Energy Imbalance Market Collaborative Workshop #2

Puget Sound Energy

Power Cost Only Rate Case, Docket UE-200980

July 21, 2021

Proposed collaborative roadmap has 4 workshops

1. Objective & principles	• Settlement agreement • EIM[1] overview • Objective of collaborative workshops • Principles for treatment of EIM impact in power costs
2. Current model & CAISO estimates	• CAISO's[2] EIM benefits calculation • PSE's validation of CAISO's calculation and hydro-adjusted benefits • Other Pacific Northwest entities' treatment of EIM benefits in rates • PSE's approach to modeling power costs and proposed sub-hourly modeling
3. Sub-hourly model	• Proposed approach to including net impact of EIM participation in current power cost models
4. Conclusion	• Discussion of approach to including net impact of EIM participation in rate year power cost projections • Discuss final work product of collaborative

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[1]Energy Imbalance Market
[2]California Independent System Operator

Agenda for today

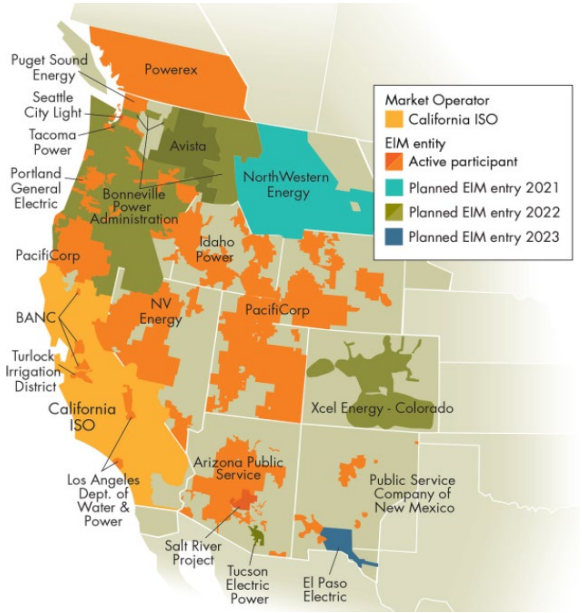
CAISO calculation | PSE validation | Benchmarking | PSE approach

- CAISO's EIM benefits calculation
- PSE's validation of CAISO's calculation & hydro-adjusted benefits
- Benchmarking other Pacific Northwest (PNW) entities' treatment of EIM
- PSE's approach to modeling power costs and proposed sub-hourly modeling
- Review proposed roadmap & agenda for workshop #3

The Western EIM connects multiple BAAs in a real-time energy market

CAISO calculation | PSE validation | Benchmarking | PSE approach

- EIM is a voluntary, sub-hourly wholesale energy market currently serving 14 separate participating balancing area authorities (BAAs)
- A BAA is an entity responsible for reliably planning and operating an area of the high voltage grid according to federal standards
- All BAAs balance supply with demand in real time



