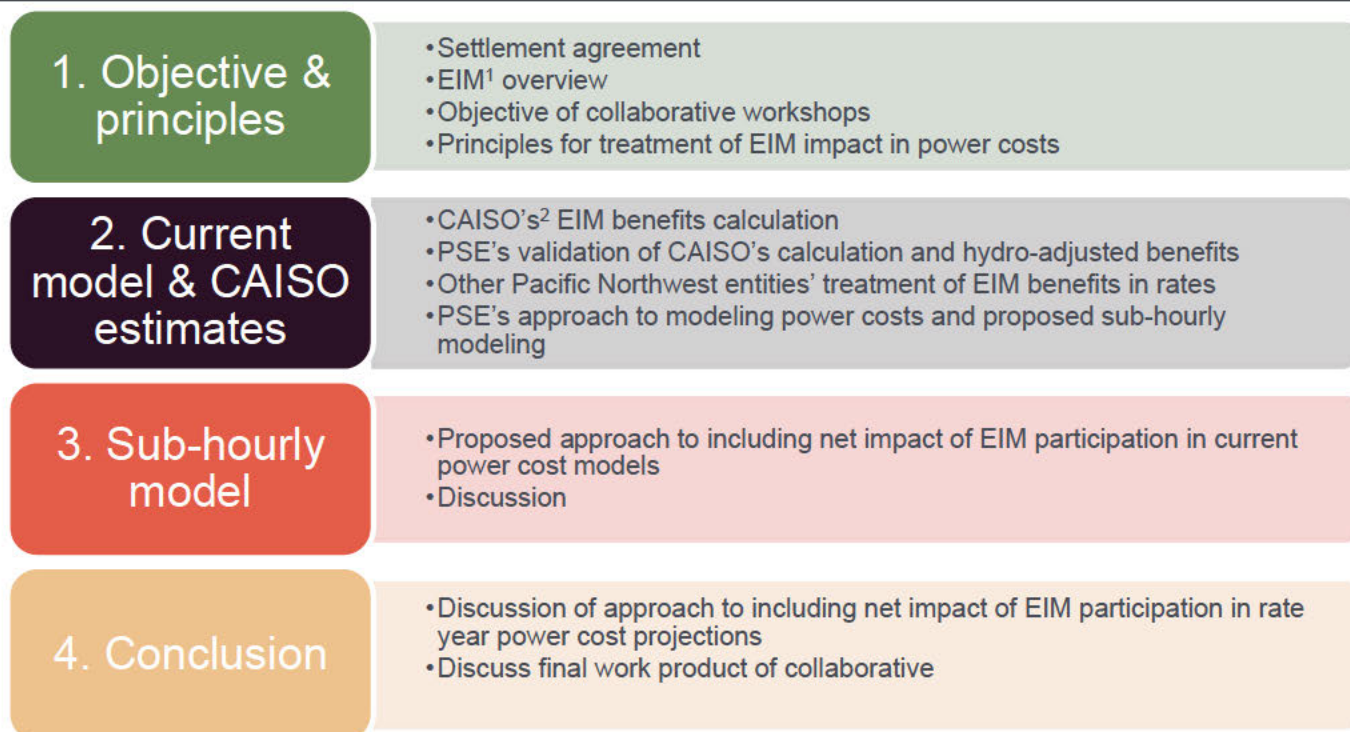

Energy Imbalance Market Collaborative Workshop #3

Puget Sound Energy
Power Cost Only Rate Case, Docket UE-200980



August 4, 2021

Proposed collaborative roadmap has 4 workshops



Agenda for today

PSE approach > Sample results > Net impact > Discussion

- Proposed approach to modeling sub-hourly power costs and EIM benefits
- Sample model results
- Net impact of proposed approach to rate year power cost forecast
- Open discussion

Proposed approach uses Aurora model to calculate sub-hourly balancing costs and benefits of EIM

PSE approach

Sample results

Net impact

Discussion

- Current PSE modeling at the hourly level does not capture the within-hour balancing costs against which EIM benefits are measured
- Aurora model can be run at sub-hourly intervals to estimate the cost of balancing PSE load and variable resource output within each hour, both with and without access to a sub-hourly market
- Sub-hourly model *without* a market estimates what PSE's portfolio cost would be if PSE did not participate in the EIM
- Sub-hourly model *with* a market estimates PSE's portfolio cost including benefits of EIM participation.

