committed to other GHG reduction programs for non-PGE entities in the WECC?
- What, if any, is the cost premium associated with procuring surplus clean energy in a given hour? How does that cost premium vary with available supply?

To assist PGE in addressing these questions, we created an Excel-based model to estimate hourly **Clean Energy Surplus** and **Clean Energy Premium** using hourly results from PGE’s IRP scenario simulations in AURORA, and the following key parameters:

- An accounting of resources that are committed to GHG-reduction programs for non-PGE entities
- A curve capturing the relationship between available clean energy surplus and purchase premium
- Limitations on the deliverability of available surplus to PGE

Overview of Clean Energy Surplus & Premium Estimation Framework

Clean energy surplus could help offset PGE GHG emissions…

We define **Clean Energy Surplus** as the clean energy available beyond that which is needed to meet annual state-level clean energy targets

- We allocate annual surplus to calculate the hourly clean energy surplus metric

The main drivers of clean energy surplus are:

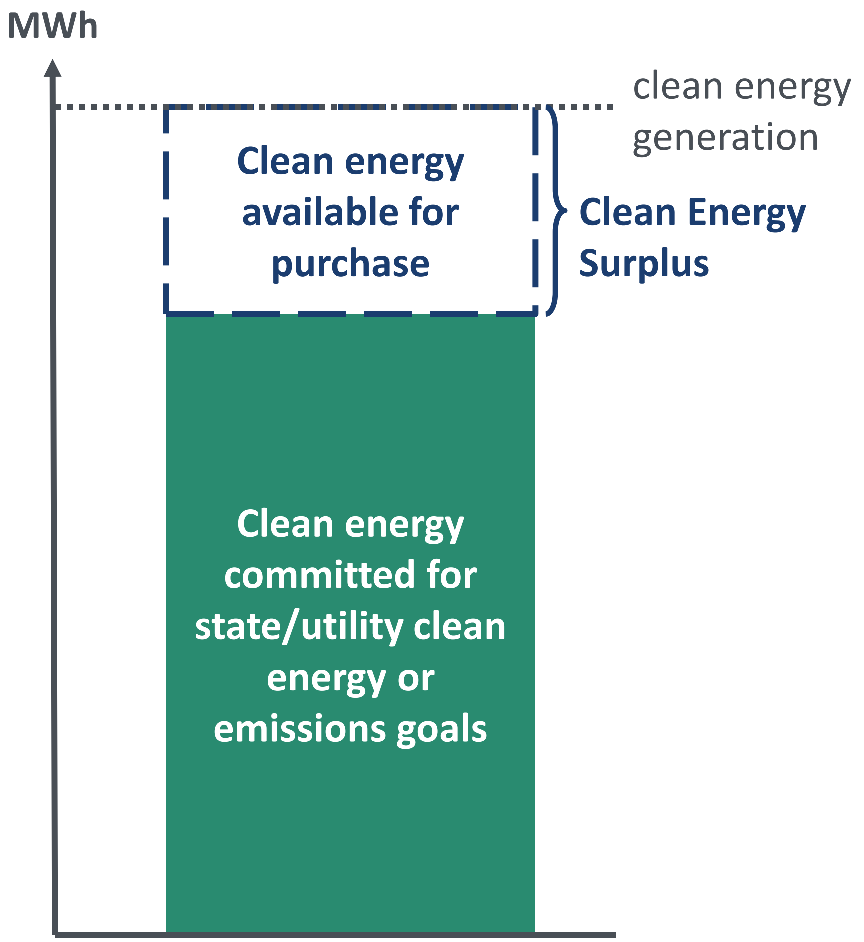
- Availability, e.g., due to regional / seasonal weather patterns affecting supply
- Policy targets (see table) reduce the quantity of surplus clean energy
- Deliverability through the transmission system

Long-Run WECC State Clean Energy Targets

(interpolated in intermediate years)

State	Clean Energy Target
Arizona	15% renewable portfolio standard
California	100% clean energy standard by 2045
Colorado	100% clean energy standard by 2050
New Mexico	100% clean energy standard by 2050
Nevada	100% clean energy standard by 2050
Oregon	100% clean energy standard by 2040
Washington	100% clean energy standard by 2030

Annual WECC Clean Energy Production



…But surplus clean energy may command a premium

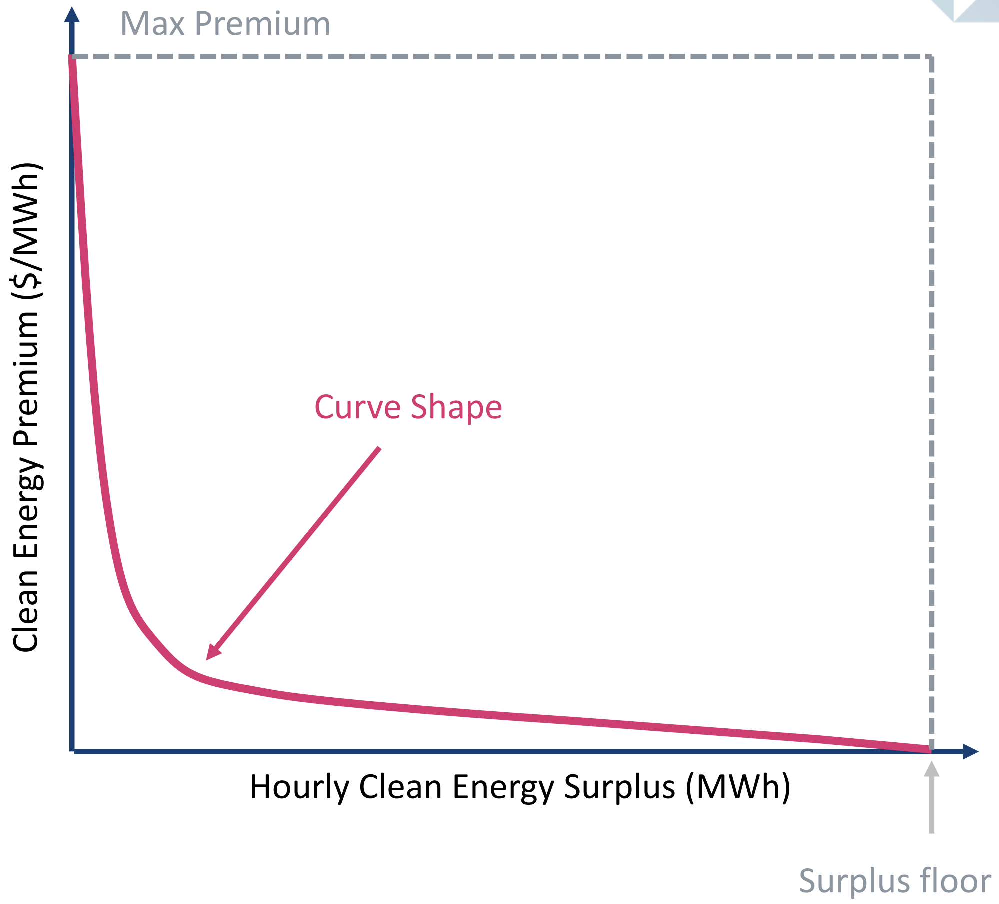
We define **Clean Energy Premium** as the additional cost beyond the energy price associated with the purchase of surplus clean energy

- Captures impact on clean energy value of competition for scarce clean energy to meet targets/goals, such as from corporations or cities with goals
- Calculated on an hourly basis using the clean energy surplus and the clean energy premium curve (CEPC)
- Quantity/value dynamics assumed to mimic those observed in REC markets

We construct the CEPC using the following parameters:

- **Curve shape** reflecting the relationship between clean energy premium and surplus, similar in shape to the relationship between REC quantity and price
- **Max premium** related to the cost of new build wind for PGE and the hourly availability of clean energy from that wind
- **Surplus floor** setting a threshold quantity above which the premium is assumed to be zero, calculated based on AURORA results

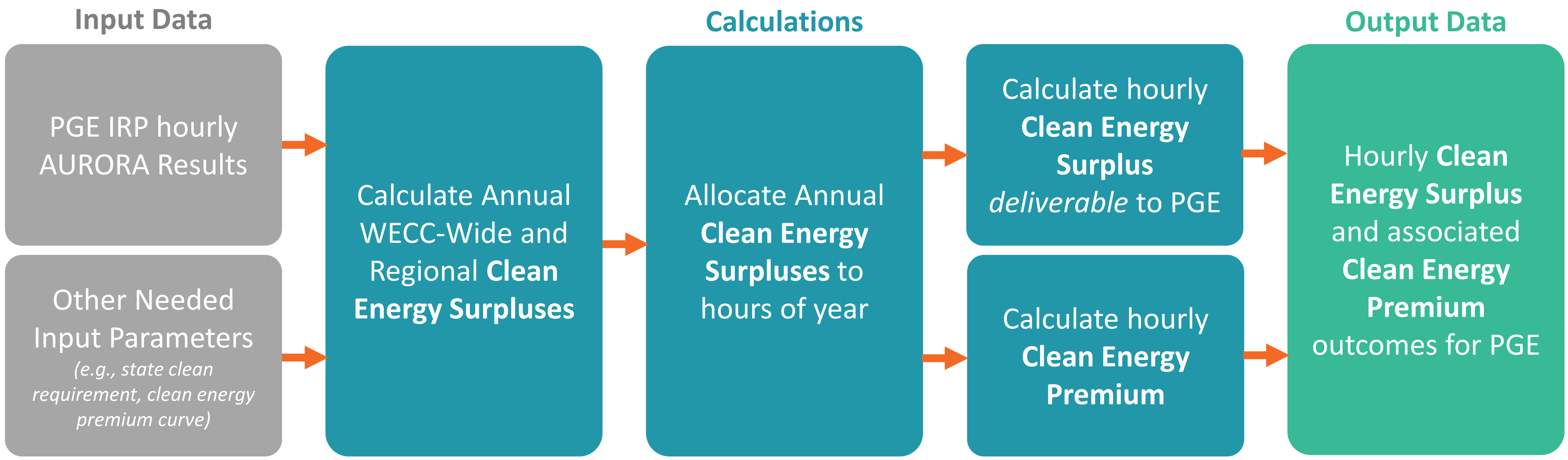
Clean Energy Premium Curve



High-level overview of the estimation framework

We developed a general framework for using PGE IRP AURORA modeling results to calculate **Clean Energy Surplus** and **Clean Energy Premium**, capturing key dynamics:

- Timing of clean resource availability and the demand created by existing state clean energy programs
- Shape of relationship between available clean surplus and the premium it may command
- Limits on the deliverability of surplus to PGE



Clean Energy Surplus Estimation

State Clean/GHG Policy (or lack thereof) relative to clean production is the primary driver of total available clean energy surplus

We find that states in the WECC fall into three broad categories, depending on clean energy production and policy requirements

Long on Clean Energy

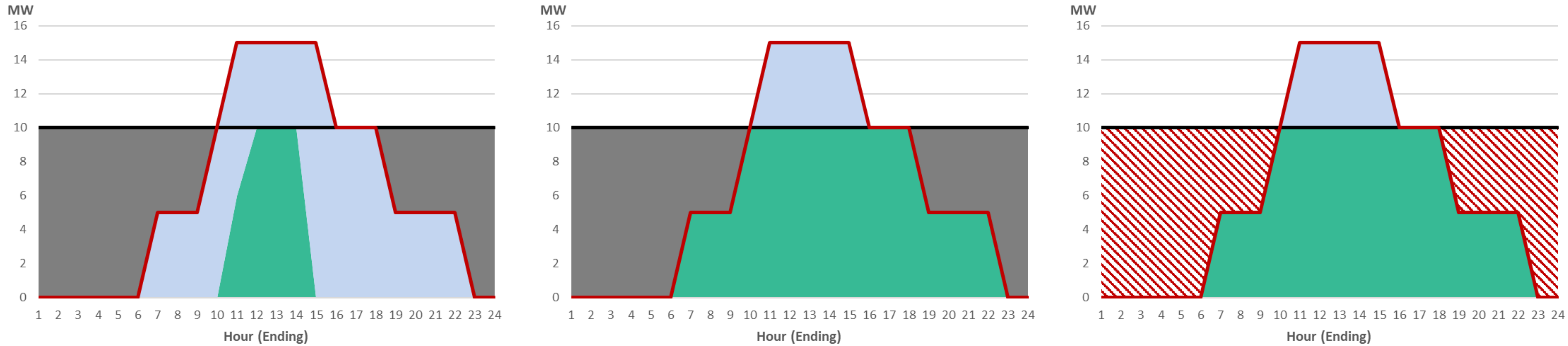
States with high renewable generation and low policy requirements have ample annual surpluses.

Own Production Matches Needs

States whose clean generation matches their policy requirements have surplus only when clean energy exceeds load, and deficits otherwise.

Short on Clean Energy

States short on clean energy on an annual basis or after accounting for periods when clean energy exceeds load reduce the overall regional and WECC-wide surplus.



Clean Energy Surplus calculation steps

1. Read in PGE IRP AURORA hourly results & state-level clean energy requirements
2. Aggregate zonal AURORA results to state-level load and state-level clean generation
3. Calculate state-level *annual* clean energy requirements using simulated annual demand and % requirements
4. Calculate state-level *annual* clean energy surplus or deficit (hourly clean energy in excess of hourly load assumed to be surplus)
5. Allocate state-level annual surpluses/deficits to hours (***details on following slides***)
6. Sum hourly state-level surplus and deficits to calculate regional & WECC-wide values
7. Apply deliverability constraints to calculate surplus deliverable to PGE

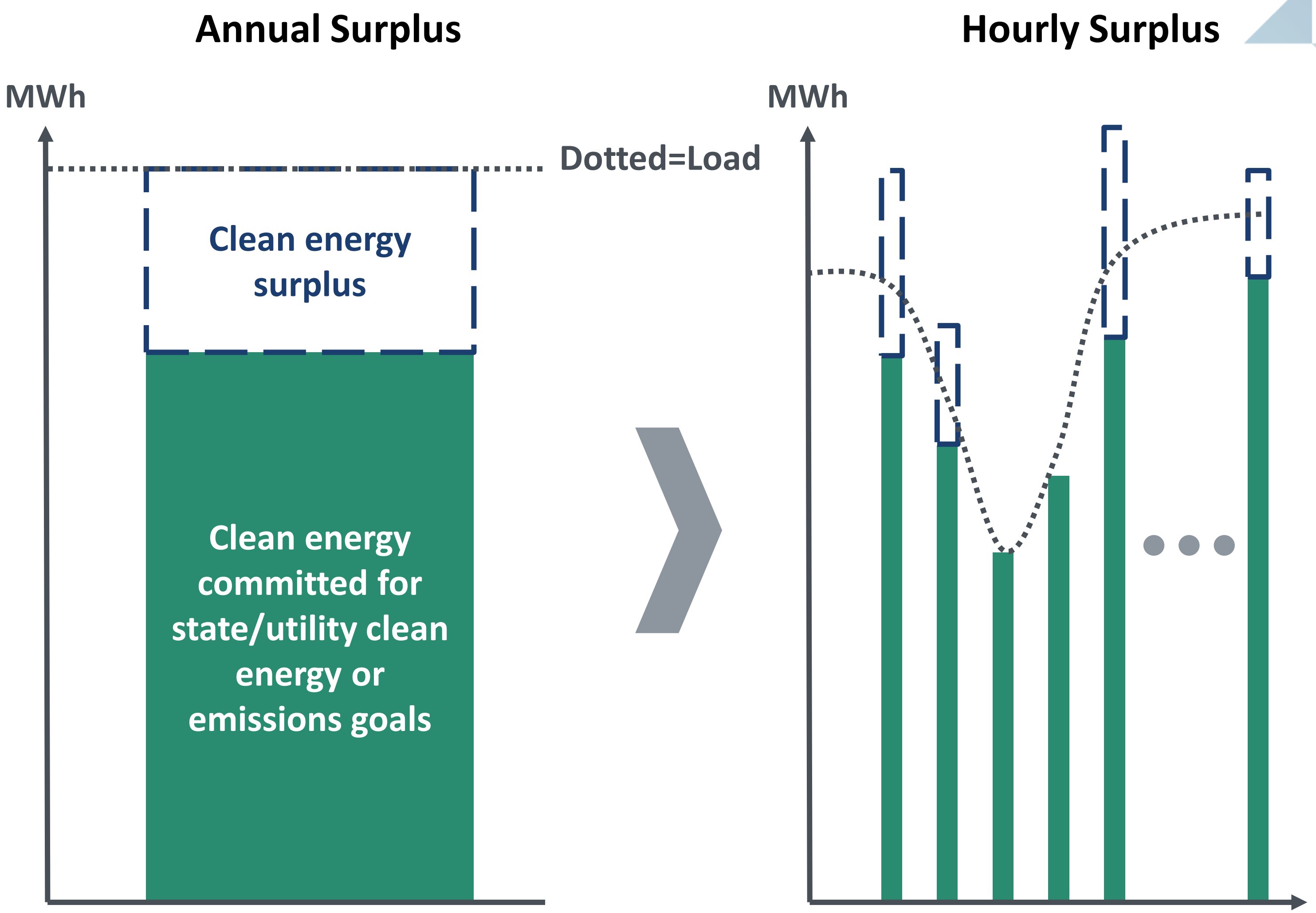
We explored two approaches to allocating annual surpluses to hours

5a **Proportional Allocation**: clean energy needed to meet local requirements allocated to hours in proportion to hourly production

- Surplus correlates to availability of clean energy, concentrating in periods of high production

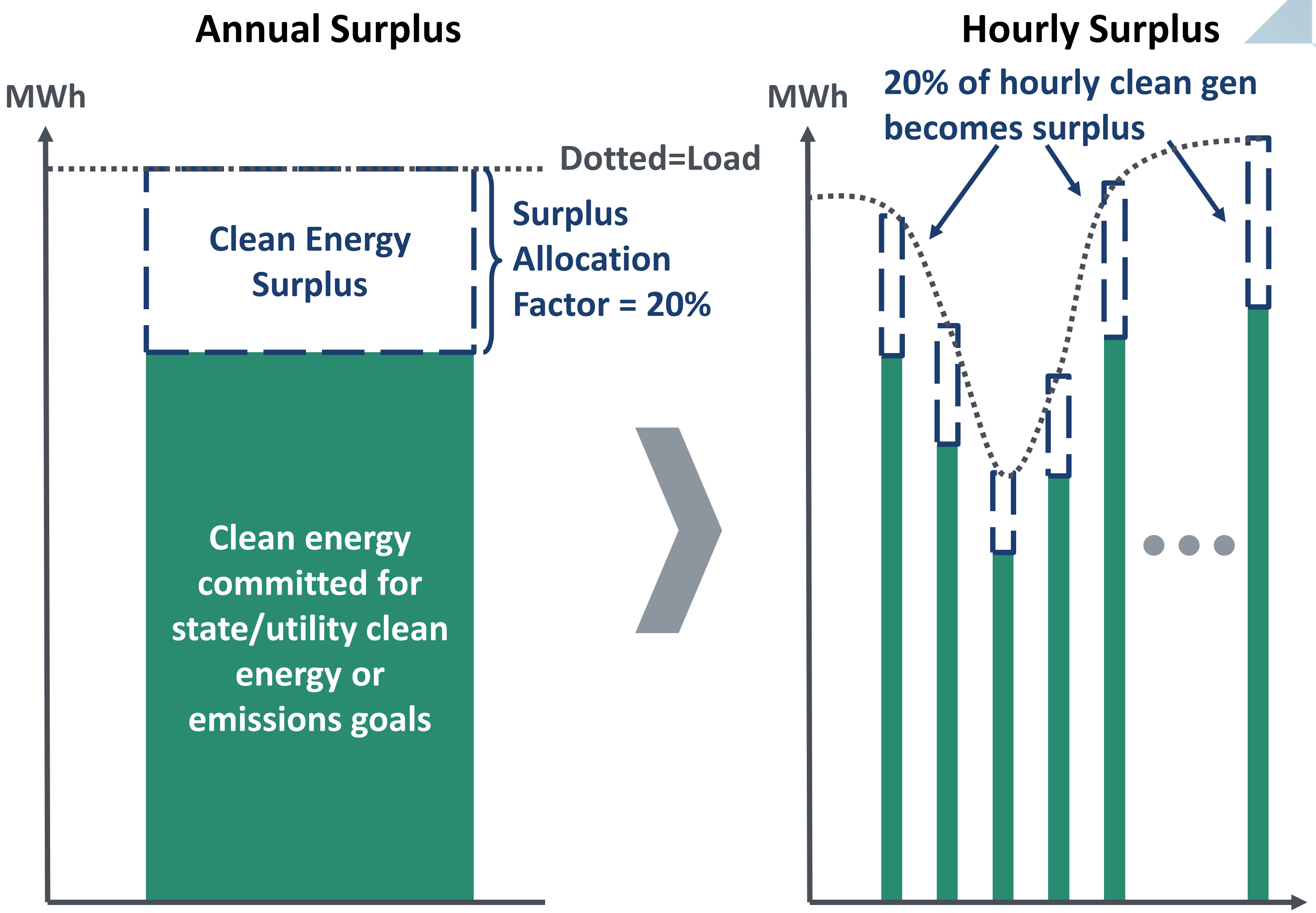
5b **Value-Based Allocation**: clean energy surpluses allocated to hours with highest prices

- Surplus quantities tend to shift away from periods with highest available clean energy (which tend to have lower prices)