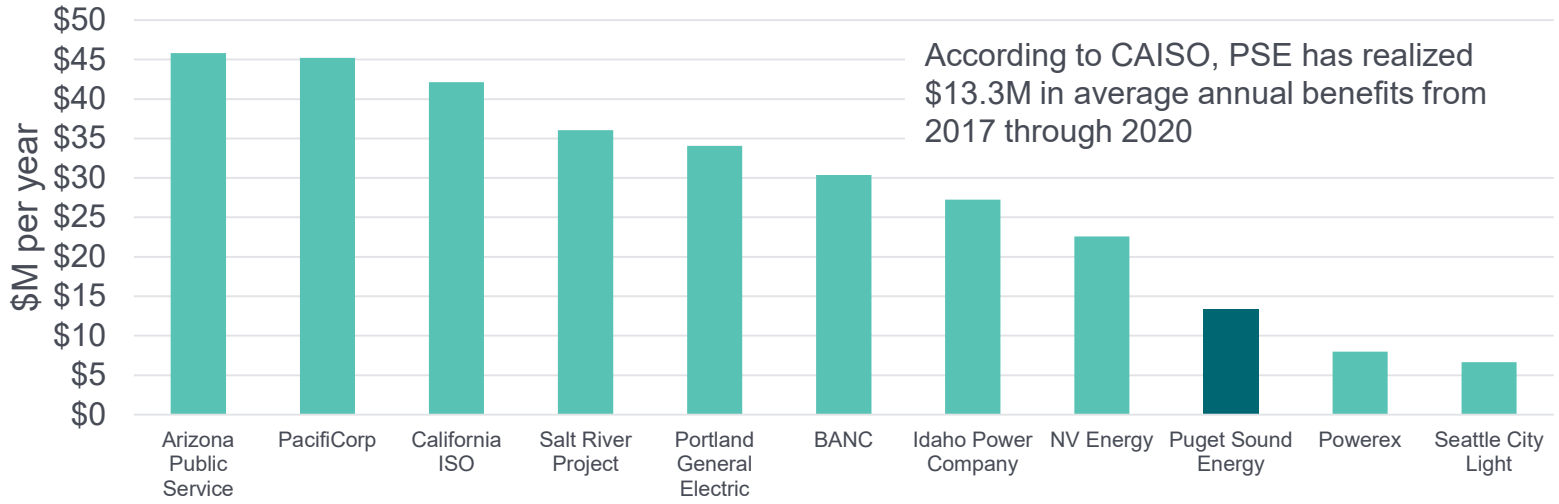
Source: https://www.caiso.com/Documents/BA-EIM-FullParticipation-Checklist.pdf

EIM participation benefits power consumers across the West

CAISO calculation | PSE validation | Benchmarking | PSE approach

CAISO-published annual average EIM benefits ($M)

from first full year of EIM participation through 2020
by BAA



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CAISO uses a counterfactual approach to estimate the benefits of EIM participation

CAISO calculation | PSE validation | Benchmarking | PSE approach

- The counterfactual dispatch meets the same amount of real-time load imbalance in each BAA *without* EIM transfers between neighboring EIM BAAs
  - Real-time load imbalance is the difference between sub-hourly net load and hourly base schedule
- The benefit can take the form of cost savings or net revenues or their combination

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Source: https://www.westerneim.com/Documents/EIM-BenefitMethodology.pdf

EIM participation cost is made up of 4 components

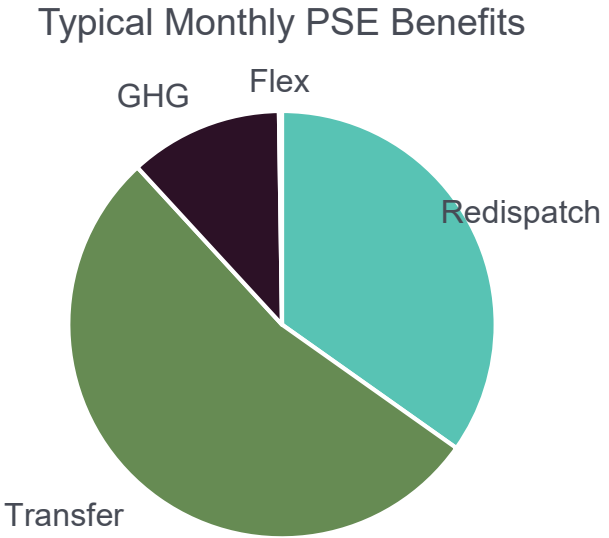
CAISO calculation → PSE validation → Benchmarking → PSE approach

[1]Greenhouse gas (GHG)

The majority of PSE's benefits are derived from transfers and the difference between counterfactual and EIM dispatch costs