Aurora methodology is conceptually similar to CAISO benefits methodology



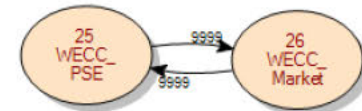
- Sub-hourly model *without* a market is analogous to the counterfactual dispatch cost used in CAISO's benefits estimates
 - Includes costs of following sub-hourly load/resource imbalances using only PSE's resources
- Sub-hourly model *with* a market is analogous to the net EIM participation cost used in CAISO's benefits estimates
 - Includes benefits of using lower cost market resources to follow imbalances and benefits from sales of surplus generation in sub-hourly intervals
 - But does not include net GHG¹ revenue, which will need to be accounted for outside the model

Aurora methodology includes three modeling stages

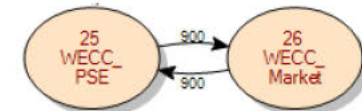
PSE approach → Sample results → Net impact → Discussion

1. Hourly pricing model followed by hourly two zone model as in 2020 PCORC
 - Hourly market purchases and sales from this run represent bilateral transactions included in base schedules
2. Run sub-hourly pricing model followed by sub-hourly two zone model **with** sub-hourly market available and bilateral transactions fixed
 - Sub-hourly prices represent EIM prices
 - Sub-hourly market represents EIM (limited by PSE's transmission availability)
3. Run sub-hourly two zone model **without** sub-hourly market and with bilateral transactions still fixed
 - Only PSE resources respond to intra-hour variability

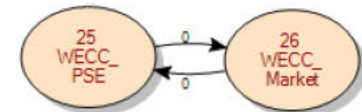
Hourly – unlimited¹ market



Sub-hourly - EIM



Sub-hourly – no market



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

Assumptions and inputs in hourly model are mostly* identical to those used in PSE's 2020 PCORC

PSE approach > Sample results > Net impact > Discussion

- Load and variable resource inputs are based on normal conditions
 - Hourly values for entities/resources throughout the WECC are from Aurora database.
 - Hourly values for PSE are monthly forecasts shaped using hourly profile from Aurora database
 - Model has perfect foresight of load and variable resource outcomes
- Hourly power prices are from optimized dispatch of resources in WECC wide model
 - Modeled prices for northwest region represent Mid-C market prices
- * Monthly hydro energy volumes are average volumes from 80 historical years
 - In PSE's 2020 PCORC each of the 80 years was modeled separately and average model results were used in power cost forecast