5a Proportional clean energy surplus allocation steps

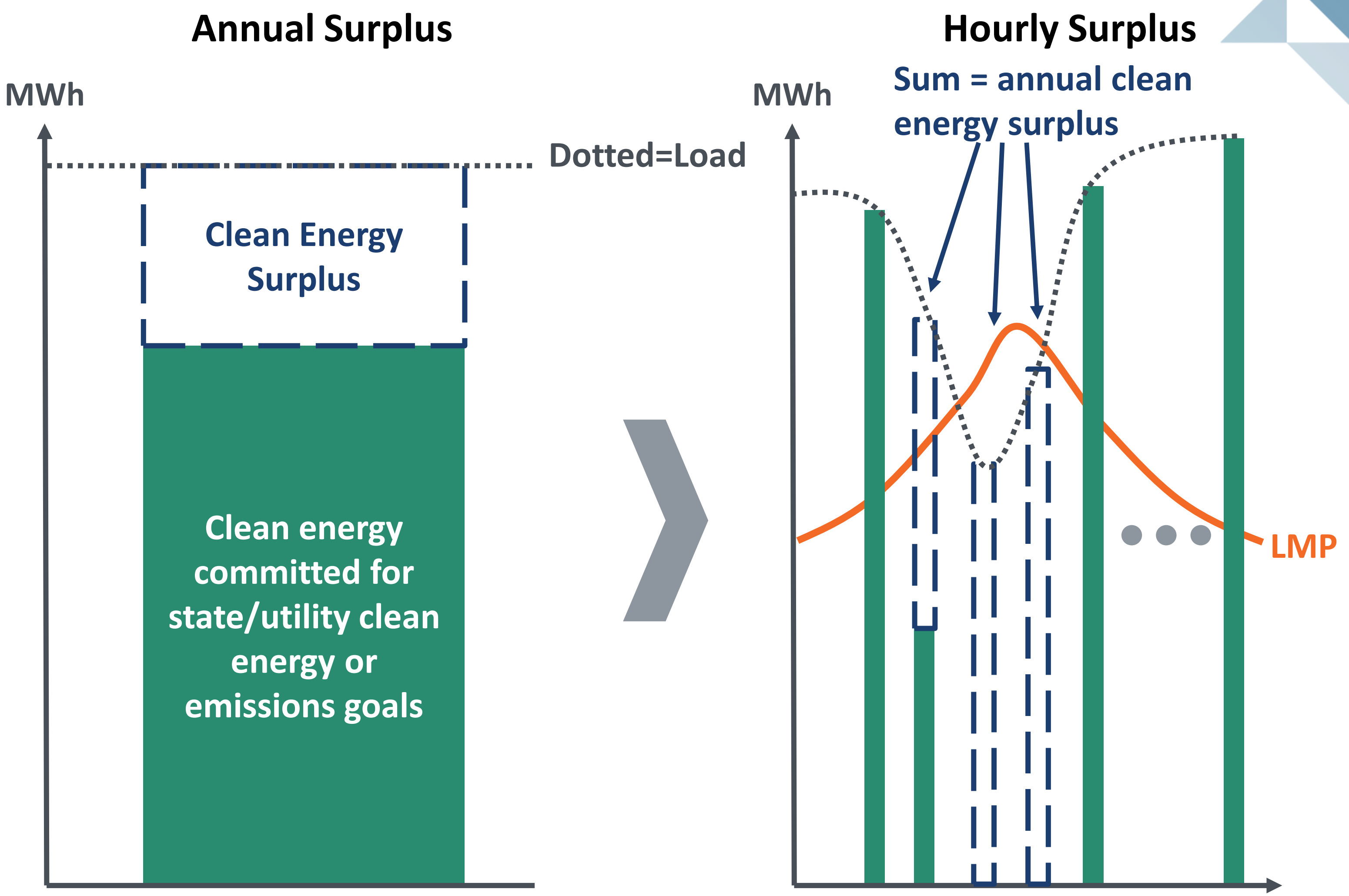
1. Calculate state-level surplus or deficit allocation factor as the annual surplus or deficit divided by the annual requirement
2. For states with net annual surplus, allocate annual surplus to hours by multiplying the hourly clean energy production by the surplus allocation factor (net of clean gen exceeding load)
3. For states with net annual deficit, allocate the annual deficit to hours by multiplying the deficit allocation factor by the difference between hourly load and clean energy



5b Value-based clean energy surplus allocation steps

1. For states with net surplus, starting from highest priced hour with available clean generation, allocate available clean energy to surplus hour-by-hour until the remaining available clean energy is equal to the requirement (final hour may be fractional)

2. For states with net deficit, starting from the lowest priced hour, allocate the difference between load and clean energy as deficit hour-by-hour until no deficit remains (final hour may be fraction)

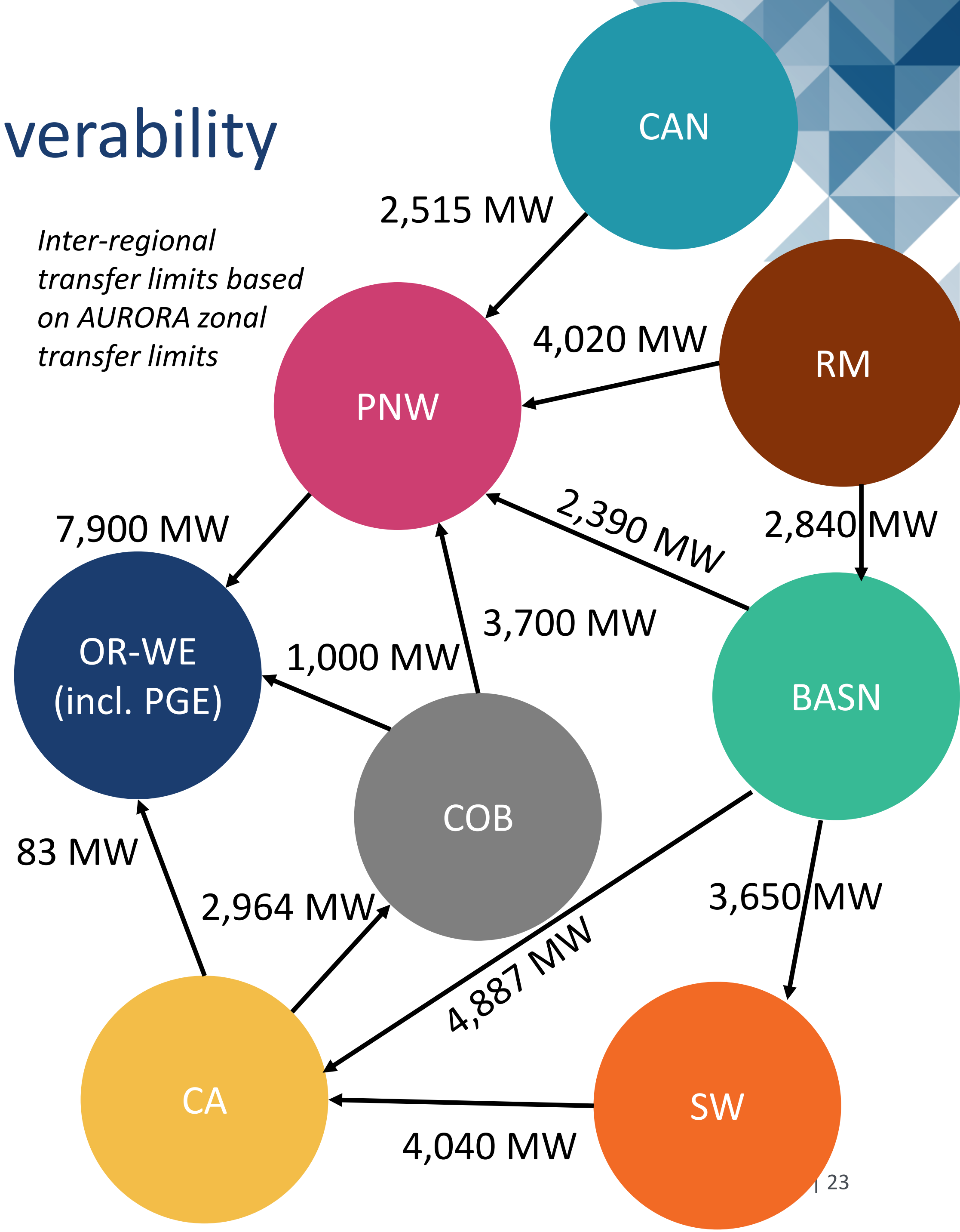


Final available surplus depends by deliverability

Even if ample WECC-wide and regional surplus is available, transmission limits may restrict its deliverability to PGE

We reflect deliverability limits by imposing constraints on hourly surplus accessible to PGE

- Deliverability depends on both inter-regional transfer limits and the simulated direction and amount of inter-regional path utilization
- E.g., PGE may have limited access to surplus in the Southwest (SW) if transfers to California (CA) are already fully utilizing transfer capability on the SW-CA path



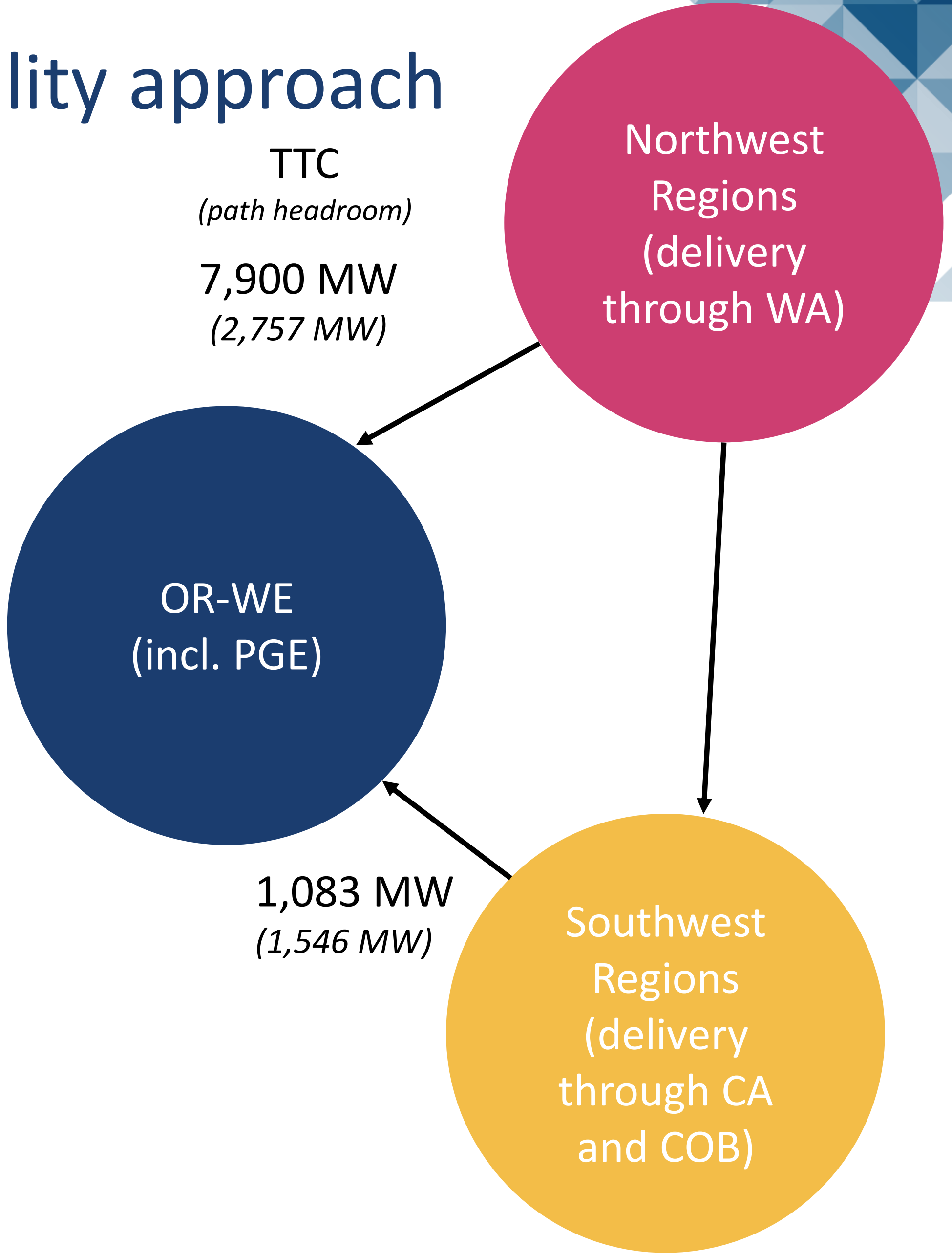
7 We use an aggregated regional deliverability approach

Recognizing the substantial transfer capability between entities in the Northwest and those in the Southwest/CA, we simplify the estimated impacts of deliverability by aggregating the system into three regions

- OR-WE (includes PGE), Northwest Region (NW), the Southwest Region (SW)
  - NW includes the WA, ID, MT, WY, CO, and Canada
  - SW includes CA, AZ, NM, NV, UT

We take a three-step approach to calculating the OR-WE (PGE) deliverable surplus, using AURORA total transfer limit (TTC) & flow data:

1. **Balance regional surpluses/deficits**: Calculate the hourly net surplus available in the NW and SW regions by aggregating the hourly surpluses and deficits from the states that comprise them
2. **Calculate available hourly path headroom:** Calculate the net TTC available on each path into OR-WE and between the SW and NW Regions by subtracting simulate flow from the path TTC in each hour
3. **Adjust net NW and SW surpluses for deliverability into OR-WE**: Calculate the net surplus deliverable to OR-WE from the NW and SW regions that is within headroom, accounting for transfers from the NW to SW region



Clean Energy Premium Estimation

The Clean Energy Premium assigns a value to Clean Energy Surplus

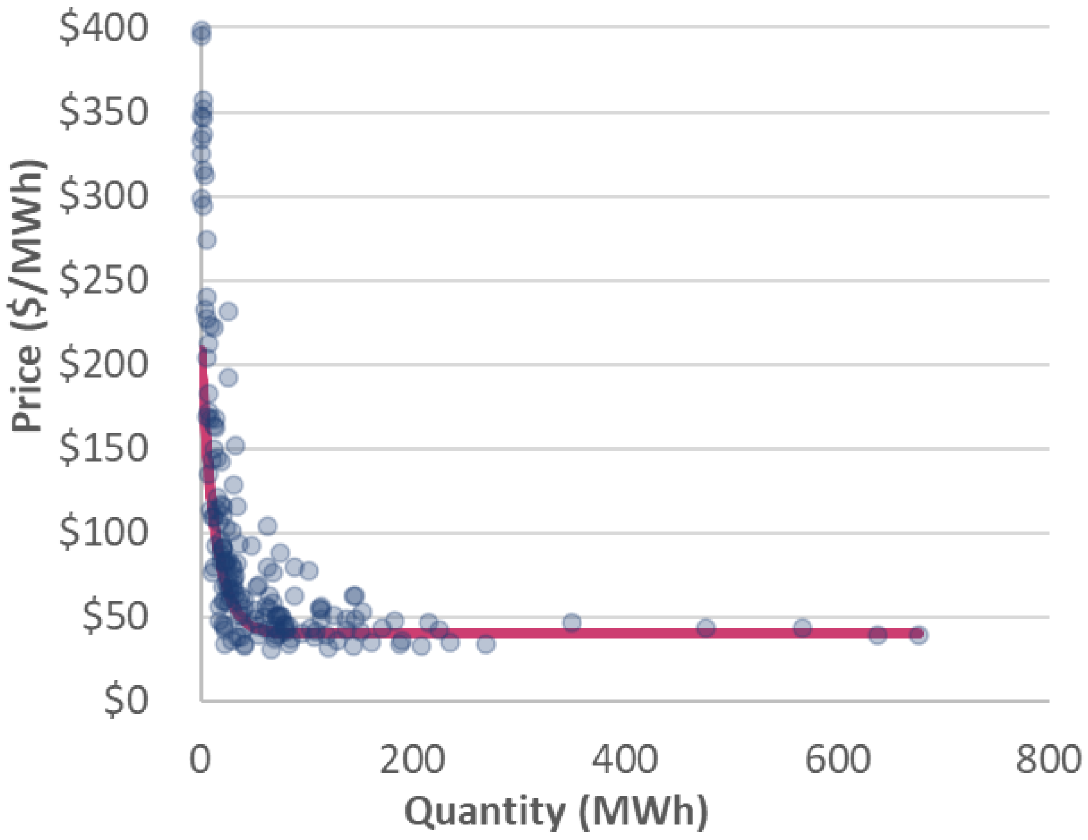
Many entities have mandatory targets or voluntary goals to procure a minimum amount of electricity for their consumption from clean sources, which creates competition for available clean energy and potential value beyond energy value for the "clean attribute"

We assume the demand for clean energy beyond state-mandated targets in the WECC has value dynamics similar to RECs in other markets

- Liquid REC markets reveal for those markets the relationship between REC quantity and value

We us a **Clean Energy Premium Curve** as a "filter" to translate **Clean Energy Surpluses** (in MWh) into **Clean Energy Premiums** (in $/MWh)

Illustrative REC empirical demand curve



Clean energy premium calculation steps

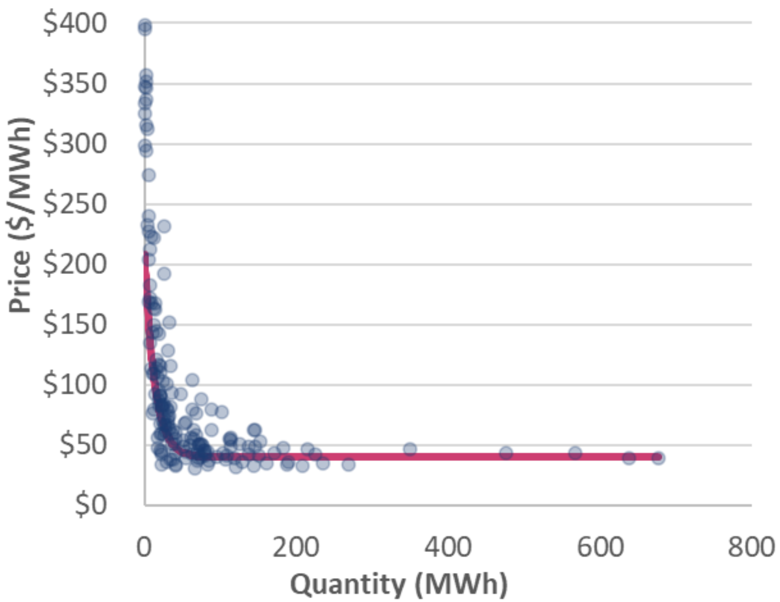
1. Create a WECC-wide Clean Energy Premium Curve for simulation year
2. Apply the WECC-wide Clean Energy Premium Curve to the calculated WECC-wide hourly surplus to calculate hourly Clean Energy Premiums
3. Scale hourly Clean Energy Premiums to capture dependence of value on PGE reference wind shape hourly capacity factor

We use data from REC markets to inform the curve shape

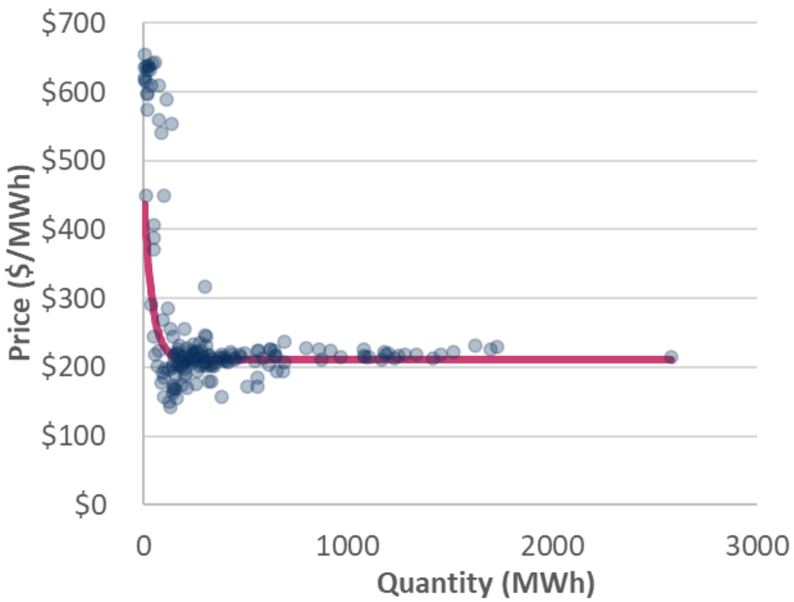
We base the Clean Energy Premium Curve shape on observed outcomes of REC (sREC) auctions

- Broadly capture the relationship between clean energy value and available quantity
- Historical PJM sREC auction results show power or exponential relationship between trade volumes and clearing prices
- We normalize a historical-data-based curve to capture only the shape, iterating as necessary to tune the curve