CAISO calculation | PSE validation | Benchmarking | PSE approach

- **Redispatch** is the difference between counterfactual and EIM dispatch costs
- **Transfers** are the net of payments for imports and exports between PSE and other BAAs
- The bulk of PSE **GHG** benefits are derived from hydro or wind exports being designated as having flowed to CAISO
- **Flex ramp** transfers are payments for imports or exports of flexible ramping capacity reserved to handle intra-hour load and generation uncertainties



These are three key terms to understanding EIM benefits

Base schedules

An hourly forward energy schedule submitted by the Scheduling Coordinator for a BAA

Balances hourly generation with load and provides sufficient flexible ramping capacity for the BAA

-Tests and penalties to ensure compliance

For use in the Real-Time Market

Bids

The price at which an EIM entity is willing to increment or decrement a resource's generation from its base schedule

3 parts required for each bid

-Energy cost

-Min load cost

-Startup cost

Optional GHG adder

-For energy flowing to CAISO BAA

-Covers CARB[1] obligations for greenhouse gas emissions

LMP

Locational Marginal Price

Includes 4 components

-Energy

-Congestion

-Losses

-GHG

LMP determined for each node on the network

-ELAP (external load aggregation point)

-DGAP (default generation aggregation point)

-Participating resources

[1]California Air Resources Board

The counterfactual dispatch cost is the cost to meet intra-hour load imbalances with a BAA's own resources

CAISO calculation | PSE validation | Benchmarking | PSE approach

The counterfactual dispatch moves units inside the BAA to meet the 5 minute interval real-time load imbalance based on economic merit order

Example:

- Net load imbalance is -36 MW
  - e.g., base schedule = 100 MW, actual net load is 64 MW in a particular interval
- Decrement units starting with the most expensive until 36 MW are cut
- Counterfactual cost = delta instruction * bid price / 12[a]
- Counterfactual cost savings is $60 for the interval in this example

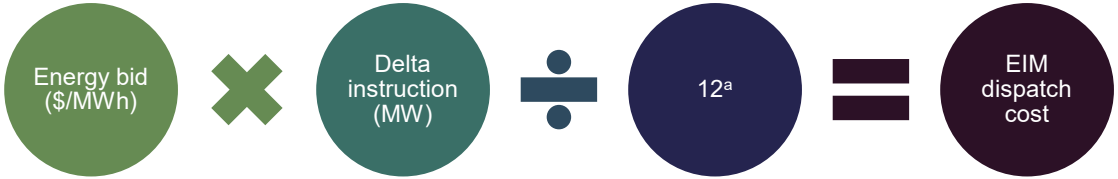
Table 1: Economic merit order to decrement units

Unit	Bid segment volume (MW)	Bid Price $/MWh	Decrement (MW)	CF Cost
Unit A	10	$25	-10	($20.83)
Unit A	15	$20	-15	($25.00)
Unit C	5	$18	-5	($7.50)
Unit B	5	$15	-5	($6.25)
Unit D	20	$5	-1	($0.42)
Total			-36	($60.00)

[a] Divide by 12 to convert $/MWh to $/MW per 5 minute interval

The EIM dispatch cost in the benefits model is simplified to exclude certain non-variable costs

CAISO calculation | PSE validation | Benchmarking | PSE approach



- For all BAAs other than CAISO, the dispatch cost only includes variable dispatch cost
  - i.e. the energy bids submitted by the corresponding Scheduling Coordinator
  - Variable O&M (VOM) is embedded in the energy bid
- Volume is delta instruction from base schedules, an increment or decrement
- CAISO ignores start up and min load costs in its benefits calculation so it can evaluate cost differences between EIM dispatches and counterfactual dispatches without performing sophisticated unit commitment simulations

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[a] Divide by 12 to convert $/MWh to $/MW per 5 minute interval

Net transfer costs are payments for optimized transfers of MWs between BAAs, and can be positive or negative