Additional assumptions and inputs are needed for sub-hourly models

PSE approach

Sample results

Net impact

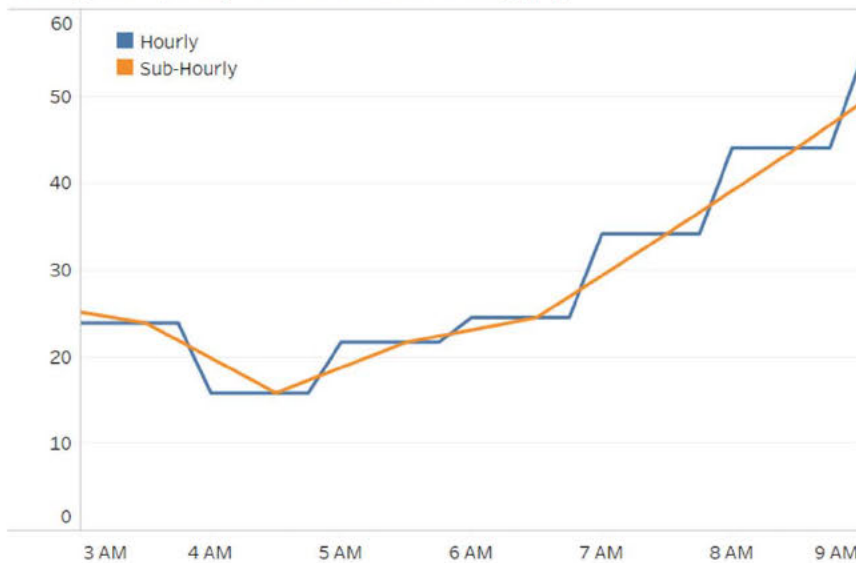
Discussion

- Sub-hourly load and wind inputs are interpolated from same normal values in hourly model – on average sub-hourly outcomes are identical to hourly values used to establish base schedules
- Sub-hourly power prices are from optimized dispatch of resources in sub-hourly WECC wide model
 - Modeled prices for northwest region represent EIM prices at PSE system
 - Implicit assumption that all WECC entities are EIM participants
- PSE's market purchases and sales from hourly model are an input to sub-hourly models
 - These transactions represent bilateral market transactions included in PSE's hourly base schedules

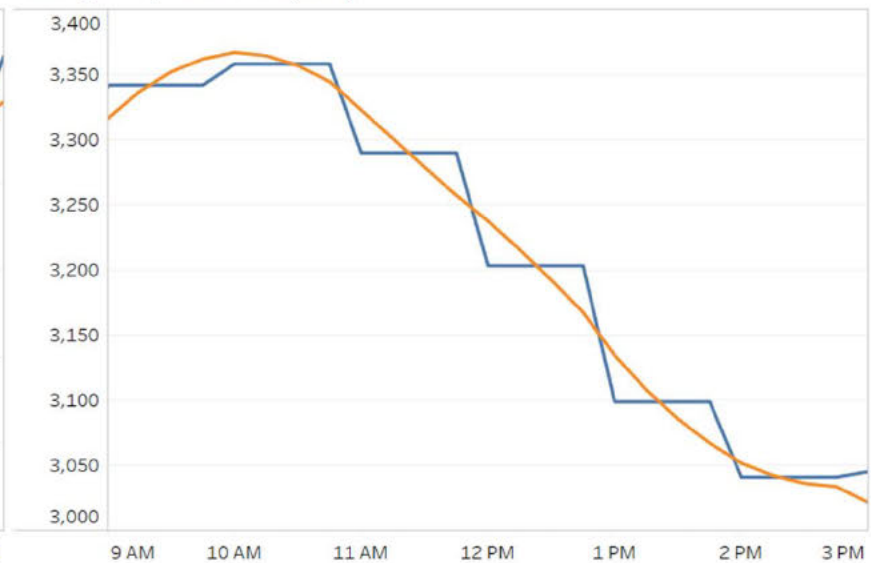
Sub-hourly load and wind inputs are interpolated from normal values in hourly model



Example - capacity factor at a wind facility (%)



Example - system load (MW)



Simplified hydro assumption is necessary to manage model run times and output data

PSE approach

Sample results

Net impact

Discussion

- Current forecasts use average results from 80 individual scenarios (one for each year in the historical hydro data set). This requires 160 model runs in the current hourly modeling approach.
- Proposed sub-hourly modeling approach includes three additional model runs for each scenario. This would require 400 total model runs to do each hydro year individually.
 - Additional runs are in 15-minute intervals, requiring four times as much run time and generating four times more output data to process than the hourly model
 - Proposed approach includes five total runs with average hydro to manage run time
- Avista used median hydro as model input in its 2020 GRC¹ per E3² recommendation
 - E3 reviewed hydro forecast methodologies of seven utilities and PSE is the only one modeling more than one hydro scenario



¹ Docket UE-200900, Exh. CGK-1T and CGK-8
² Energy + Environmental Economics ("E3")

GHG benefits must be estimated outside the Aurora model

PSE approach → Sample results → Net impact → Discussion

- Aurora model approach cannot estimate net GHG benefits from EIM participation
 - Does not allocate sub-hourly market exports to specific BAAs
 - Does not identify which PSE resource directly supplied exports
- Simple average of historical¹ GHG net benefits provides a reasonable estimate of expected future benefits