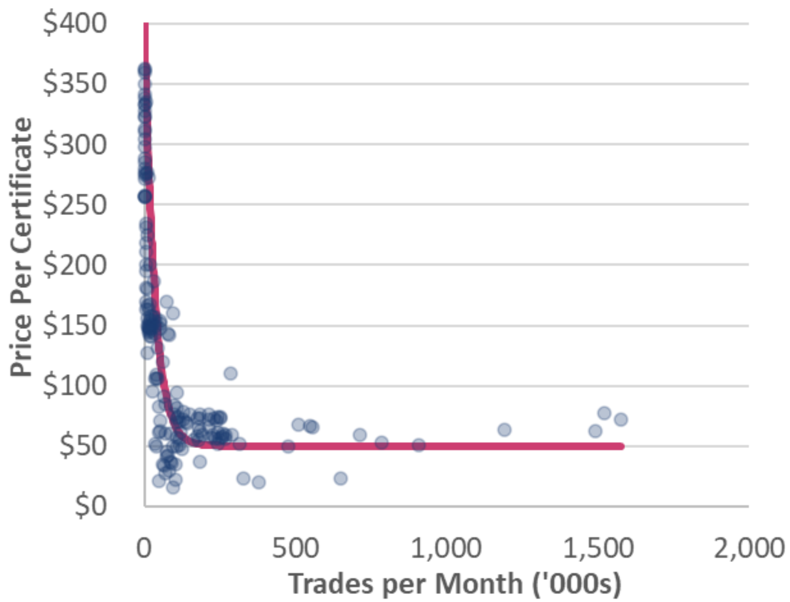
Pennsylvania sREC Auction Outcomes



New Jersey sREC Auction Outcomes



Maryland sREC Auction Outcomes



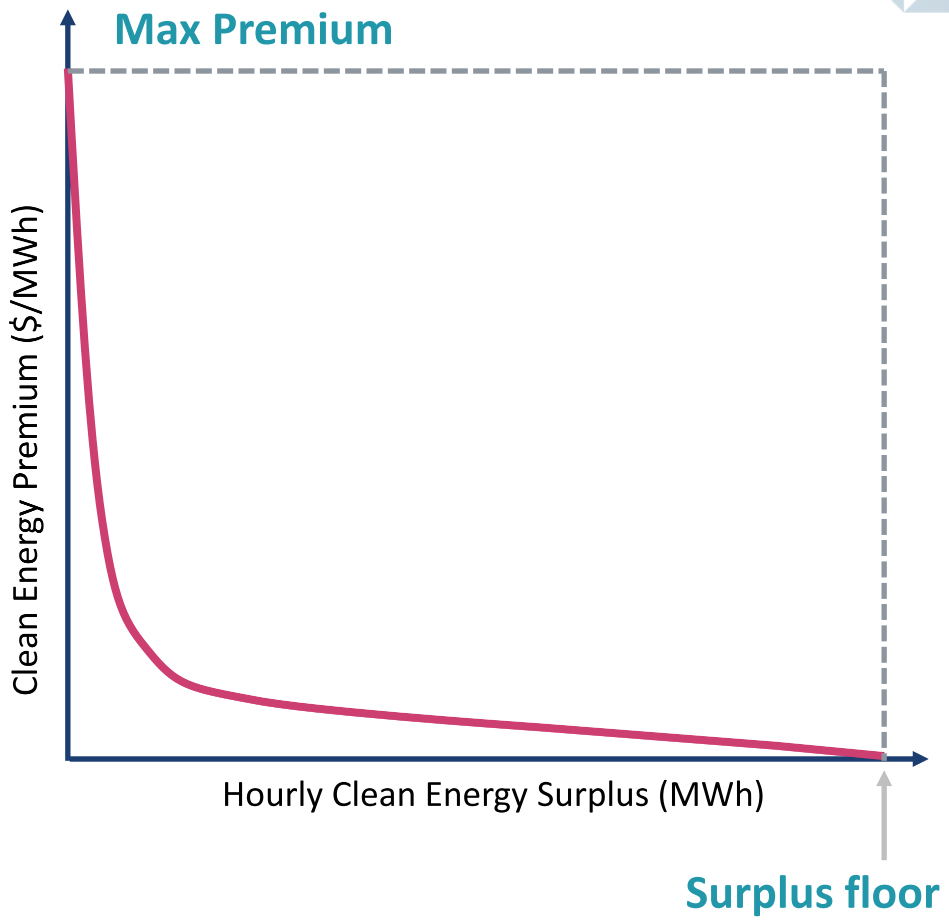
Source: 2010-2024 PJM sREC auction monthly price-quantity data

We scale the general curve shape using system-specific data

To adjust the curve to the specific simulation year and appropriate max premium we rely on PGE resource cost data and AURORA results

- We set **Surplus floor** scalar based on the relationship between hourly WECC-wide prices and premiums from the AURORA results used for the surplus calculation
  - We choose a threshold price, in this study $0/MWh
  - We set the floor at the min surplus observed in the AUORA results for hours with a price below the threshold, based on the intuition that low prices generally indicate surplus levels at which there should be no premium
- We set the **Max premium** scalar based on the cost of PGE new build renewable, the alternative to purchasing surplus clean and thus the ceiling on PGE's "willingness to pay" for surplus clean energy
  - The nominal max premium is set to the levelized cost of energy for a new wind resource (~$10/MWh, including the Production Tax Credit)
    - We apply a scalar of 1.5 to reflect uncertainty/development cost not reflected in the LCOE
  - In each hour we divide the max premium by the capacity factor of a reference wind profile, which captures impact of wind availability on the cost of meeting 1 MWh of clean energy need in a given hour
- See the appendix for a sensitivity study of how these parameters impact the curve shape and resulting clean energy premiums

Clean Energy Premium Curve



Preliminary Results

PGE IRP REFERENCE CASE - YEAR 2030

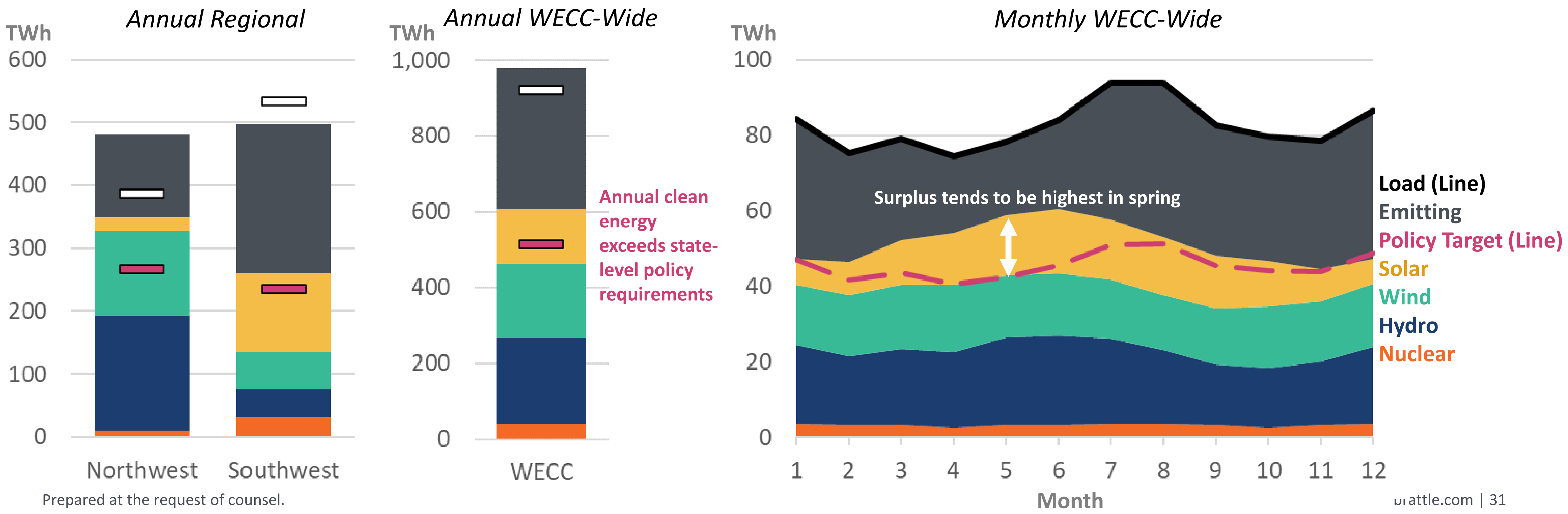
NOTE: RESULTS ARE SPECIFIC TO THE AURORA RESOURCE BUILDOUT USED IN PGE'S IRP MODELING

Overview of PGE IRP Reference Case 2030 gen mix & load

WECC-wide and regional generation mix has high proportion of clean energy, with **overall an annual surplus**

- Northwest has higher surplus than the Southwest despite higher policy requirements due to substantial wind and hydro
- WECC-wide surpluses tend to concentrate in spring months, with relatively low load and high clean energy

Generation Mix, Load, and Policy Requirements

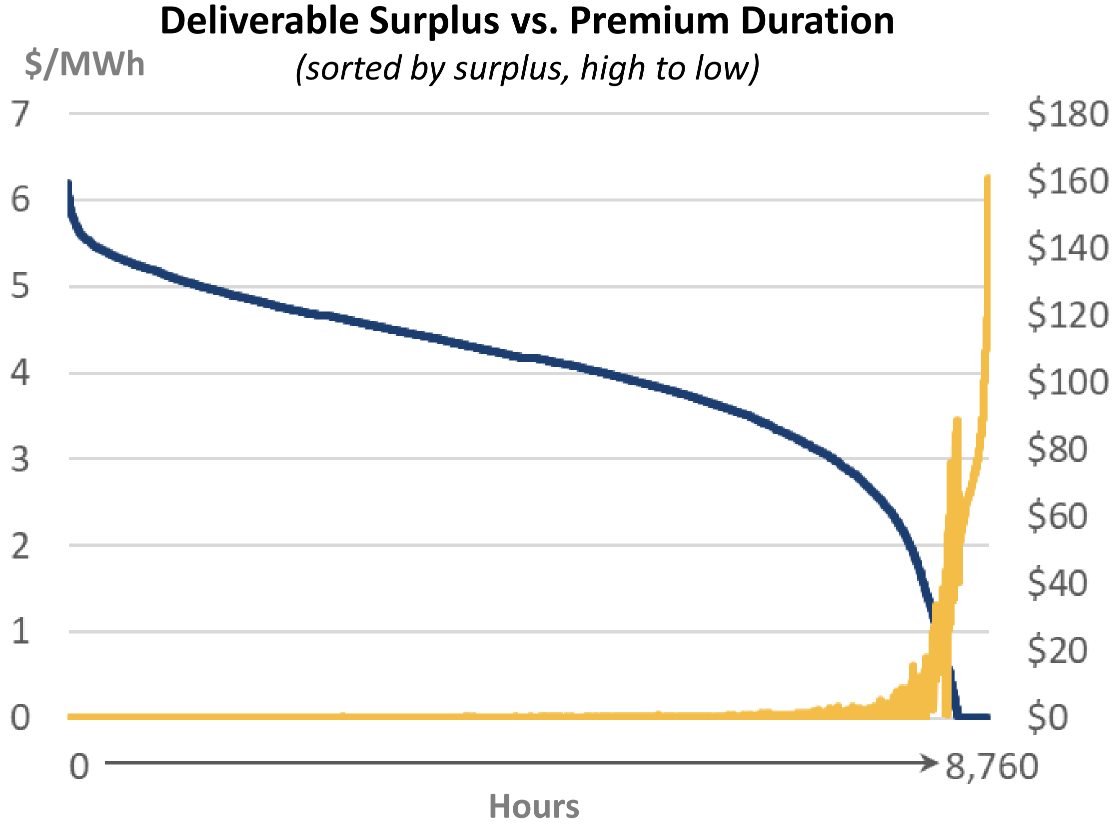


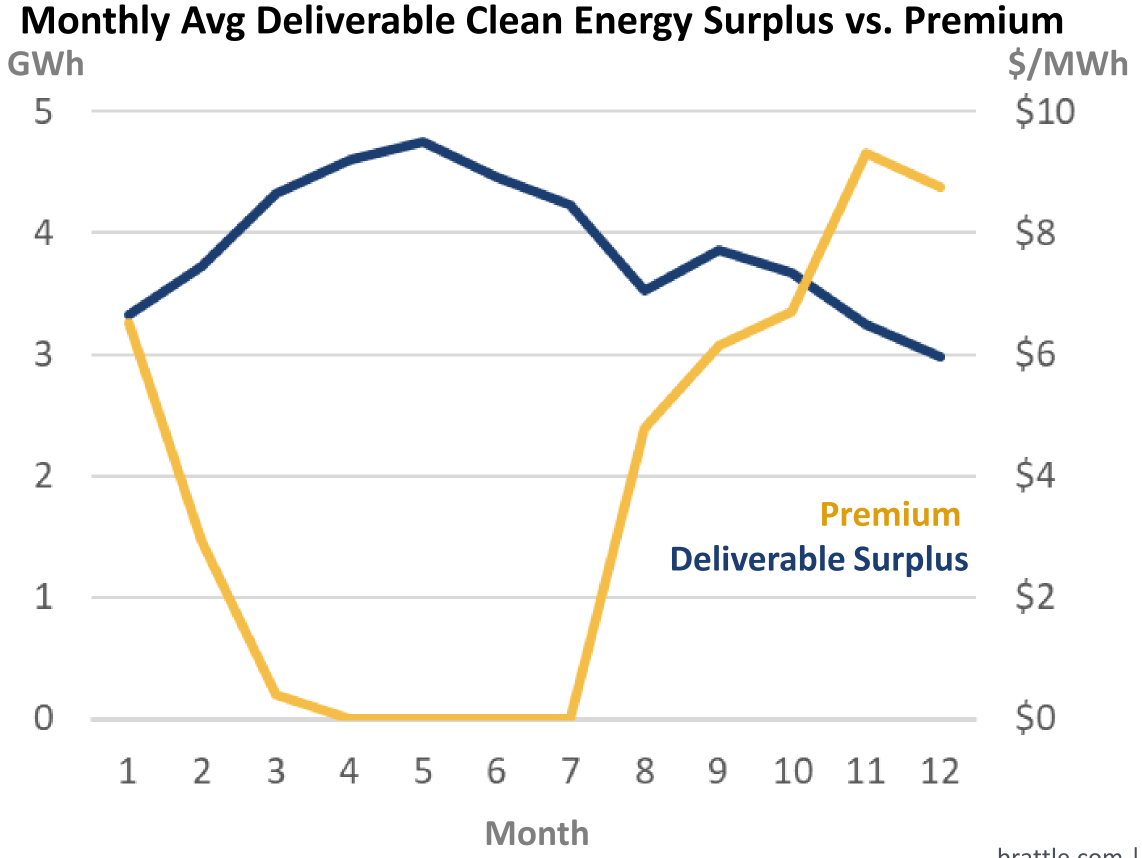
Prepared at the request of counsel.

Deliverable surpluses are highest in spring and early summer

Deliverable surpluses roughly align with clean generation seasonality, premiums follow inverse patterns

- Spring and early summer see highest surpluses and lowest average premiums
- Winter sees lowest surpluses and highest average premiums



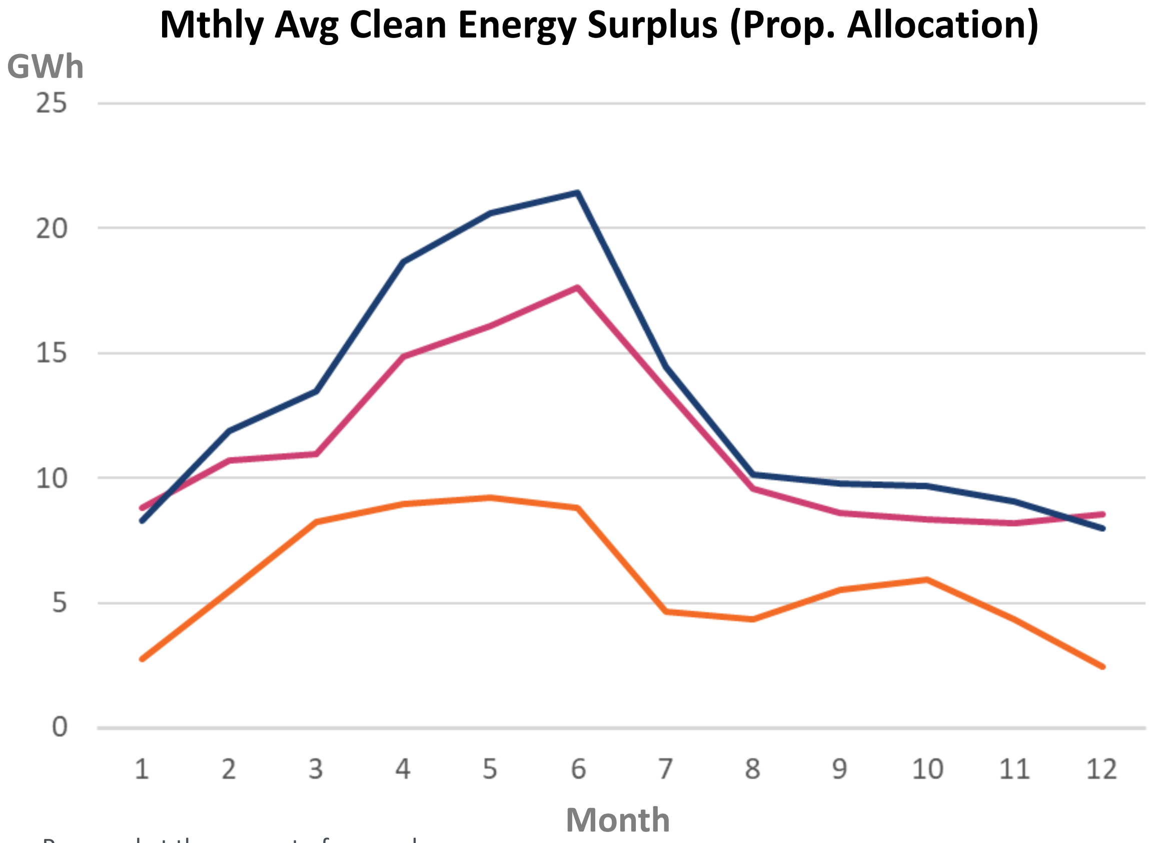


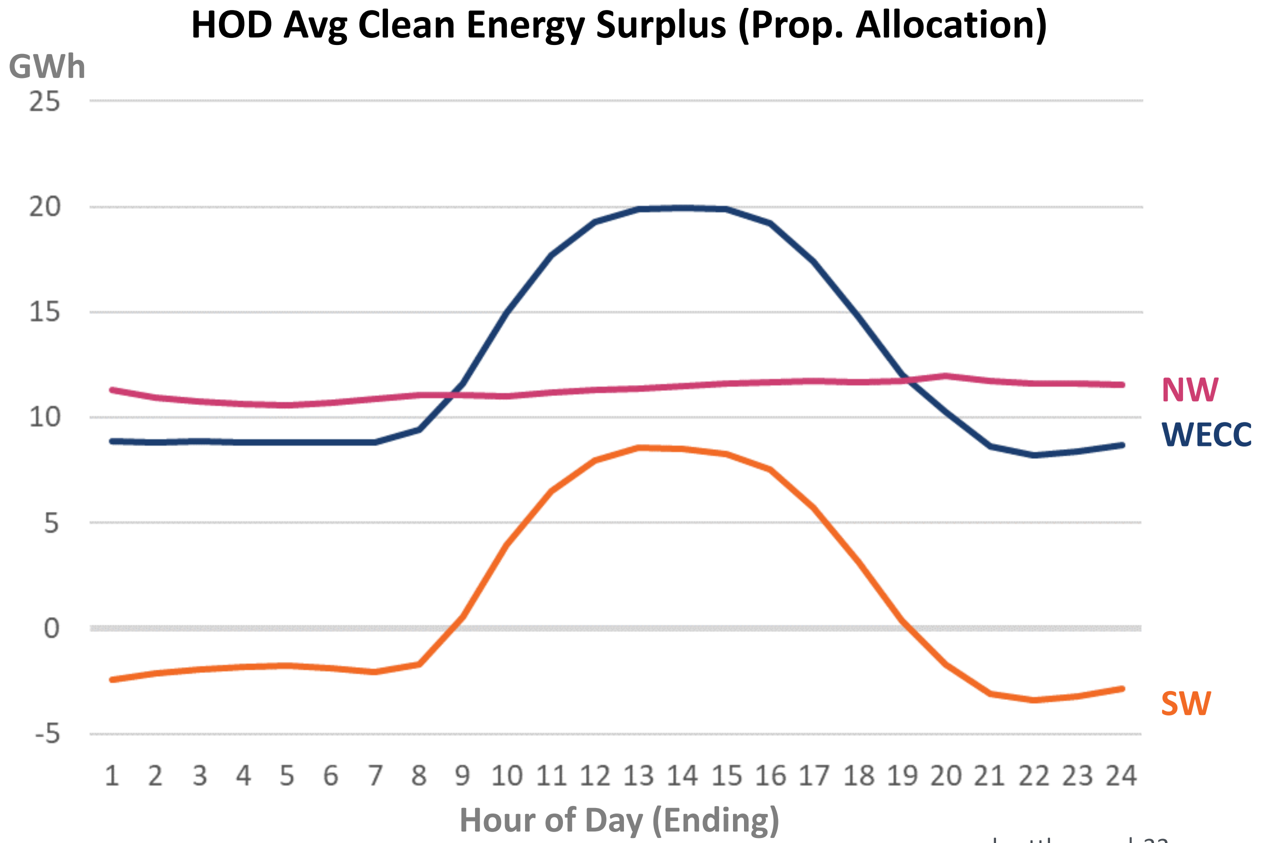
Prepared at the request of counsel.