CAISO calculation | PSE validation | Benchmarking | PSE approach

- CAISO deems importing transfers as positive and exporting transfers as negative
  - Imports are an addition to EIM participation costs, while exports are a reduction
- The transfer cost is equal to the transfer MW * transfer price ÷ 12[a]
- The transfer price is the BAA's locational marginal price (LMP) adjusted for congestion between the receiving BAA and the delivering BAA

[a] Divide by 12 to convert $/MWh to $/MW per 5 minute interval

GHG and flexible ramp contribute to EIM benefits on a smaller scale

CAISO calculation | PSE validation | Benchmarking | PSE approach

- A BAA usually realizes positive GHG net revenue when a resource is allocated GHG MW
  - 'Allocated' means that power generated by a particular resource was designated to flow into the CAISO market, creating a CARB GHG compliance obligation
  - Allocated resources generate GHG revenue based on the market-clearing GHG cost, which will be greater than or equal to the compliance obligation
  - GHG compliance obligations for hydro and wind resources are zero, so for PSE these resources are often the primary contributor to GHG benefits

- Flexible ramp transfers can be positive or negative and result from a BAA being long or short flexible ramping capacity in any given interval
  - Flex ramp benefits are not material for PSE

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CAISO benefits estimates should not be interpreted as direct reductions to “power costs”

CAISO calculation | PSE validation | Benchmarking | PSE approach

- Calculated at the BAA level so will include 3rd party (non-utility) loads and generation resources
  - e.g. Microsoft, Green Direct[1], non-utility generators
- Assume resource bids are equal to actual costs
  - Hydro has no incremental power costs
  - Hydro bids in EIM are used to communicate operational considerations and opportunity cost, and do not represent actual costs
  - Include non-fuel resource costs such as variable O&M[2] which are not included in power costs
- Measured against base schedules which may be sub-optimal due to bilateral market inefficiency

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[1]Green Direct is technically not a third party load, but is treated as such for power cost ratemaking
[2]VOM is embedded in the energy bid submitted to CAISO

PSE uses SettleCore software to validate CAISO's EIM benefits calculation

CAISO calculation | PSE validation | Benchmarking | PSE approach

- SettleCore downloads raw EIM data directly from CAISO
  - Base schedules
  - LMPs
  - Bid curves
- SettleCore applies algorithms to the raw data to replicate the benefits calculation
- Other EIM entities use the SettleCore application

PSE's EIM hydro bids can skew EIM benefits estimates

CAISO calculation | PSE validation | Benchmarking | PSE approach

- PSE's EIM bids for hydroelectric resources are sometimes used to manage reservoir storage levels
  - e.g. When storage levels are low PSE may submit a very high EIM bid for a hydro resource to ensure the EIM does not dispatch that resource to a higher output level
  - If the EIM then decrements the resource to a lower output level, the CAISO counterfactual measures the benefit as the difference between the high PSE bid and the lower cost to replace that resource
- To make the adjustment in the SettleCore benefits calculation model
  - Next-day ICE Mid-C day-ahead peak prices are substituted for actual EIM hydro bids
  - Economic merit order is not adjusted, original EIM dispatch quantities are left unchanged
- In 2018, this adjustment resulted in a downward revision of $6.3M in EIM benefits vs. CAISO's version[1]

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[1] $6.3M hydro adjustment was revised from $5.7M when duplicate data was discovered during a review of the analysis

Other utilities recognize shortcomings of CAISO methodology

CAISO calculation | PSE validation | **Benchmarking** | PSE approach

In rate proceedings in WA, OR, and ID, PacifiCorp[1], Portland General Electric[2] and Idaho Power[3] all have **not** included the published CAISO benefits numbers as reductions to power costs

- Each entity has chosen to reflect the benefits of EIM in rate proceedings using different methods
- While all are in the Pacific Northwest, each entity's generating and transmission resource portfolio is unique
- Each entity also forecasts power costs in rate cases differently

PUGET SOUND ENERGY

[1]WA – UE-191024; OR – UE-375
[2]OR – UE-337
[3]OR – UE-384

PacifiCorp projects future benefits based on historical relationships

CAISO calculation | PSE validation | **Benchmarking** | PSE approach

An independent calculation of historical benefits is used to develop a regression model to estimate future EIM benefits[1]