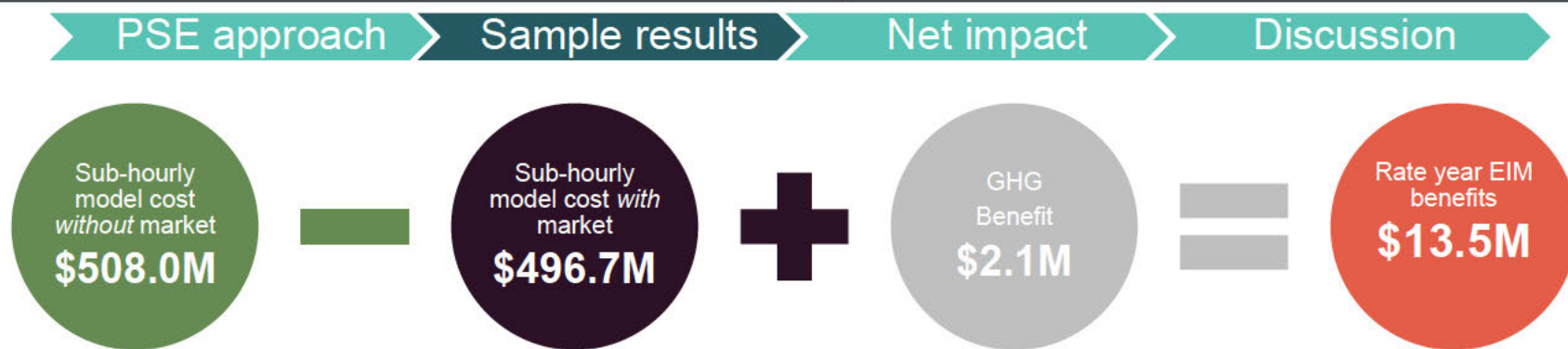
PSE historical actual CAISO EIM GHG net revenue			
	GHG revenue	CCA ² cost	Net GHG benefit
2017	\$1,943,657	(\$2,218)	\$1,941,438
2018	\$2,152,132	(\$9,728)	\$2,142,404
2019	\$2,094,266	(\$16,929)	\$2,077,337
2020	\$2,475,190	(\$73,537)	\$2,401,653
Average	\$2,166,311	(\$25,603)	\$2,140,708



¹ CAISO altered its method for allocating GHG revenue on 11/1/2018. Data from after this time may better reflect future benefits, but the difference would not have a meaningful impact on the numbers presented here.

² California Carbon Allowance ("CCA")

PSE's proposed approach estimates EIM benefits of \$13.5 million for the 2020 PCORC rate year



- 2020 PCORC rate year is the 12 months ending May 31, 2022. Sample results here rely on the same natural gas prices and PSE portfolio inputs used in PSE's supplemental filing.
- Aurora model cost results are only a portion of PSE's total power costs. Remaining costs, approximately \$271.0 million, are fixed costs that do not vary materially based on model output.