Annual surpluses highly variable by month and time-of-day

WECC-wide surpluses driven by NW in the spring and SW during the day

- NW surpluses tend to be higher during periods with high hydro
- SW surpluses higher during the hours of the day with high solar





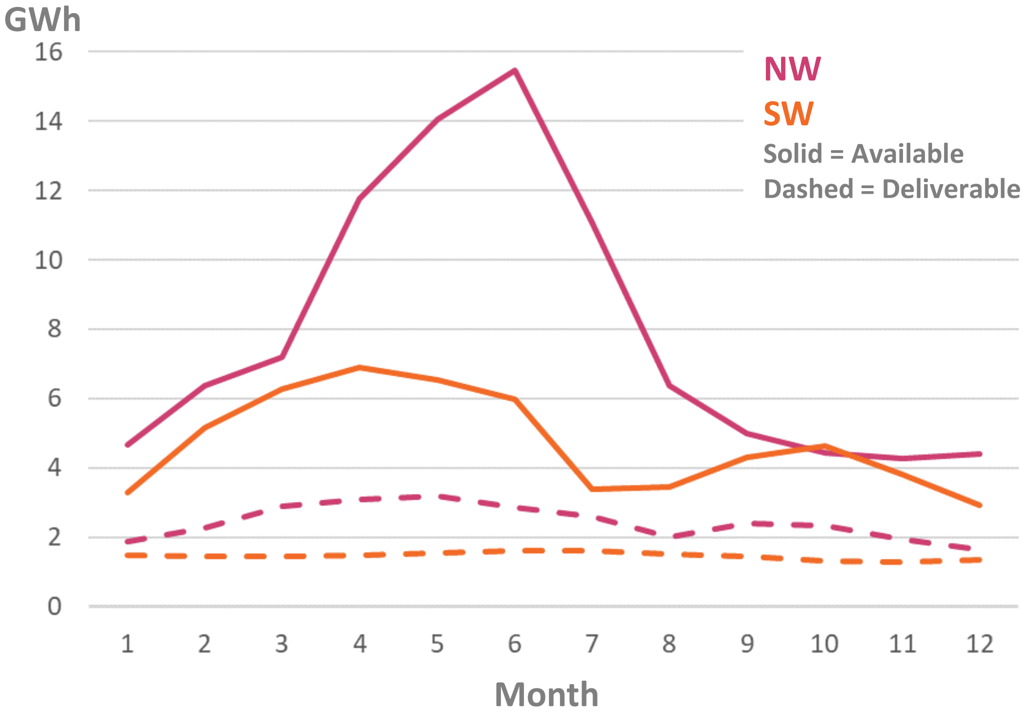
PRELIMINARY RESULTS

Deliverability constraints limit PGEs access to clean surplus

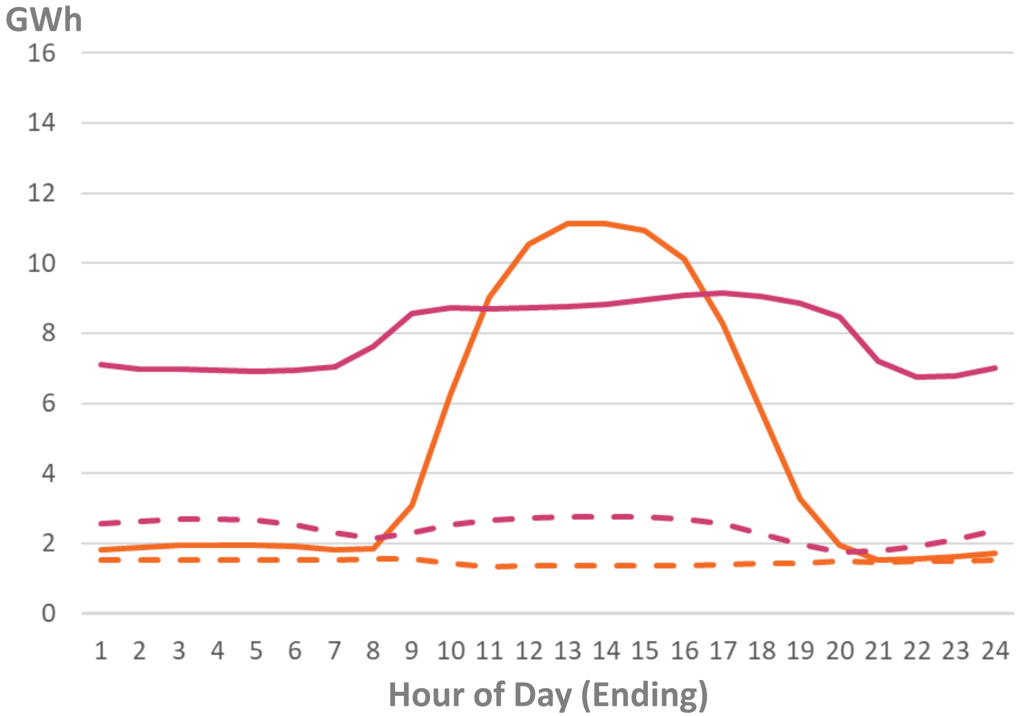
Clean surplus transfers to PGE from both the SW and NW regions limited by deliverability

- Constraints particularly impactful during spring in the NW, and high solar periods in SW
- Approximately 31% of available regional surplus is deliverable to PGE

Mthly Avg Available vs Deliverable Surplus (Prop. Allocation)



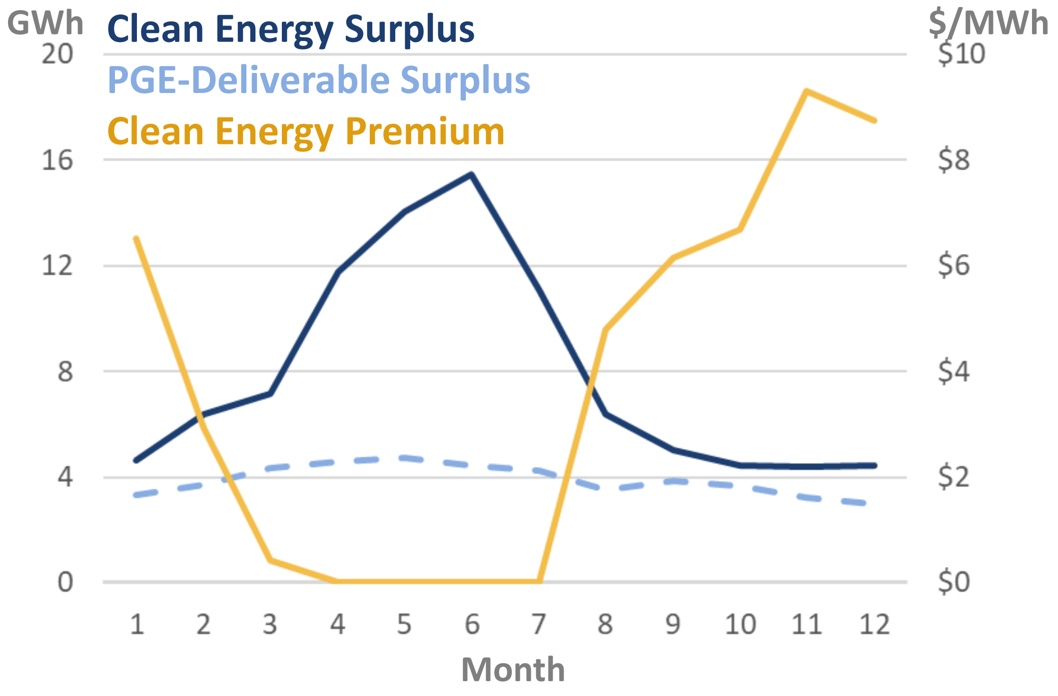
HOD Avg Available vs Deliverable Surplus (Prop. Allocation)



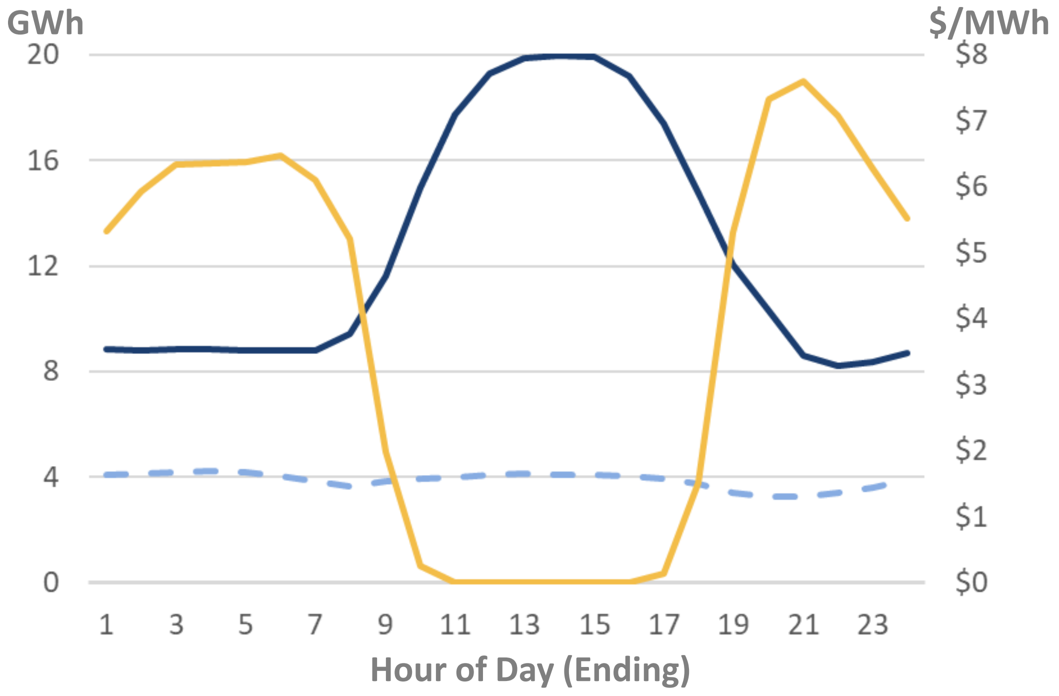
Hourly premiums driven by WECC-wide surplus dynamics

High WECC-wide clean energy surpluses in the spring and middle of day drive down premiums during those periods

Mthly Avg WECC Clean Energy Surplus and Premium



HOD Avg WECC Clean Energy Surplus and Premium



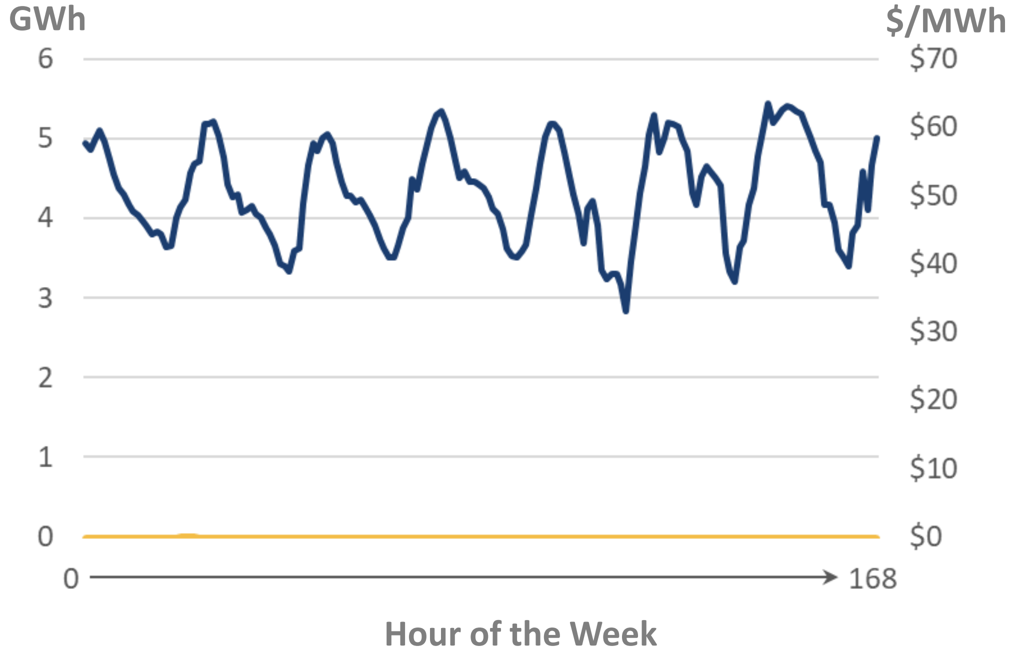
Prepared at the request of counsel.

Representative hourly results illustrate surplus/premium variability

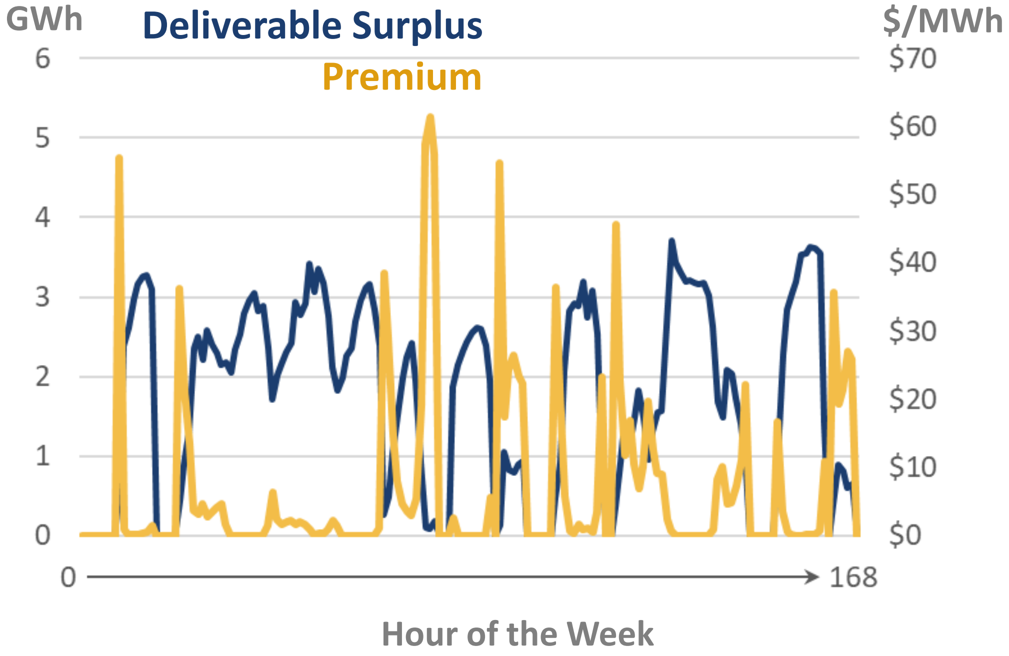
- High surplus periods, such as June, tend to show no premium due to ample surpluses
- Low surplus periods, such as December, show high premiums during low surplus periods, which tend to be highly variable

Hourly PGE-deliverable Clean Energy Surplus and associated Premium

June Week (high surplus month)



December Week (low surplus month)



Conclusions & Next Steps

Takeaways

Conclusions

- We developed a general approach to estimating PGE-deliverable hourly clean energy surplus and associate premium using hourly AURORA simulation results
  - Broadly captures surplus timing and pricing dynamics
  - Provides a starting point for assessing clean energy availability/cost in other PGE IRP analysis of PGE's GHG position
- When applied to IRP Reference Case results for the year 2030, we find:
  - Clean energy surplus tends to be lowest in the winter months and at night
  - Premiums are, on average, ~$5-10/MWh during those periods of low surplus

Next Steps

- Work with IRP team to finalize Excel-based tool implementing methodology described here
  - Tool will allow IRP team to calculate hourly surplus/premium for any AURORA simulation & year

Future Extensions/Refinements (outside of current scope)

- Representation of uncertainty, e.g. in renewable generation, demand, outages, when calculating clean energy surplus/premium via Monte Carlo or other probabilistic methods
- Refine state/utility clean energy and emissions goals modeling, including closer review of RPS/CES/emissions policies and alignment to accounting
- More detailed accounting of resource classification as “clean” resources
- Refine cost basis and shape of clean energy premium curve using more regionally-specific data (pending data availability)
- More detailed accounting of deliverability constraints and potential impacts of surplus premium of transmission charges
- Include simulated storage dispatch as indicator of some time-shifting of clean energy

Appendix

Key simplifying assumptions used in the framework

General assumptions

- Each AURORA zone falls within a single state
  - Zones that are not labeled as belonging to specific states will be mapped based on proximity
- Clean energy surplus reflects availability *after* accounting for clean energy commitments to other states' policy goals
- Clean energy generated outside of PGE is only committed to state-legislated targets, not corporate or voluntary goals (i.e., those goals compete with PGE for clean energy surplus)
- Curtailed clean energy assumed to be undeliverable and thus is not considered part of the WECC-wide surplus
- Same set of resource types considered "clean" for all state RPS programs

Surplus estimation assumptions

- All clean energy policy targets increase linearly by year from 2024 until their mandated achievement year, with trajectories including interim targets
- Hourly clean energy in excess of a BA's hourly load is counted as surplus
  - If this results in an annual deficit relative to policy targets for the BA, then we assume that WECC-wide surpluses in other hours are reduced proportionally to return the BA to annual compliance
- Clean energy in states without policy targets is all counted as surplus
- There are no contributions to meeting annual policy targets from banked clean energy credits
- Surplus deliverability is not meaningfully impacted by sub-zonal transmission constraints
- Sufficient TTC exists between sub-zones of NW and SW deliverability regions to balance surpluses/deficits
- No shifting of surpluses between hours within a day (e.g., by using storage)

Premium estimation assumptions

- Premium price quantity dynamic is similar to that of REC markets
- Maximum premium is representative levelized net cost of new wind build for PGE with hourly adjustments for wind availability
- Minimum premium is zero
- Surplus floor will be related to AURORA surplus quantities and energy prices
- Premium curve is static across the year

Clean Energy Surplus Model Overview

Our Excel-based Clean Energy Surplus Model (CESM) uses AURORA results and other input parameters to help PGE evaluate the hourly availability of surplus clean energy in the WECC and any associated premium for purchasing that clean energy.

CESM Schematic

Excel-Based Model Inputs

AURORA Results (Multiple Years)

- Hourly generation by BA and type
- Hourly zonal load-weighted LMP
- Hourly zonal load

Other Input Parameters

- Generation state mappings
- State RPS requirements
- Utility-state mapping
- Choice of heuristic for allocating annual surpluses to each hour
- Clean energy premium curve

Excel-Based Model

Retrieve AURORA Results

- Process one model year at a time for tractability

Process AURORA Results

- Estimate hourly surplus clean energy available on WECC-wide and regional basis, shaped based on either a “proportional” or “value-driven” approach
- Estimate potential hourly premium associated with the purchase of surplus clean energy

Excel-Based Model Outputs

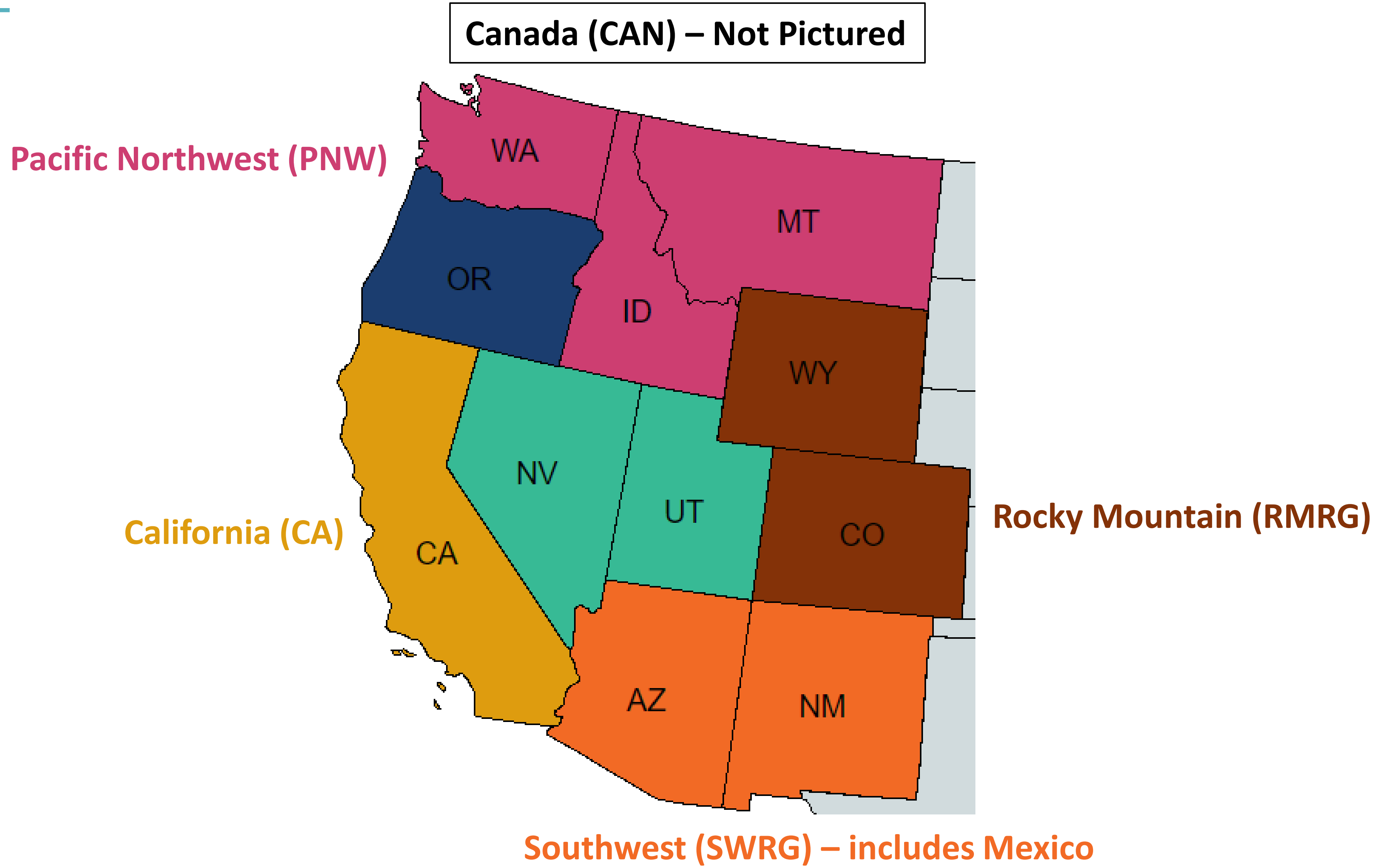
Clean Energy Surplus and Cost

- Hourly WECC-wide clean energy surplus
- Hourly WECC-wide clean energy premiums
- Hourly regional clean energy surpluses
- Hourly regional clean energy premiums
- Aggregated statistics and visuals illustrating the WECC-wide and regional surplus and premium results

CGSM data input sources

CESM Input	Source
Generator state mappings	AURORA input
Generator type mapping	AURORA input
State RPS/CES targets	Brattle team assumption based on public data from LBNL
Mapping of AURORA zones to states	Brattle team assumption
RPS unit type eligibility by program	Brattle team assumption
Transmission capacity from WECC zones to PGE/trading hubs	AURORA input
Hourly flow on transmission paths	AURORA results
Zonal hourly load	AURORA results
Hourly generation by unit	AURORA results
Zonal generator-weighted LMP	AURORA results
Annual market purchase premium floor and ceiling	Brattle team assumption
Clean energy premium curve shape	Brattle team assumption based on REC auction outcomes

WECC regions considered



Prepared at the request of counsel.