- Actual transfer revenue minus estimated cost of dispatch is used to calculate historical benefits independent of the CAISO calculation
- A regression model expresses those benefits as a function of market prices and transfer capability
- The regression model is applied to a future period, with future benefits estimated as a function of forward market prices and EIM transfer capacity
- Historical GHG revenue is assumed as a benefit in the future year

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[1]WA – UE-191024; OR – UE-375

Portland General adjusts hourly model results to include estimated EIM transactions

CAISO calculation | PSE validation | **Benchmarking** | PSE approach

Results of forward-looking hourly production cost model are adjusted to include EIM re-dispatch and transfer benefits[1]

- A ratio of historical EIM and Mid-C prices is applied to forward Mid-C prices to derive a forward EIM price curve
- The forward EIM price curve is used to determine in which hours there would be EIM transactions relative to model output
- EIM transactions are subject to volume constraints based on historical EIM volumes or projected hourly volumes
- GHG revenue based on historical transactions adjusted to current California Carbon Allowance (CCA) prices
- Benefits are reduced by CAISO grid management charges

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[1]OR – UE-337

Idaho Power adjusts CAISO calculations for hydro bids in Oregon

CAISO calculation | PSE validation | **Benchmarking** | PSE approach

The CAISO methodology is replicated using SettleCore and adjusted for hydro bidding[1]

- Hydro bids are used to communicate operational constraints to CAISO rather than to represent costs
  - Hydro bids are replaced by the Powerdex hour ahead real time index price to determine the cost in the benefit calculation
- EIM benefits accrue at the BAA level, so Idaho Power proposed to allocate a portion of benefits to third party loads based on their historical use of Idaho Power transmission
  - Denied by Oregon Commission

Idaho Power excludes EIM adjustment from projections in Idaho because annual true-ups allow actual costs to flow to customers

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[1]OR – UE-384

Different approaches have been approved for different companies, even by the same commission

CAISO calculation → PSE validation → Benchmarking → PSE approach

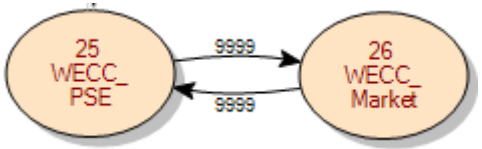
PacifiCorp	Portland General Electric	Idaho Power Company (OR)	Idaho Power Company (ID)
1. Independently estimates historical benefits 2. Develops regression analysis using independent estimate 3. Estimates future benefits based on regression analysis with forward prices and EIM transfer capacity as explanatory variables 4. Adds GHG benefits	1. Starts with forward-looking hourly model 2. Identifies hours when there should be EIM transactions using price comparisons and volume limits 3. Adjusts results of hourly model with EIM analysis 4. Includes GHG using forward CCA prices	1. Replicates CAISO benefits method for historical period 2. Adjusts replicated historical benefits for hydro value	Excludes EIM impacts from projected power costs because annual changes to rates include recovery of deferred costs including EIM impacts

PSE uses the Aurora model to forecast power costs

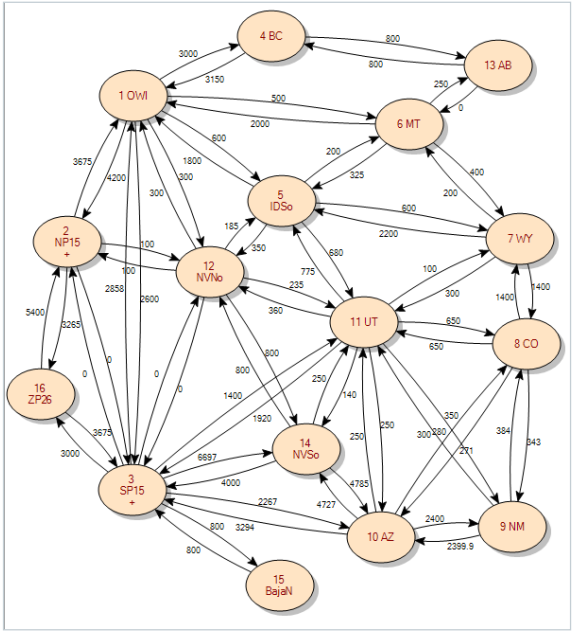
CAISO calculation | PSE validation | Benchmarking | PSE approach