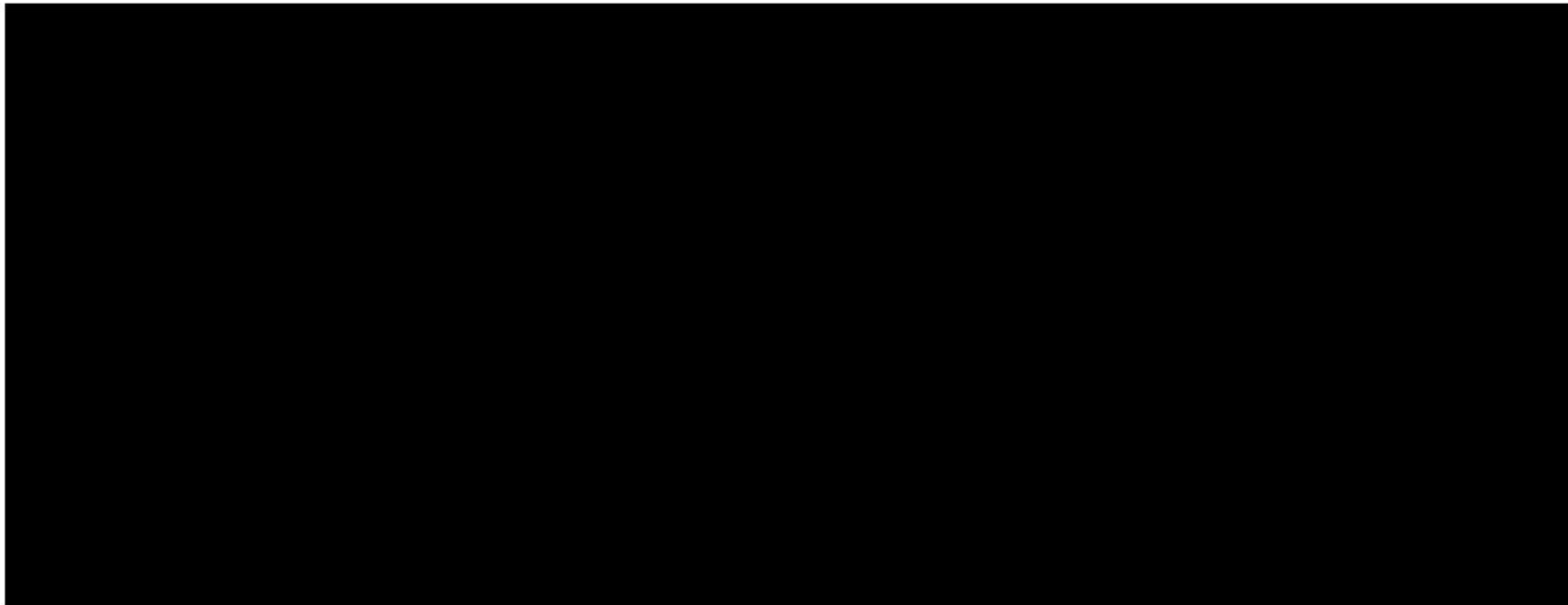
Average sub-hourly market prices align with hourly prices, with increased volatility sub-hourly

PSE approach

Sample results

Net impact

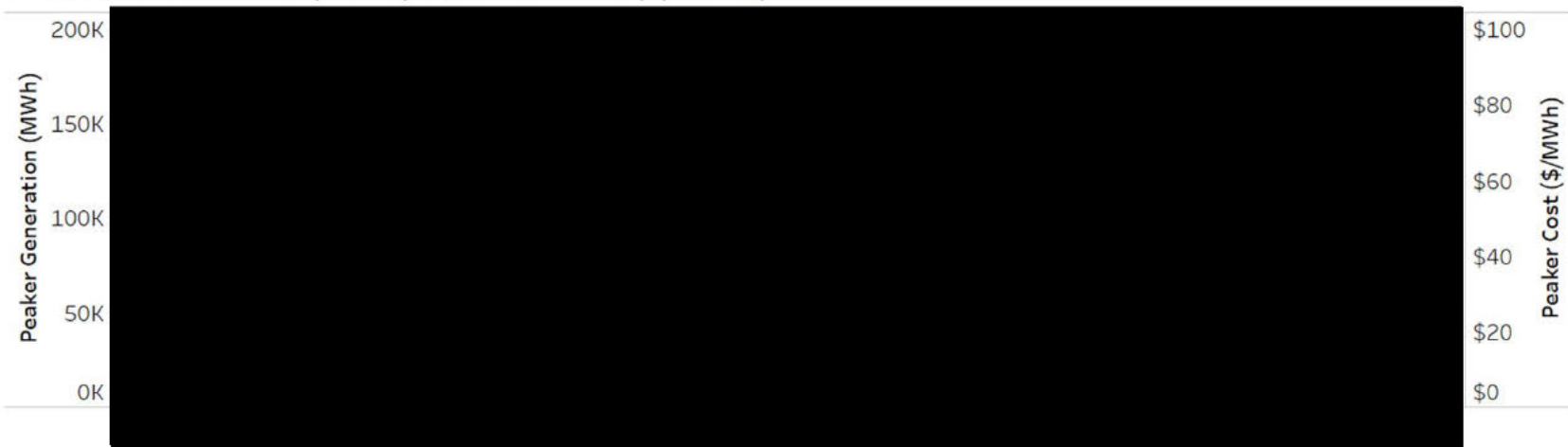
Discussion



Natural gas-fired peaking units generate more with a sub-hourly market, and at a lower average cost