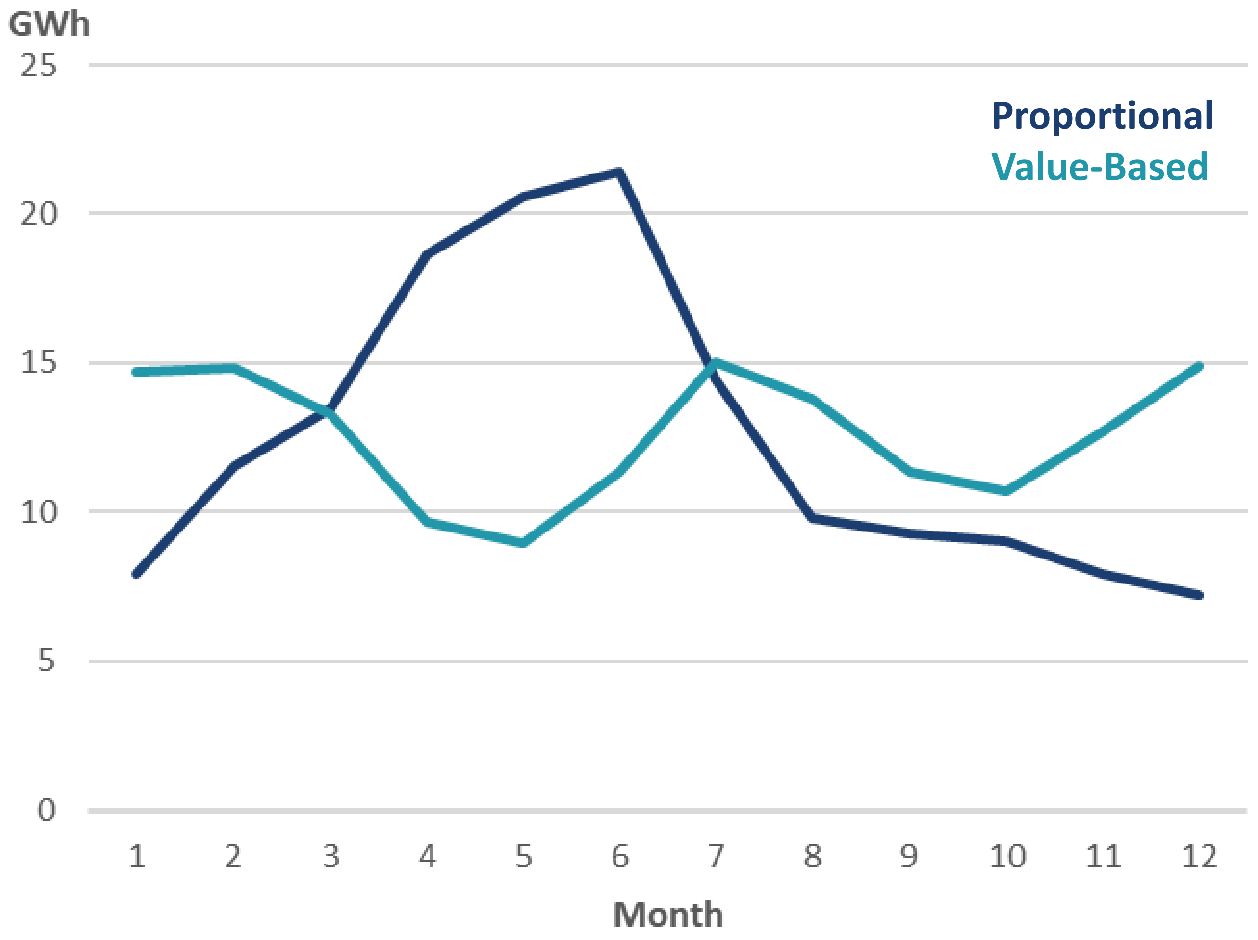
Proportional vs Value-Based allocation

Higher prices in winter relative to the spring cause surpluses to shift accordingly in the value-based allocation compared to the proportional allocation

- This dynamic tends to “flatten” surpluses across the year in the value-based approach

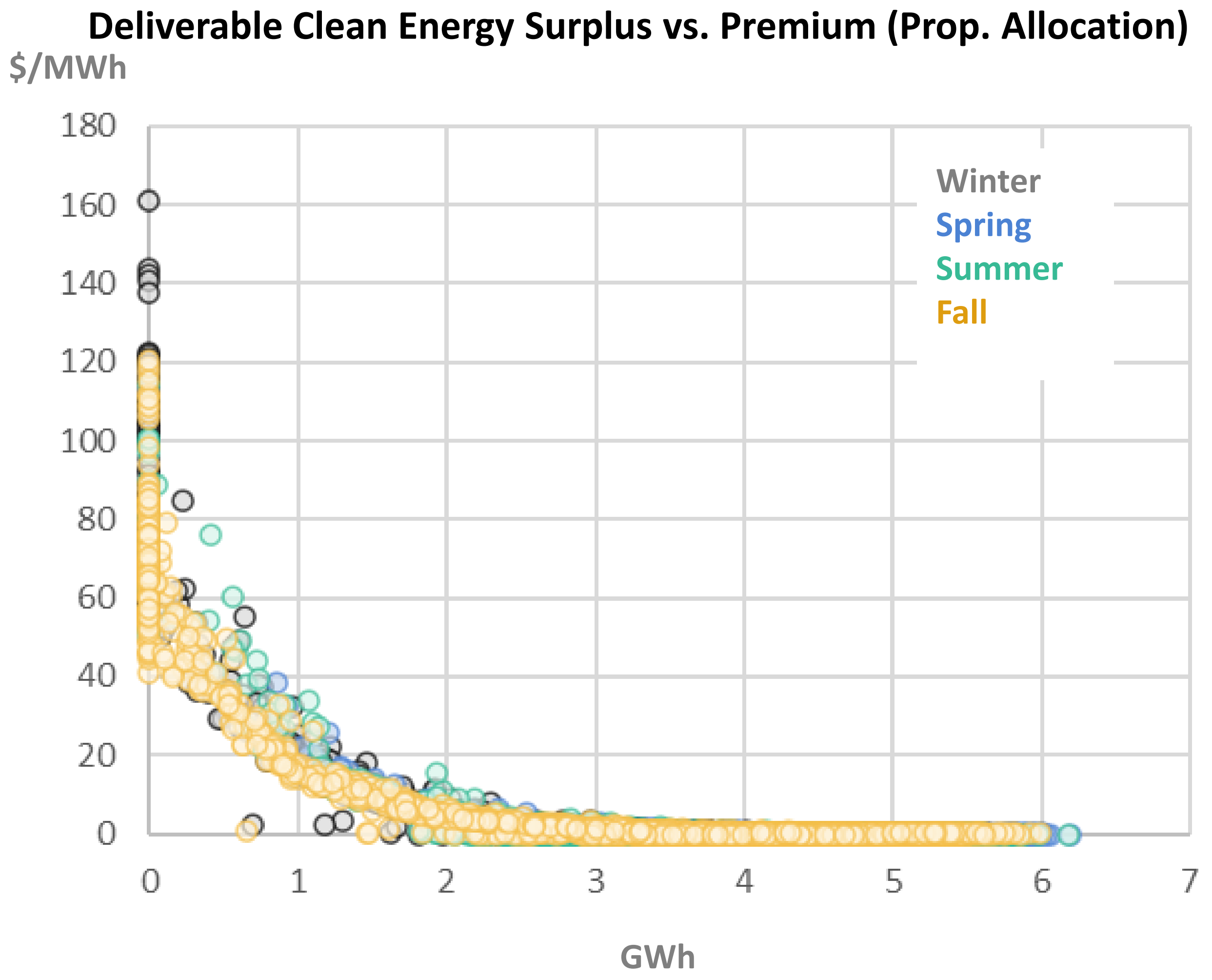
We find that the value-based approach requires further refinement to produce sensible hourly deficit results, and so focus on the proportional allocation as our primary approach for this work

Mthly Avg WECC-wide Clean Energy Surplus, Proportional vs Value-Based



WECC-Wide premiums exhibit some seasonal variation

Premiums highest in the late summer through early winter and lowest in the spring



Example: premium sensitivity to curve shape

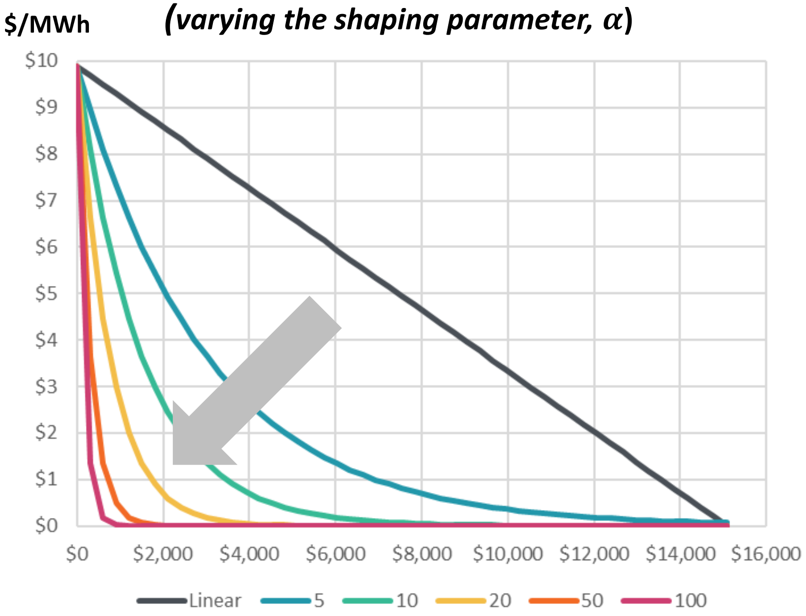
We define the premium curve as $Premium_{SurplusMW} = MaxPremium * e^{-\alpha * \frac{SurplusMW}{SurplusFloor(LMP)}}$

Increasing the curve shaping parameter α makes the premium curve steeper, reducing the premium at a wider range of surpluses

- A linear curve assigns a premium to all surplus levels

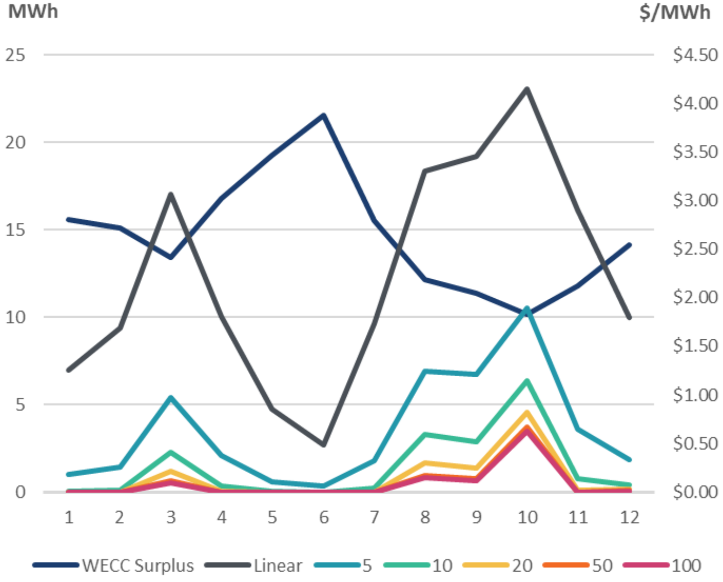
Premium Curves

(varying the shaping parameter, α)



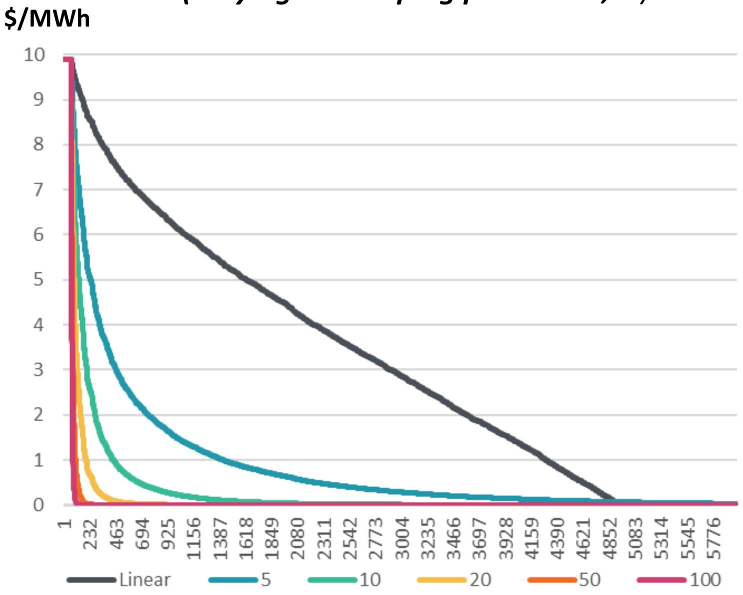
WECC-wide Monthly Avg Surplus/Premium

(varying the shaping parameter, α)



WECC-wide Premium Duration

(varying the shaping parameter, α)



APPENDIX

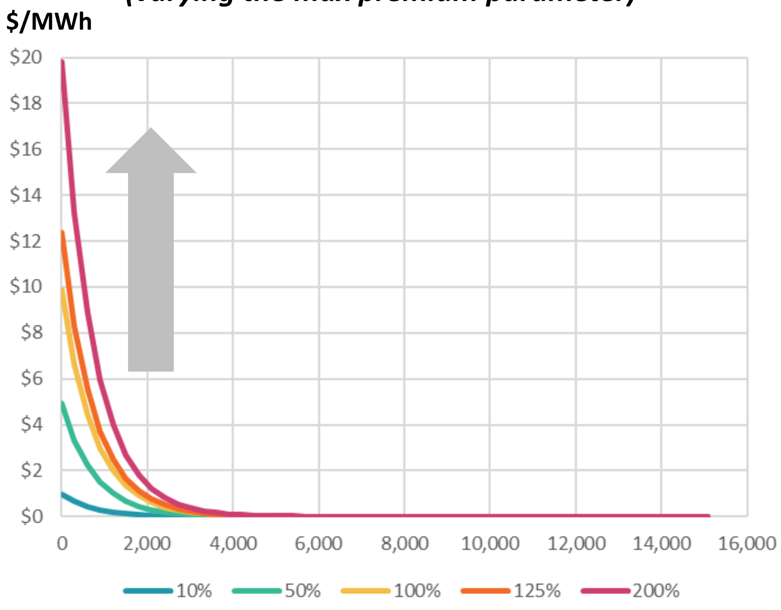
Example: premium sensitivity to max premium

We define the premium curve as $Premium_{SurplusMW} = \mathbf{MaxPremium} * e^{-\alpha * \frac{SurplusMW}{SurplusFloor(LMP)}}$

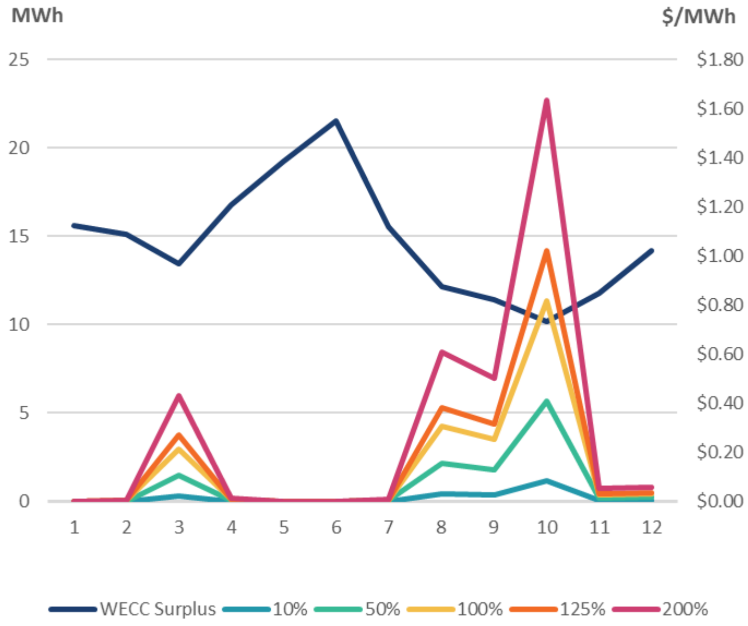
Increasing the max premium linearly increases the clean energy premium in every hour

- Largest effect during hours with a relatively lower surplus

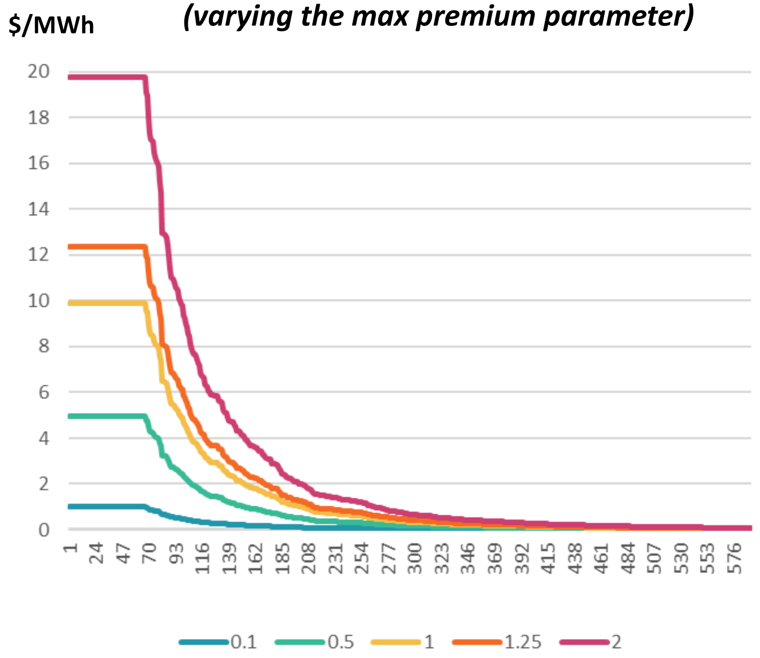
Premium Curves
(varying the max premium parameter)



WECC-wide Monthly Avg Surplus/Premium
(varying the max premium parameter)



WECC-wide Premium Duration
(varying the max premium parameter)



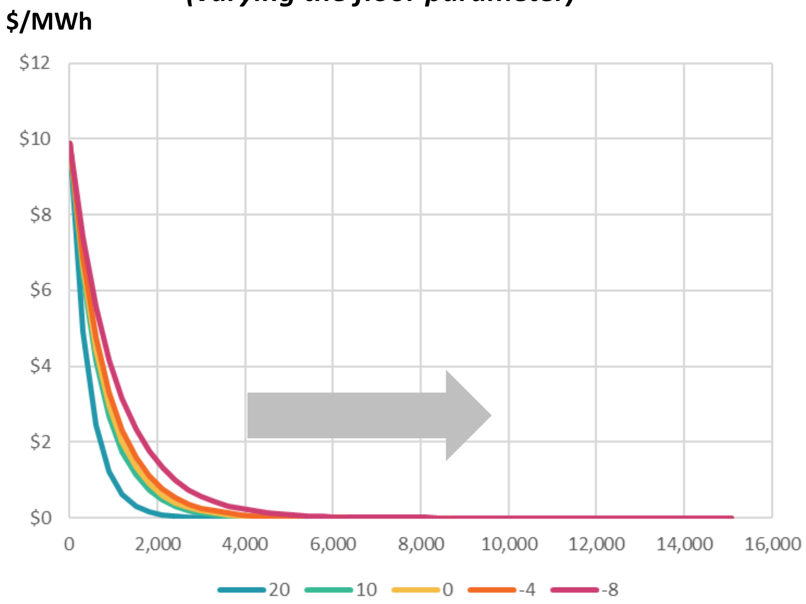
Example: premium sensitivity to surplus floor

We define the premium curve as $Premium_{SurplusMW} = MaxPremium\ * e^{-\alpha * \frac{SurplusMW}{SurplusFloor(LMP)}}$

We define the surplus floor as the minimum surplus among hours with load-weighted average LMPs below a certain threshold

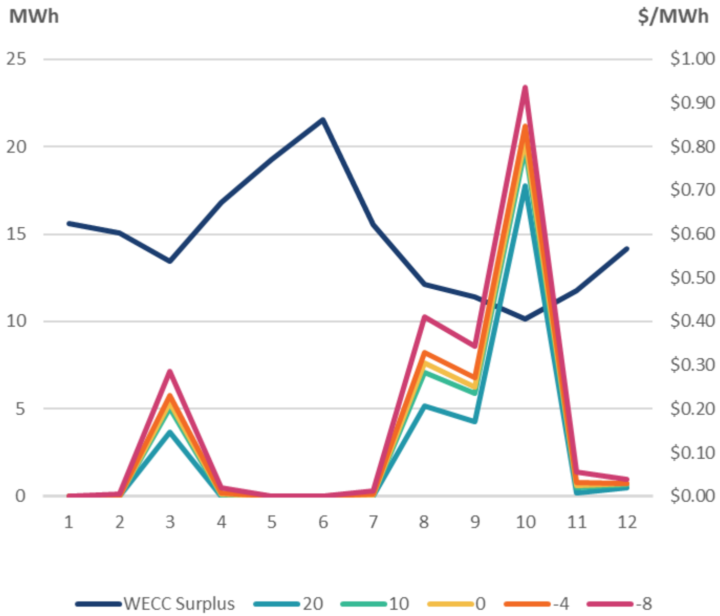
Increasing the foot stretches out the surplus curve and increases clean energy premiums

Premium Curves
(varying the floor parameter)

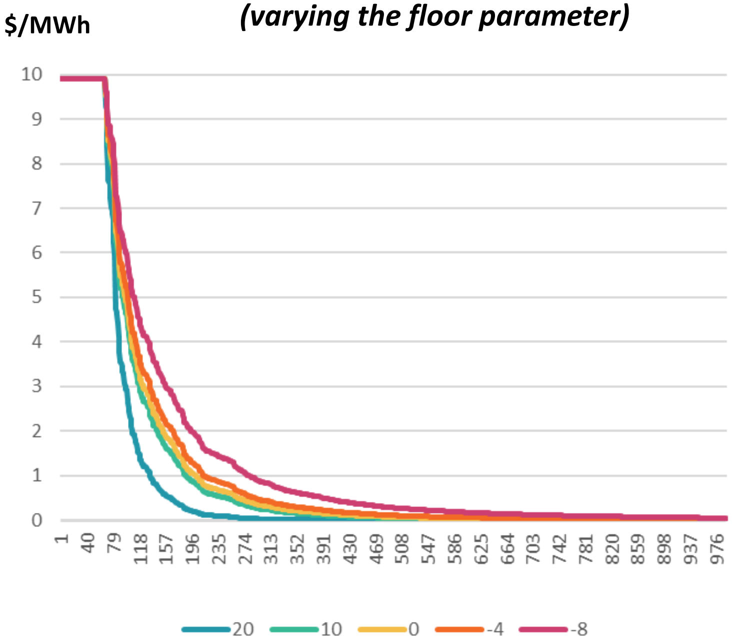


Note: Curve truncated for readability.