- Aurora model used to optimize resource dispatch and market transactions for every hour of the rate year
- WECC-wide pricing model assumes optimal resource dispatch and transmission utilization across the entire footprint (i.e., there is no bilateral market inefficiency)
- Two-zone model mimics PSE operations through the hourly base schedule using prices from the pricing model as an input

Two Zone Model



Pricing Model

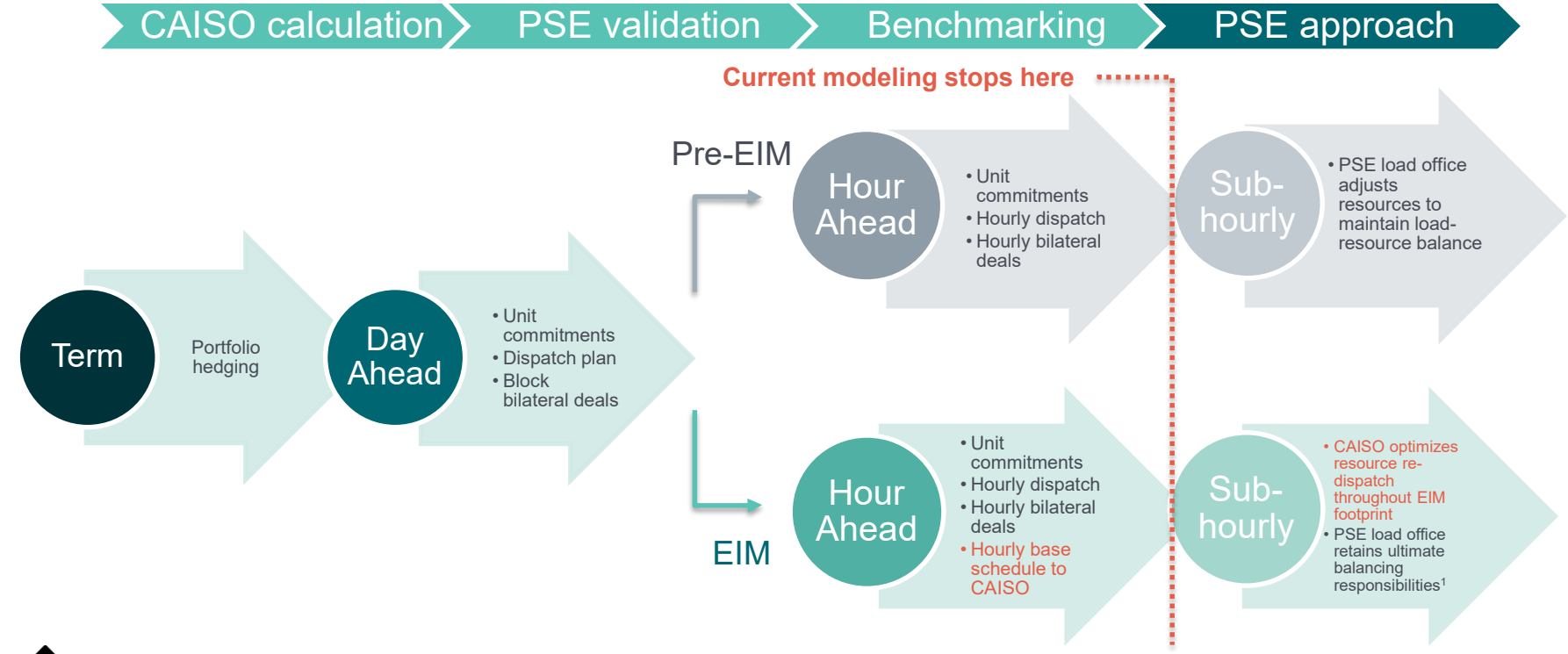


Current model optimizes PSE portfolio at the hourly level

CAISO calculation > PSE validation > Benchmarking > PSE approach

- Model inputs are all based on normal conditions
- Model has perfect foresight for load and variable resource generation
  - Inputs = outputs, no uncertainty or variability
- Beginning in 2019 GRC Aurora model includes costs of holding reserved capacity and flexibility to meet reliability requirements AND prepare to manage within-hour changes
  - But resources are never deployed to actually respond to within-hour changes because there are none

Current modeling stops short of sub-hourly operations



[1]Load office continues to balance moment-to-moment and meet reliability requirements for the entire Balancing Authority Area

But there are costs associated with sub-hourly balancing

CAISO calculation | PSE validation | Benchmarking | PSE approach

- Actual load and resource volumes change constantly, not flat for an entire hour as modeled
- Without EIM, these changes must be followed using only PSE's own resources
  - Dispatchable resources operate at less than optimal output to follow variations
  - Additional, more expensive resources may need to be dispatched to meet within-hour peaks (which don't show up on an hourly average basis)
  - Such resources may need to continue to run out-of-the-money due to minimum run times or physical operating constraints
  - Hydro may need to be spilled or wind curtailed to make room for now running uneconomic resources
- With the EIM, imports and exports can be used to follow load and resource changes

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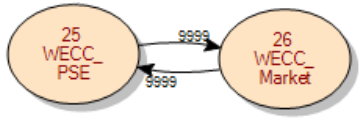