Peaker Generation (MWh) and unit cost (\$/MWh)



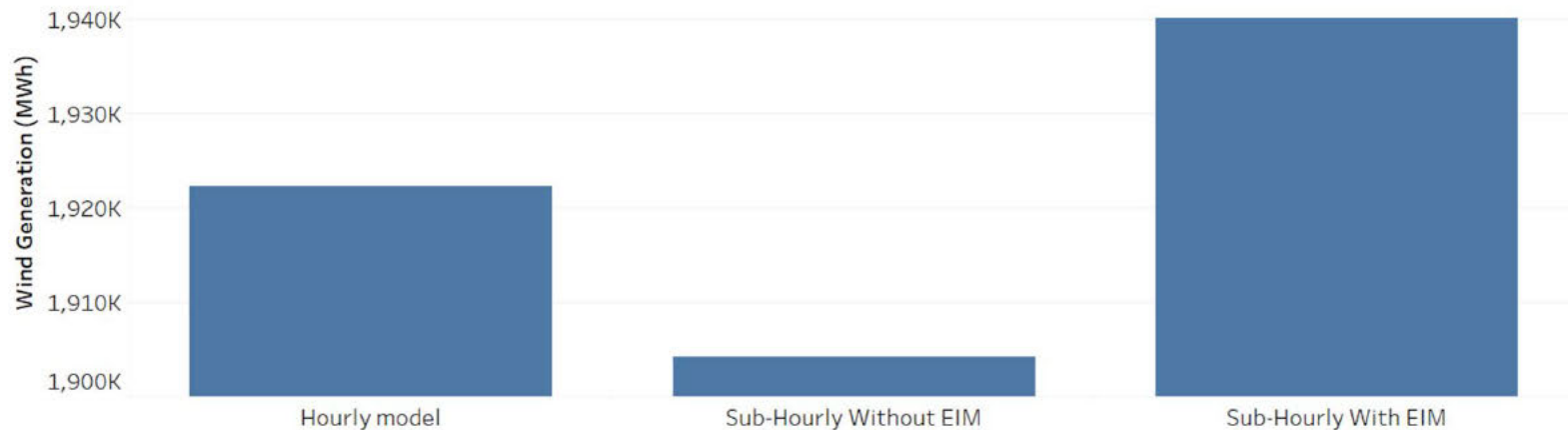
- Lower average cost is the result of operating at more efficient output levels
- Combined cycle gas units have similar but less pronounced results



Wind generation is higher with a sub-hourly market due to fewer curtailments



Wind Generation (MWh)



- PSE wind generation is 1.9% (35,984 MWh) higher with the sub-hourly (SH) market than without.

More thermal resource generation and fewer wind curtailments drive sub-hourly market sales revenue

PSE approach

Sample results

Net impact

Discussion

- PSE is a net exporter in the sub-hourly market model, exporting 395,620 more MWh than it imports
- Net exports generate net market sales revenue of \$16.6 million
- The benefit of sub-hourly market sales revenue is partially off-set by \$5.2 million higher total fuel costs
- \$16.6 million net sales revenue minus \$5.2 million higher dispatch cost equals \$11.4 million EIM benefit in model.

The net impact of including EIM in PSE’s power cost forecast¹ is less than estimated EIM benefits



\$ in millions

1. Hourly model (current method) portfolio cost	\$502.1	Hourly pricing model followed by hourly two zone model (end of current forecast process) using average hydro
2. Sub-hourly model without EIM	\$508.0	Including bilateral market purchases and sales from 1. as an input
3. Increase from sub-hourly costs without EIM	\$5.9	Costs of sub-hourly balancing with only PSE resources, not captured with current hourly model
4. EIM benefits	(\$13.5)	See calculation on slide 11
5. Net impact to variable power costs	(\$7.6)	3. plus 4., compare to (\$8.0) in PCORC settlement
6. Fixed EIM labor & admin. expense	\$3.9	2020 PCORC test year actual
7. Net impact of including EIM in forecast	(\$3.6)	Compare to (\$4.1) in PCORC settlement