WECC-wide Monthly Avg Surplus/Premium
(varying the floor parameter)



WECC-wide Premium Duration
(varying the floor parameter)

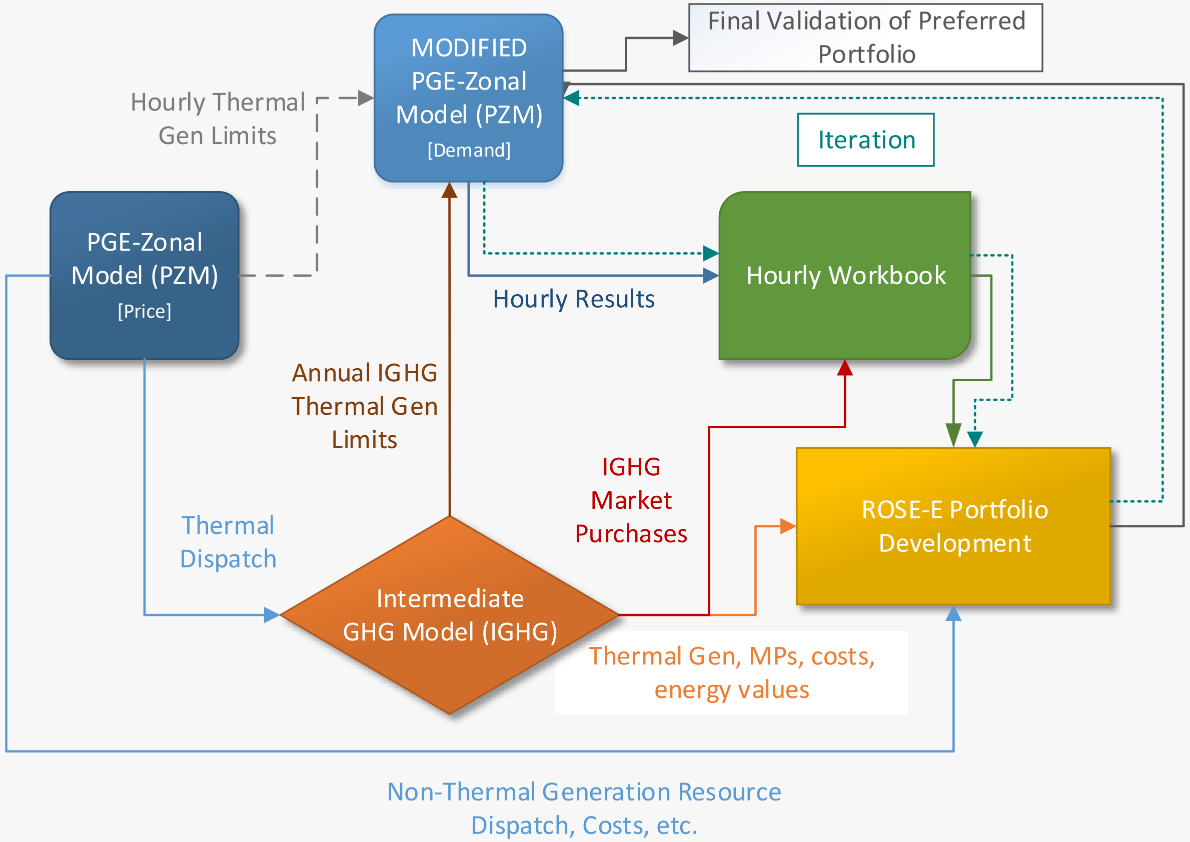


Market Non-Emitting Generation

The Modified PZM will incorporate market non-emitting generation into its dispatch logic and hourly results.

This availability will inform ROSE-E's portfolio selection during hours of need.

The output of the market non-emitting generation will represent the contributions of regional diversity in non-emitting generation to serve Oregon retail customers with clean energy.



Capacity Need

Devin Mounts, PGE

Contents

1. Overview of PGE's resource adequacy model: Sequoia

2. Review of draft updates since 2023 Addendum: 2028 capacity need

- Increased summer need & decreased winter need:
  - 30yr. analysis period
  - Load forecasts
  - QF Assumptions
  - Not yet updated: DER & EE updates

3. Seasonal capacity need: 2025-2035

Sequoia

Sequoia is a stochastic adequacy model. It simulates load and resource combinations to answer two primary questions for long-term planning:

1. How much capacity do we need to keep the system adequate on a planning basis?
2. How much capacity could generation resources provide to the system?

Sequoia was developed following the 2019 IRP to advance modeling of energy-limited resources, such as hydro with storage, battery storage and flexible load[1]

Sequoia targets a seasonal (winter/summer) adequacy level of 24 hours in ten years (2.4 LOLH)

1. See 2019 IRP Update for more information on Sequoia.

Sequoia

Resource Adequacy Modeling

What:

- Stochastic simulation (Monte Carlo)
- Weekly dispatch (Constrained Optimization)

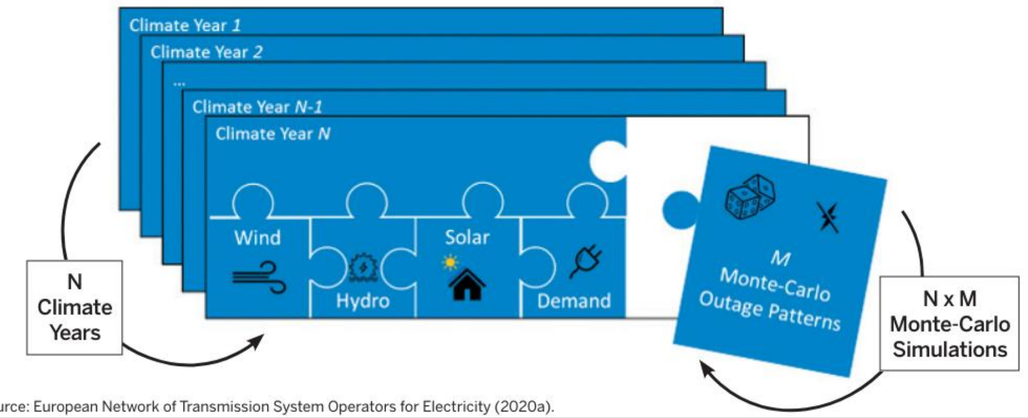
How:

- Generally 50,000 weeks in a simulation
- Hourly supply/demand
  - Daily randomness from "weather" variability

Objective:

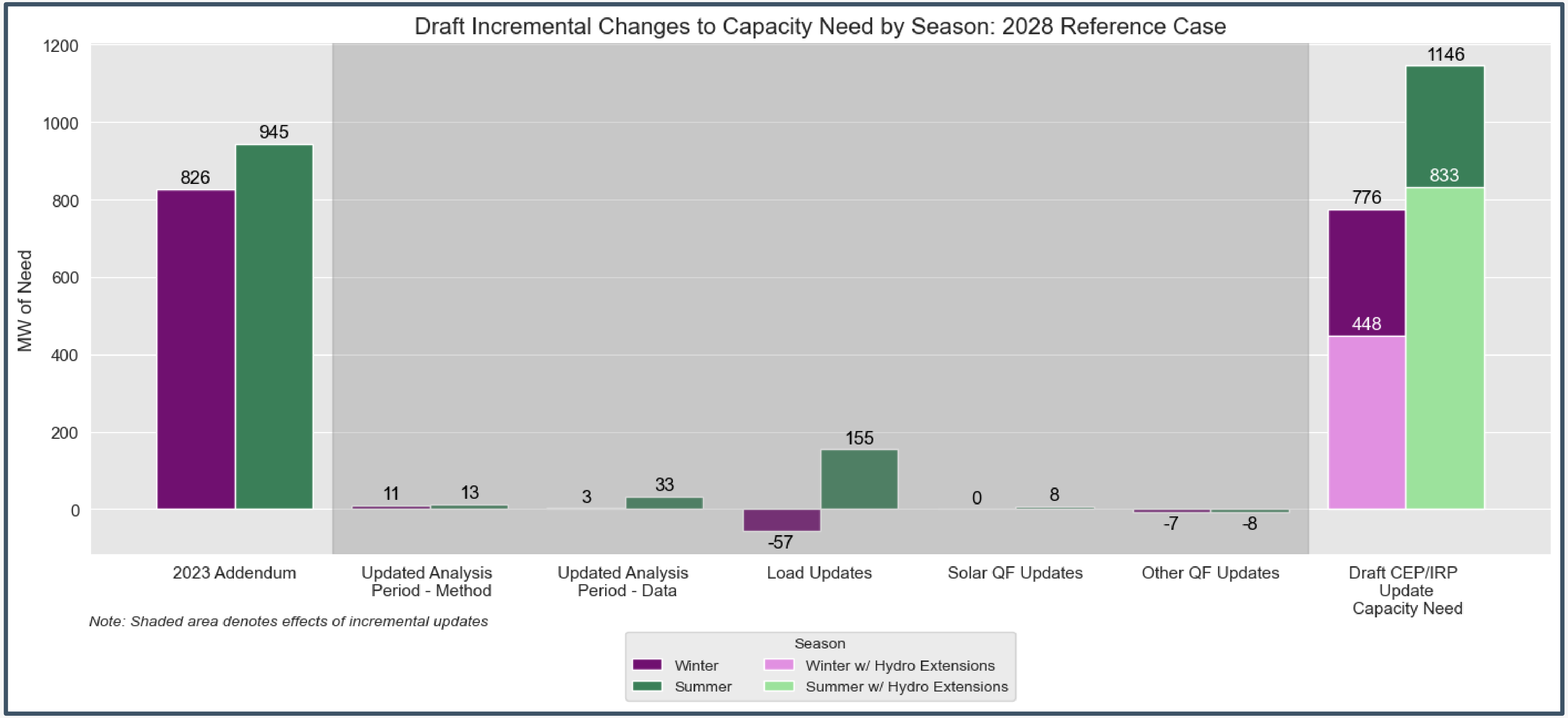
- Minimize greatest capacity shortfall (hour of max unserved energy)
- Minimize hourly average of unserved energy (weekly mean of unserved energy)

ENSTO-E Example of Monte Carlo Simulation Principles



Source: European Network of Transmission System Operators for Electricity (2020a).

Draft 2028 Updated Capacity Need



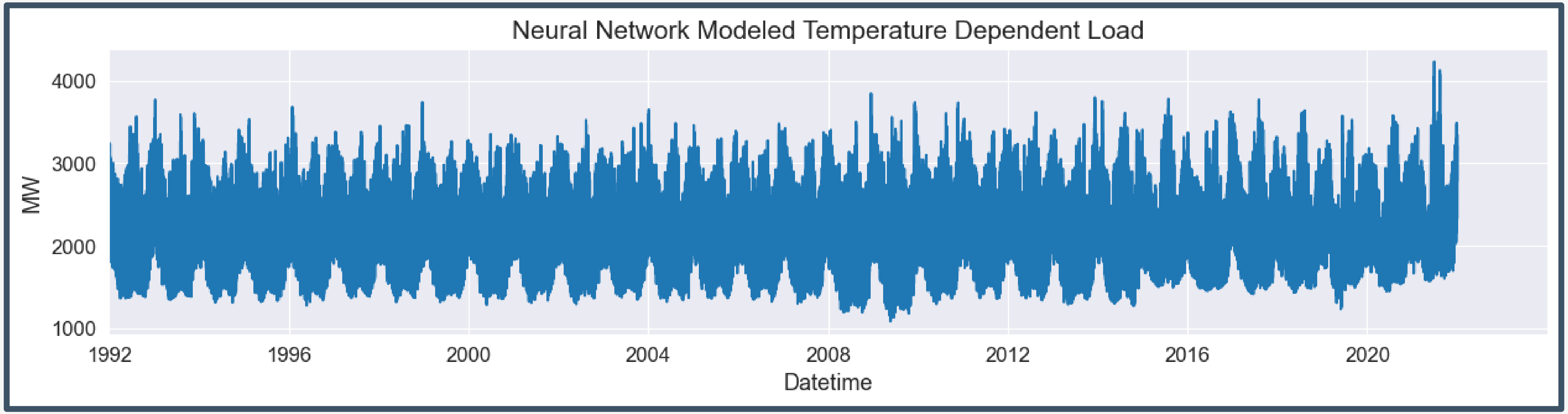
1. Incremental changes are dependent on order of updates, while terminal capacity need is not.

Updated Analysis Period

Temperature Dependent Load – Definition

Temperature Dependent Load:

- Multi-year load shape designed to represent the influence of temperature on demand
  - Does not include the effects of population/economic growth in the service territory



Historically used in Sequoia for two purposes:

1. Definition of "load bins" (month specific percentile ranges of weather-dependent load)
2. Simulation of future load forecasts across historical years[1]

1. This approach will be replaced by PGE Corporate Load Forecasts' hourly simulation.

Updated Analysis Period

Overview of Changes

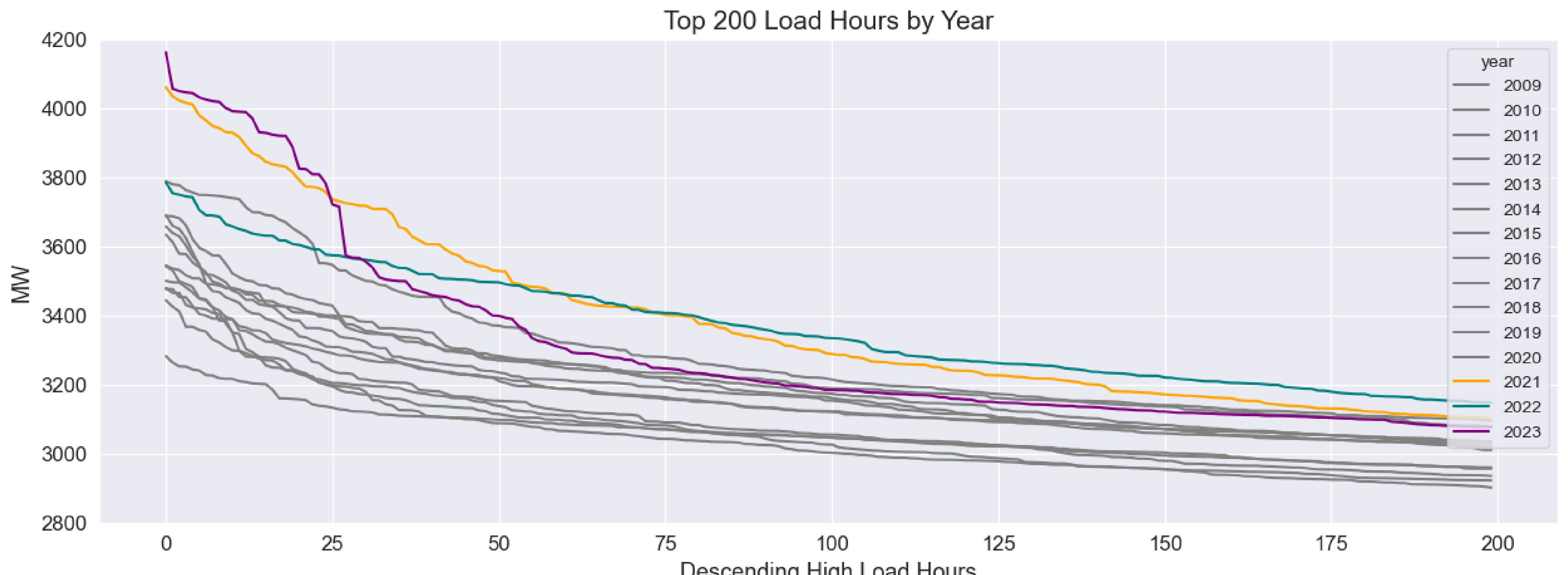
Involves two updates: Methodological & Data

Methodological: change to derive temperature dependent load	
Previous	Updated
Incrementally add historical load years to E3 provided neural net model output and manually detrend new observations through backward adjustment	Estimate historical load as a function of temperature in constant 2023 values

Data: 30-year load data used to derive load bins shifted forward 2 years	
Previous	Updated
Define load bins using 1992-2021 temperature dependent load	Define load bins using 1994-2023 temperature dependent load

Updated Analysis Period - Motivation

Recent Increases in Load (Weather) Patterns



Note: Load normalized to 2023 MW values

Updating the analysis period allows Sequoia to include recent climate trends in modeling of demand & supply.