PSE can use Aurora to calculate sub-hourly balancing costs and the benefits of EIM

CAISO calculation | PSE validation | Benchmarking | PSE approach

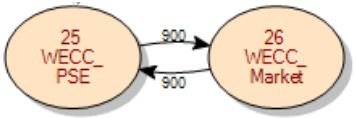
Incorporate three-stage sub-hourly modeling into PSE's current Aurora model:

1. Run hourly pricing model followed by hourly two zone model just as in 2020 PCORC
   - Hourly market purchases and sales locked in to simulate hour-ahead (HA) transactions
2. Run sub-hourly pricing model followed by sub-hourly two zone model with HA transactions fixed and sub-hourly market available
   - Sub-hourly prices represent EIM prices
   - Sub-hourly market represents EIM (limited by PSE's transmission availability)
3. Run sub-hourly two zone model with HA transactions fixed, but **without** sub-hourly market
   - Only PSE resources respond to intra-hour variability
   - Compare to results from step 2 to estimate EIM benefits

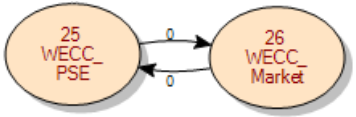
Hourly – unlimited[1] market



Sub-hourly - EIM



Sub-hourly – no market



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[1]PSE's market access is in practice limited by available transmission, but this is not enforced in the Aurora model as currently set up.

Proposed collaborative roadmap has 4 workshops

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2. Current model & CAISO estimates	• CAISO's[2] EIM benefits calculation • PSE's validation of CAISO's calculation and hydro-adjusted benefits • Other Pacific Northwest entities' treatment of EIM benefits in rates • PSE's approach to modeling power costs and proposed sub-hourly modeling
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4. Conclusion	• Discussion of approach to including net impact of EIM participation in rate year power cost projections • Discuss final work product of collaborative

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[1]Energy Imbalance Market
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Draft agenda for workshop #3

- Proposed approach to including net impact of EIM participation in current power cost models
- Discussion