¹Sample Aurora model power costs based on 2020 PCORC supplemental filing

PSE proposes to account for the net impact of EIM using sub-hourly Aurora model

PSE approach

Sample results

Net impact

Discussion

- Combine new sub-hourly Aurora model with existing hourly model to calculate portfolio cost at the sub-hourly level including the re-dispatch and transfer revenue benefits of EIM participation.
 - Sub-hourly results become the Aurora model costs used for PSE's power cost forecasts
 - Additional sub-hourly model run calculates portfolio costs without EIM and is used to identify the EIM benefits included in Aurora model costs above.
- Calculate average actual GHG benefits through most recent available data as of forecast date and include as a reduction to variable power costs.
- Include test year actual EIM costs charged to FERC account 557 in fixed power costs

Open discussion

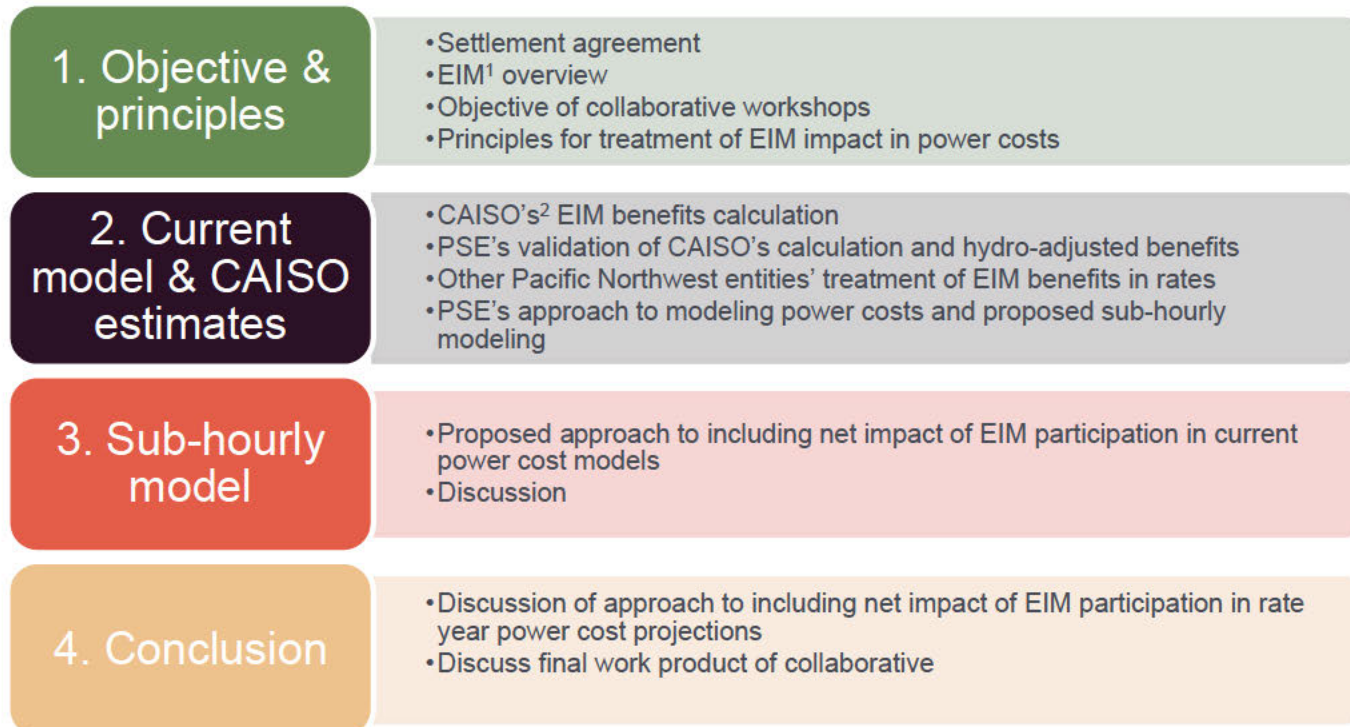
PSE approach

Sample results

Net impact

Discussion

Proposed collaborative roadmap has 4 workshops



Draft agenda for workshop #4

- Continued discussion of approach to including net impact of EIM participation in rate year power costs
- Discussion of collaborative conclusions and final work product