Updated Analysis Period - Method

Introducing Load Bins

Load bins are used to match load and intermittent resource supply for similar, but different, historical days

- Goal: Model representative scenarios of temperature dependent supply and demand
- Assumes: Correlation between temperature, load and supply from intermittent resources

Table 125. Sequoia week creation example

Start date	Month	Load bin	Weekday	Water year	Biglow	Bakeoven	Load	Thermal resources
8/5/1997	8	5	1	2003	8/6/2005	8/11/2014	8/30/2007	Resource generation varies by month and by forced outage rate.
8/6/1997	8	5	1	2003	8/25/2016	8/3/2014	8/7/1981	
8/7/1997	8	5	1	2003	8/5/2010	8/10/2014	8/13/1992	
8/8/1997	8	3	1	2003	8/22/2005	8/24/2014	8/30/1991	

Updated Analysis Period - Method

Updating Load Bins – Representing Temperature Dependent Load

Previously, temperature dependent load was derived:

1. Neural net model developed by E3
2. Additional years were added incrementally and manually detrended by IRP analyst

Manual detrending was subjective and inconsistent across years

New Approach:

Fit a regression model to explain temperature variability in load and represent values in 2023 MW

Understood to be the approach taken by E3 in original Neural Net Model

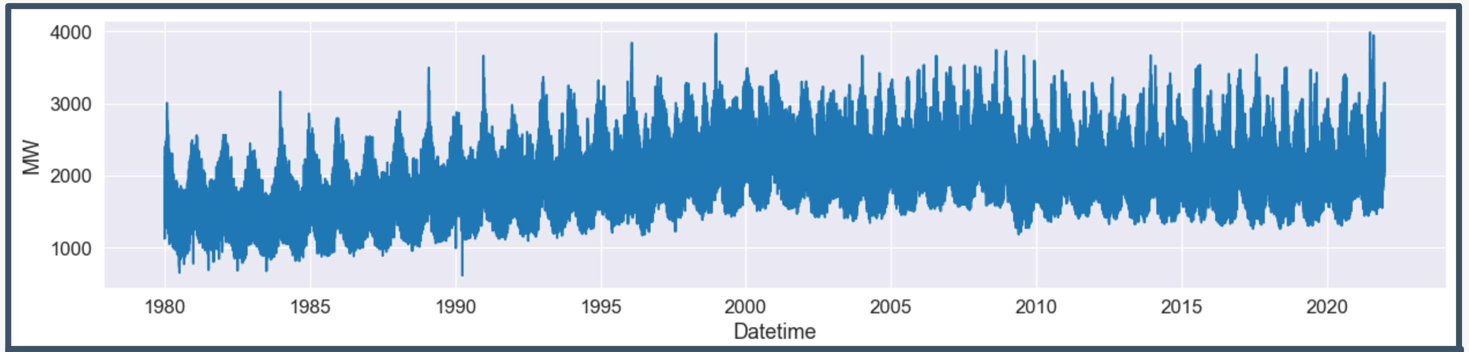
Updated Analysis Period – Method

Extracting Trend from Load

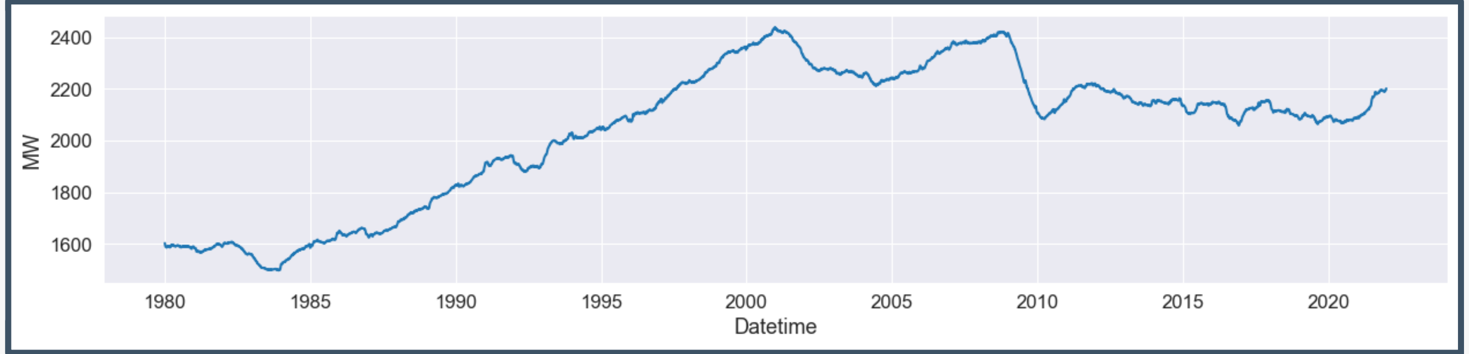
There are not enough historical observations of load shed for causal inference

As a result, temperature dependent load ("weather") is used to match supply and demand from different historical days

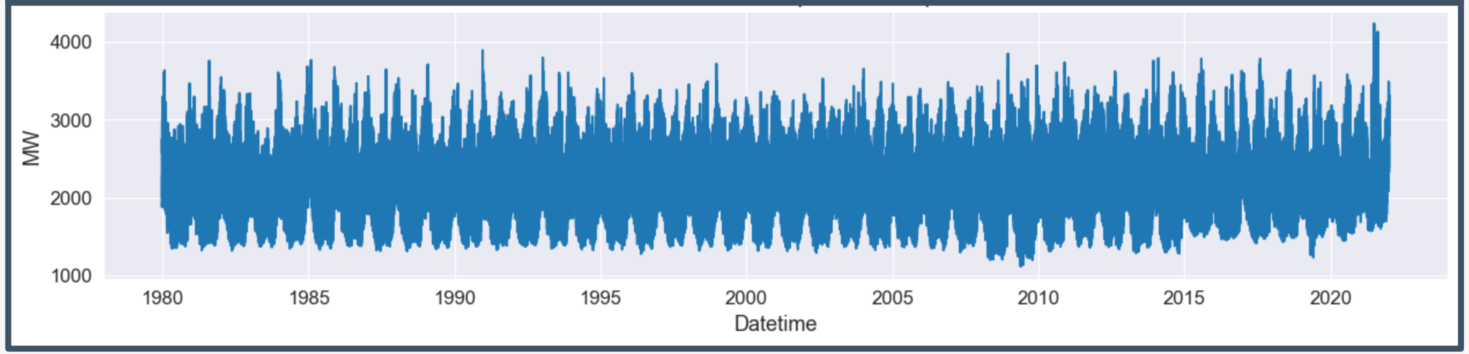
Load



Trend



Temperature

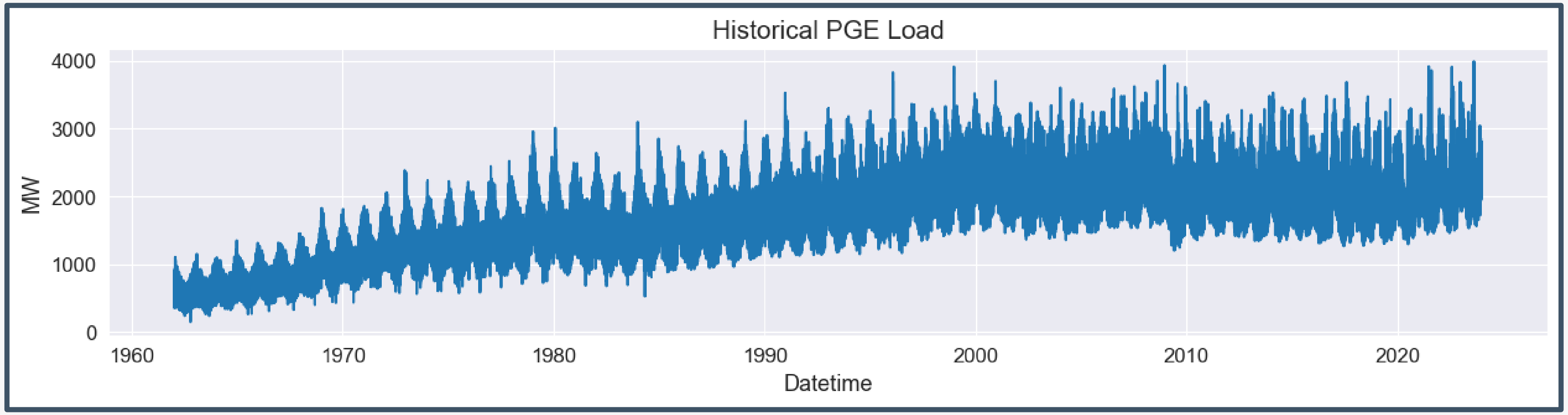


Load =

Trend+ Temperature+ Error

Updated Analysis Period – Method

Modeling Load



MW = Fixed Effects + Temperature

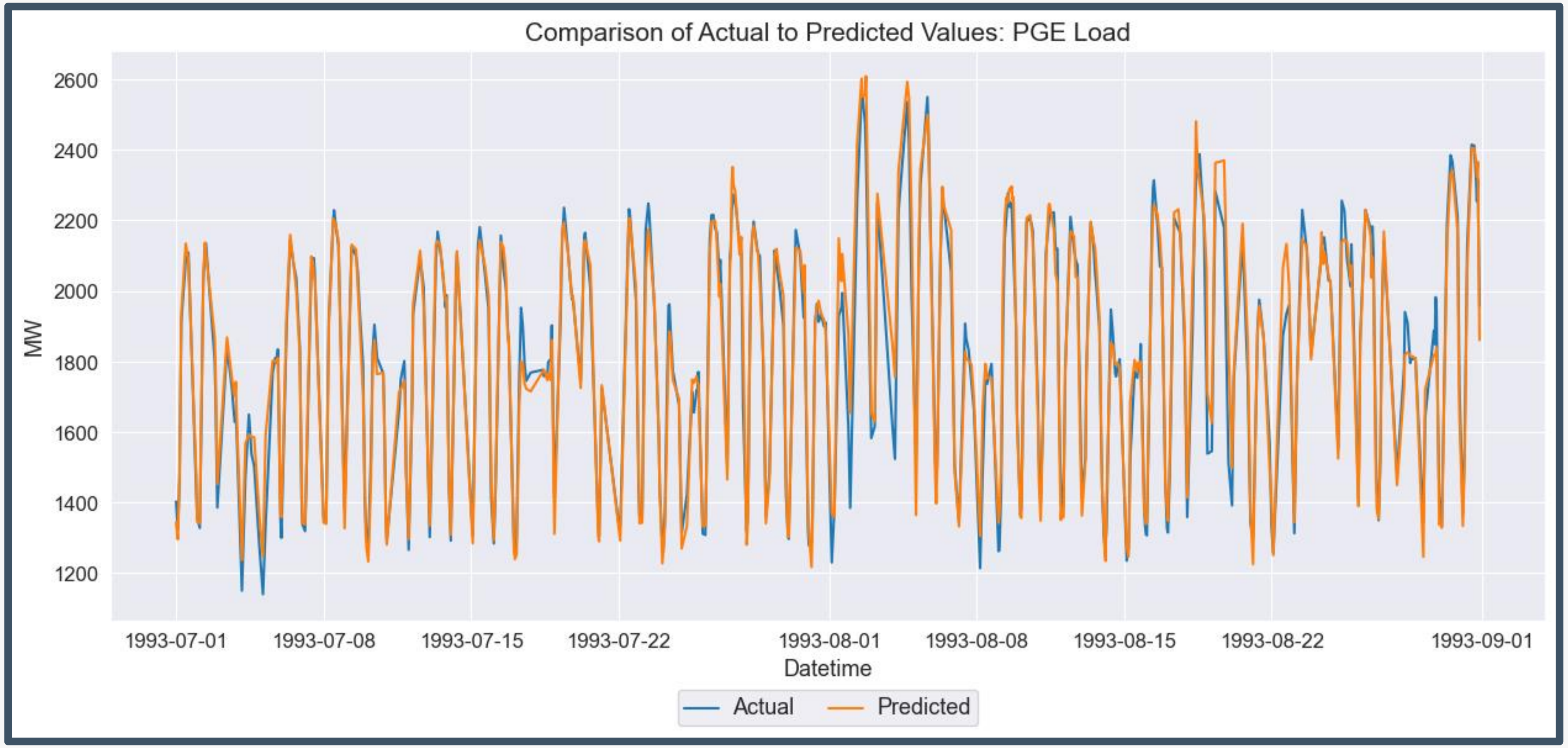
MW	Year	Month	Hour	Day of Week	Holiday	Midpoint Temp.	Heating Degrees	Cooling Degrees
2045	1990	10	16	3	0	51.5	0	13.5
2034	2013	1	1	3	0	37.5	0	27.5
2380	2020	11	9	4	0	41	0	24

A regression model was used to estimate MW, as a function of temperature and fixed date effects

- Train: 361,849 observations
- Test: 178,225 observations

Updated Analysis Period - Method

Modeling Variability in Load – Out of Sample Results



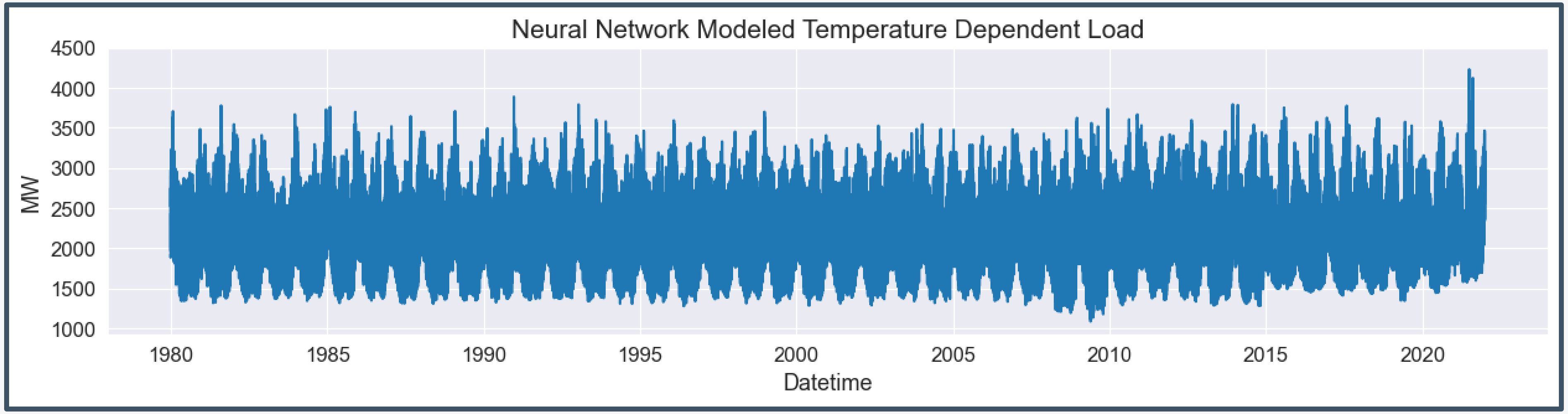
Measures of fit:

- R-sq: 98.36
- Mean Absolute Error: 56.7 MW

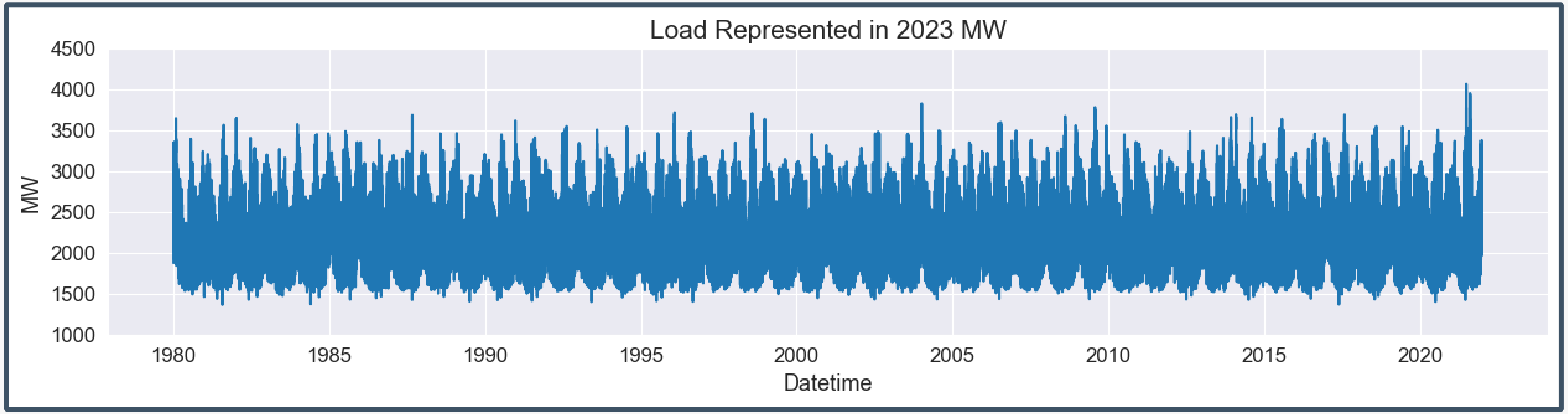
Updated Analysis Period - Method

Comparing Modeling Temperature Dependent Load

E3 Provided Temperature Dependent Load

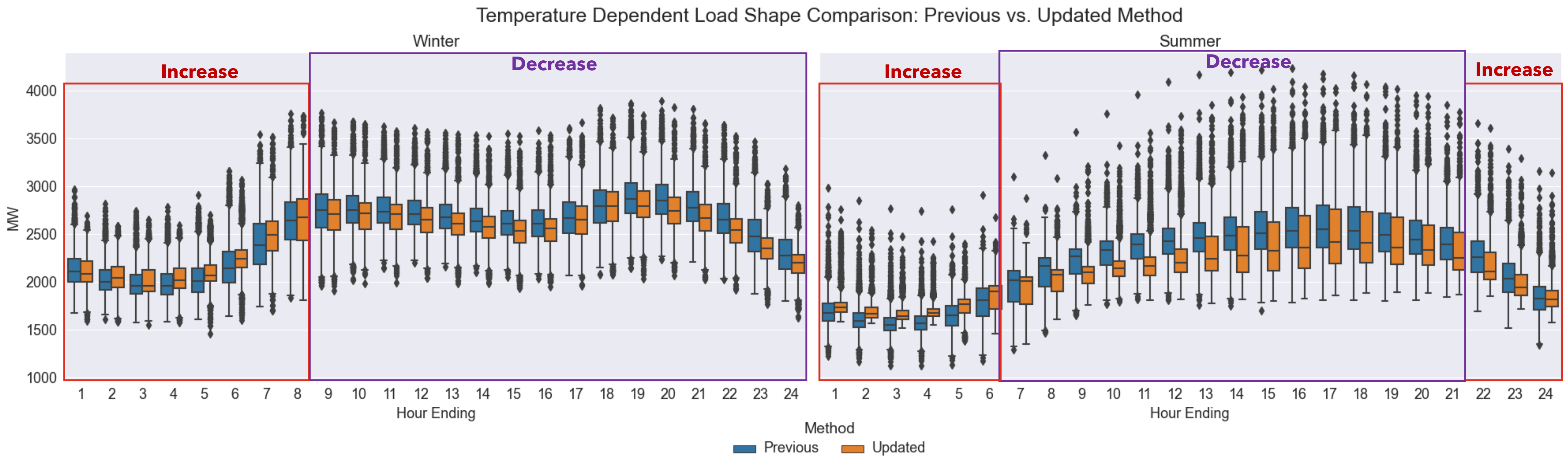


IRP Generated Temperature Dependent Load



Updated Analysis Period - Method

Comparing Modeled Temperature Dependent Load



Winter shows increased load in AM and decrease past 08:00

- 11 MW increase in capacity need

Summer shows reduced load 06:00-21:00 and increased load during late night and early AM hours

- 13 MW increase in capacity need

Updated Analysis Period – Method

Load Bins, Incorporating Randomness

Load bins are used to randomly match supply with demand.

Assumes a correlation between temperature, load and generation.

Load Bins

Percentiles of historical load
- Month specific
- Weekend/weekday specific
- 5 bins (0^{th}-20^{th}, …, 80^{th}-100^{th})
- 1992-2021

Simplified Example:

Load Bin Demand	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5
	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260

4/5 observations would have load shed

Load Bin VER Supply	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5
	75	85	95	105	115	125	135	145	155	165	175	185	195	205	215	225	235	245	255	265

Updated Analysis Period - Data

Load Bins, Incorporating Randomness

Load bins are used to randomly match supply with demand.

Assumes a correlation between temperature, load and generation.

Load Bins

Percentiles of historical load
- Month specific
- Weekend/weekday specific
- 5 bins (0^{th}-20^{th}, …, 80^{th}-100^{th})
- ~~1992-2021~~
- 1994-2023

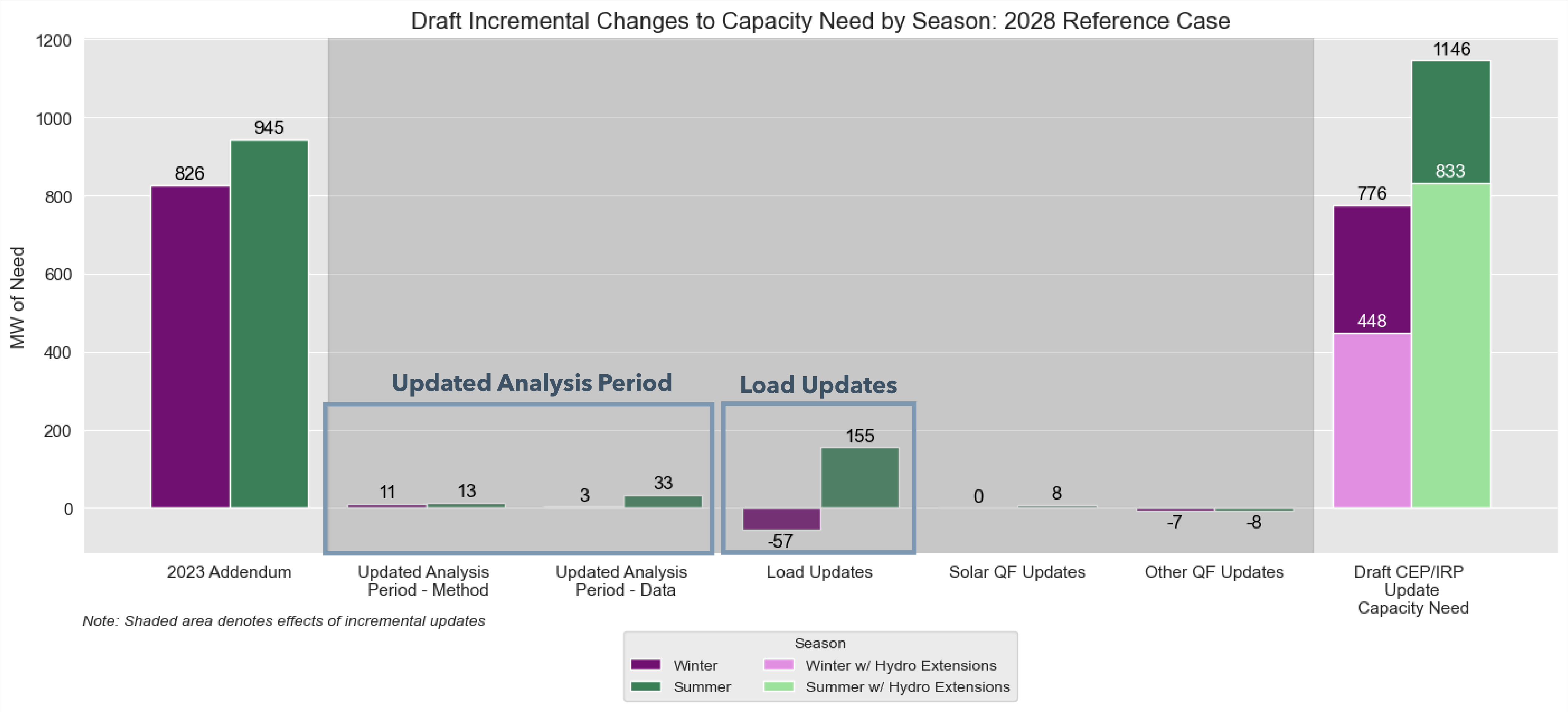
Simplified Example:

Load Bin Demand																				
Bin	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5
Value	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260

4/5 observations would have load shed

Load Bin VER Supply																				
Bin	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5
Value	75	85	95	105	115	125	135	145	155	165	175	185	195	205	215	225	235	245	255	265

Draft 2028 Updated Capacity Need



Load Updates

Overview of Changes

Load updates include two changes:

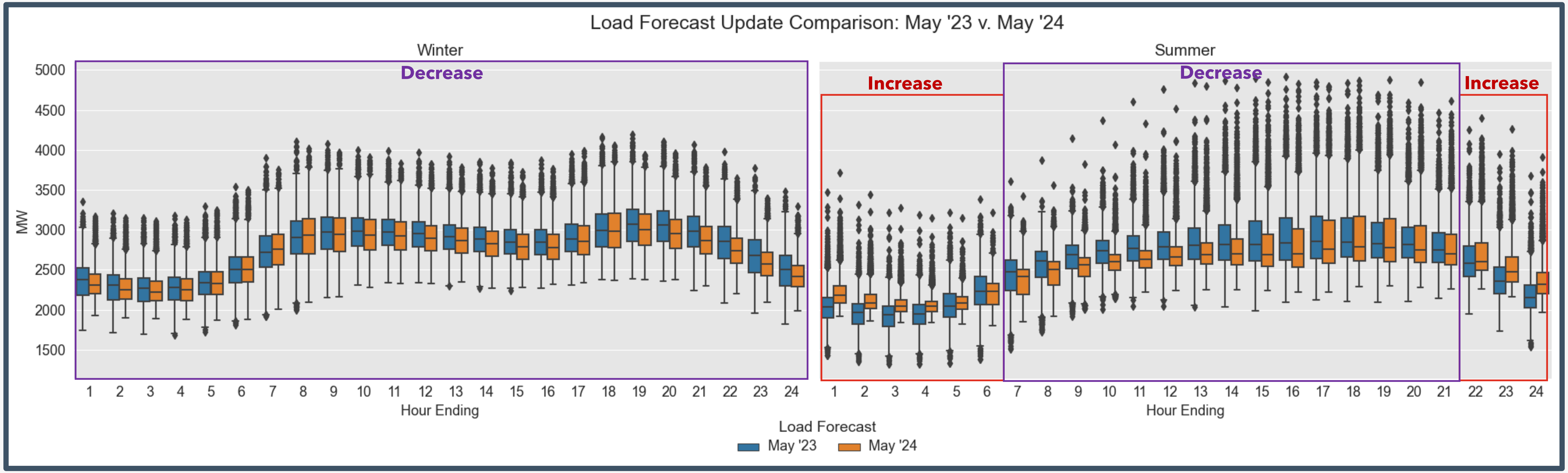
1. Updated forecasts - provided by PGE Corporate Load Forecast (CLF)
   - Previous: May 2023 forecast
   - Updated: May 2024 forecast (presented in the July Roundtable)
2. Update hourly historical simulation - provided by CLF
   - Previous: IRP adjusted historical hourly temperature dependent load to reflect CLF monthly peak and MWa forecasts for future years
   - Updated: CLF provides IRP with historical hourly simulation from regression model which estimates load by hour and customer class[1]

IRP elected to show the Capacity Need effect from these two changes as one value, due to the subjective and time-consuming nature of adjusting historical temperature dependent load data using the previous method.

1. CLF regression approach described in July 2024 Roundtable

Load Updates

Comparison of Seasonal Load Shapes



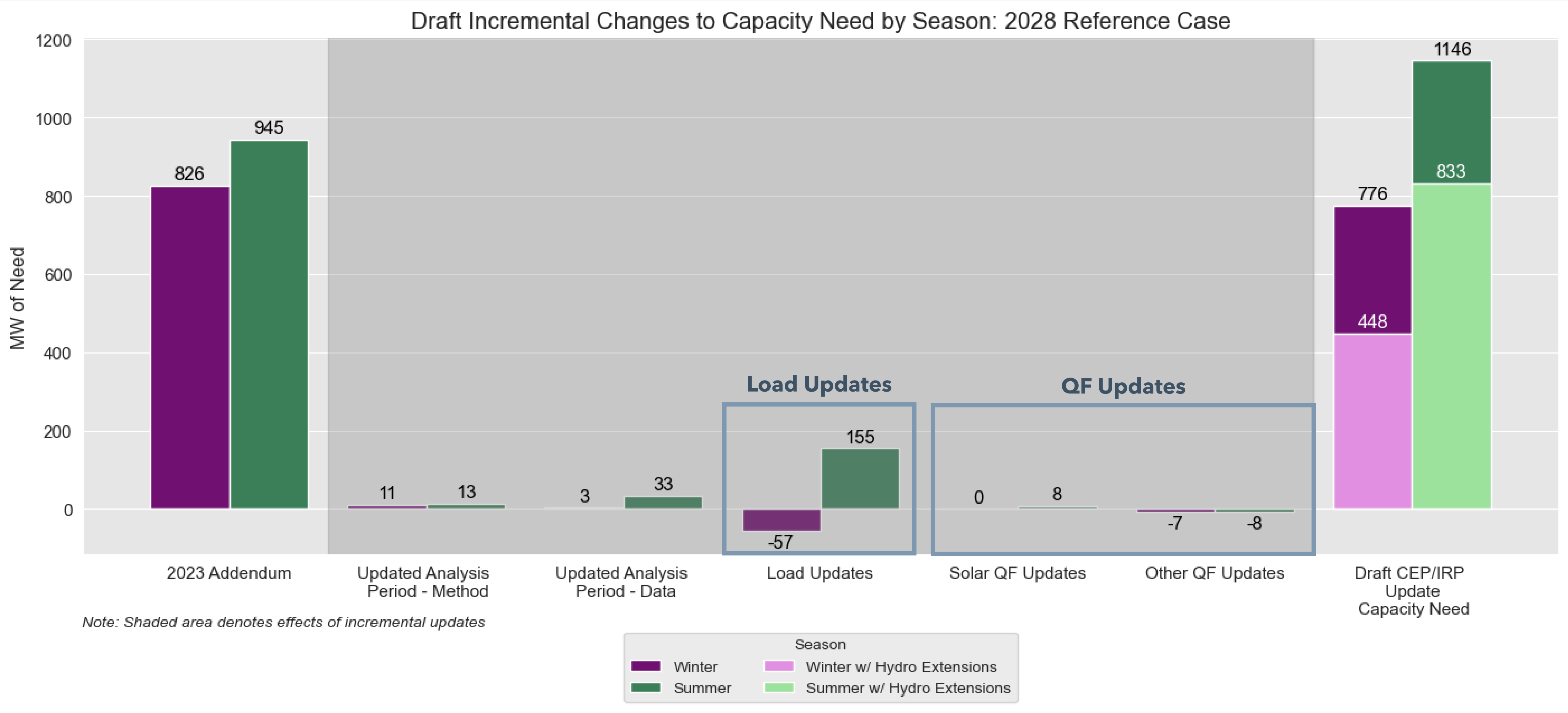
Winter shows reduced load across all hours

- 57MW decrease in capacity need

Summer shows reduced load 06:00-15:00 and increased load during night and early AM hours

- 155MW increase in capacity need

Draft 2028 Updated Capacity Need



QF Updates (first presented in June 2024 Roundtable)

PGE

Summary of QF Changes: 2028 Reference Case

Modeled QF Resource	Previous MW	Actual MW	Change MW
PV West	139.65	134.66	-4.99
PV East	263.25	234.25	-29.00
Biogas	5.20	8.92	3.72
Geothermal	0.00	0.00	0.00
Hydro	4.04	7.19	3.15
Wind	29.15	29.15	0.00

35 MW exit of solar QF resources

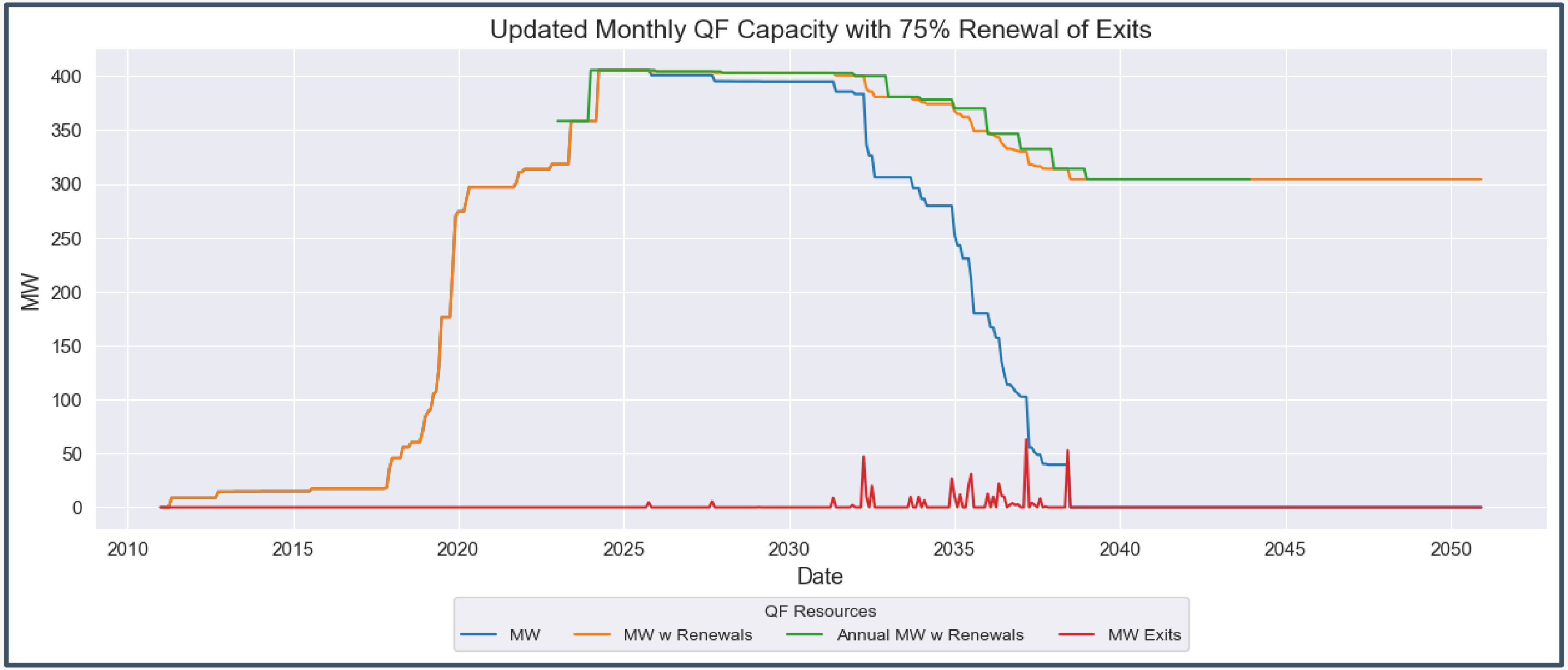
- Winter: Immaterial effect on capacity need
- Summer: 8 MW increase in capacity need

7 MW entry of other QF resources

- Winter: 7 MW decrease in capacity need
- Summer: 8 MW decrease in capacity need

QF Updates (first presented in June 2024 Roundtable)

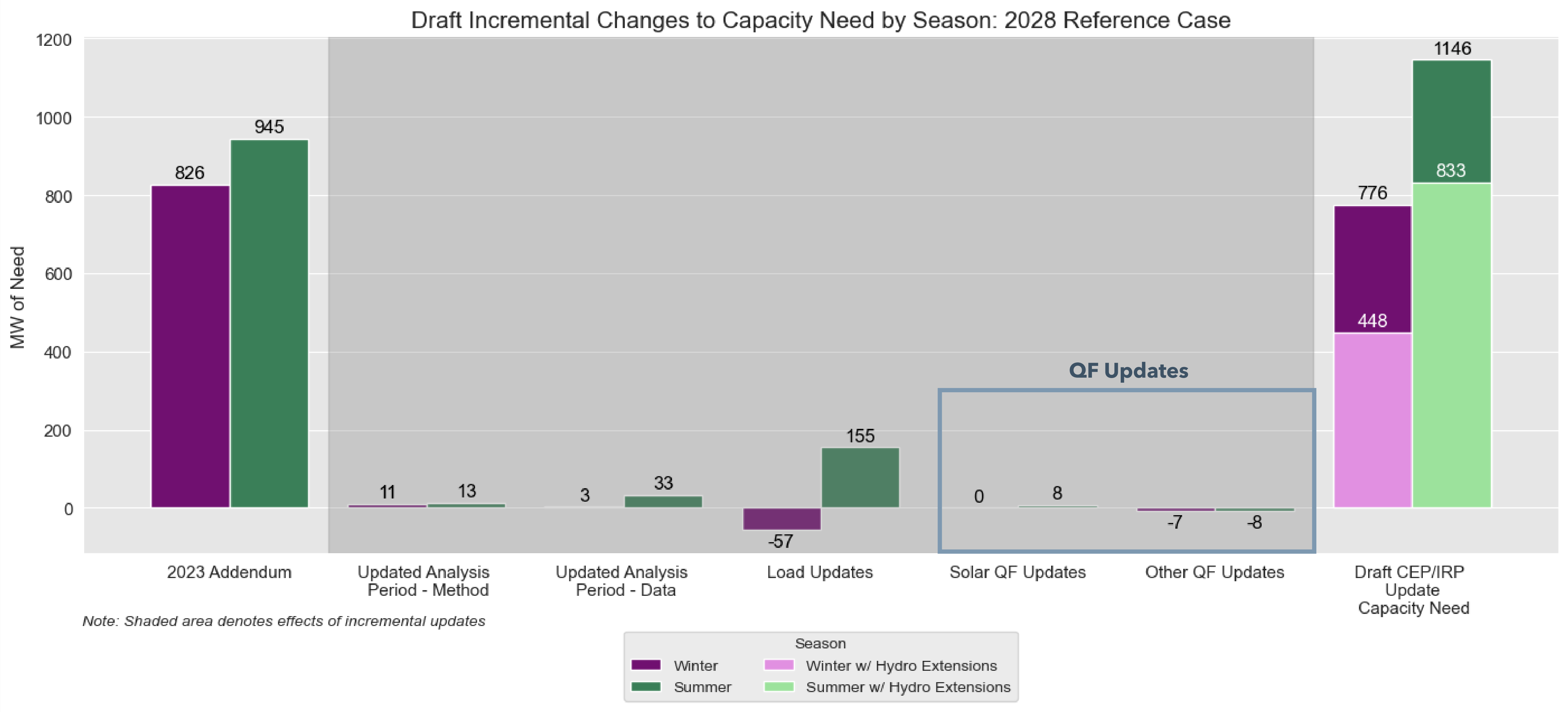
Data Review – Comparing Annual to Monthly QF Capacity



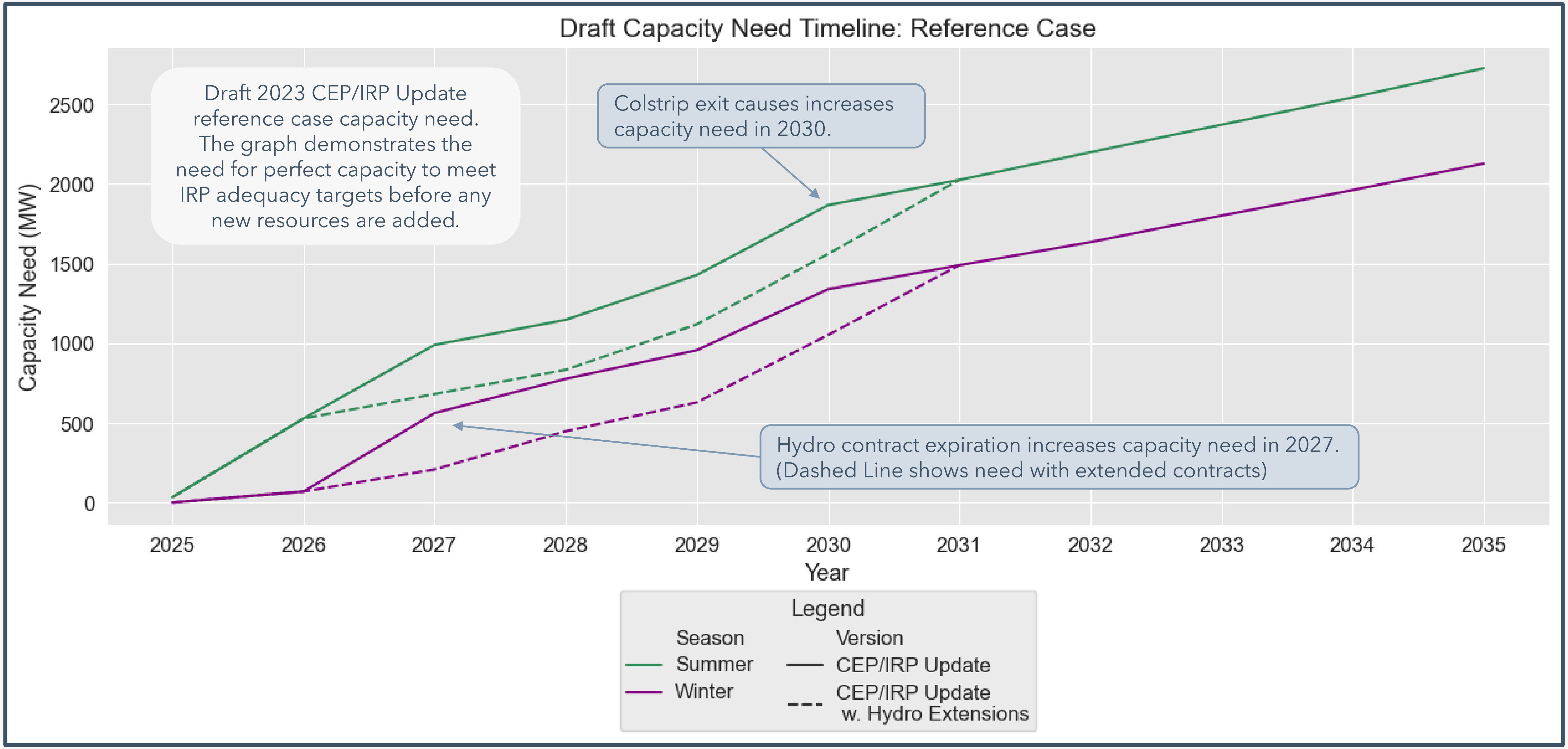
Differences in monthly and annual values due to mid-year exits.

- Sequoia model changes in monthly QF capacity
- June 2024 Roundtable displayed annual QF capacity values

Draft 2028 Updated Capacity Need



Draft Capacity Need Timeline: Reference Case



Summary

PGE

Draft updates result in:

Greater summer capacity need:	• 201MW increase from addendum in 2028 reference case • 1146MW updated total.
Less winter capacity need:	• 50MW decrease from addendum in 2028 reference case • 776MW updated total.
Hydro contract extensions will reduce need:	• 313MW decrease in winter • 328MW decrease in summer

Capacity need values will be updated prior to portfolio analysis due to RFP and other supply and demand changes.

Questions

NEXT STEPS

A recording from today's webinar will be available on our website in one week

Upcoming Roundtable: September 4th
Distribution System Workshop: September 12th

Thank you

Contact us at
IRP.CEP@PGN.COM

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kind of energy

ACRONYMS

ARIMA: autoregressive integrated moving average
ART: annual revenue-requirement tool
ATC available transfer capability
BPA: Bonneville Power Administration
C&I: commercial and industrial
CBI: community benefit indicators
CBIAG: community benefits and impacts advisory group
CBRE: community based renewable energy
CDD: colling degree day
CEC: California energy commission
CEP: clean energy plan
CF   conditional firm
DC: direct current
DER: distributed energy resource
DR: demand response
DSP: distribution system plan
EE: energy efficiency
ELCC: effective load carrying capacity
EJ: environmental justice
ETO: energy trust of Oregon
EUI: energy use intensity
GHG: greenhouse gas
HB2021: House Bill 2021
HDD: heating degree day
IE: independent evaluator
IOU: investor-owned utilities
ITE: information technology equipment
ITC: investment tax credit
kW: kilowatt
LOLH: loss of load hours
LT/ST: long term/ short term
LTF long-term firm
MW: megawatt
MWa: mega watt average
NAICS: North American industry classification system
NCE: non-cost effective
NG: natural gas
NPVRR: net present value revenue requirement
OASIS Open Access Same Time Information System
ODOE: Oregon department of energy
PPA: power purchase agreement
PSH: pumped storage hydro
PUC: public utility commission
PURPA: Public Utility Regulatory Policies Act
PV: photovoltaic
REC: renewable energy credit
RLRR: low carbon price future
ROSE-E: resource option strategy engine
RPS: renewable portfolio standard
RRRR: reference case price future
RTO: regional transmission organization
SoA: South of Allston
T&D: transmission and distribution
TSR: transmission service request
TSEP: TSR study and expansion process
Tx: transmission
UPC: usage per customer
UPS: uninterruptible power supply
VER: variable energy resources
VPP: virtual power plant
WECC: western electricity coordinating council