Extended Day-Ahead Market Benefit Study

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LAS VEGAS, NV

AUGUST 30, 2023

Brattle

Scope of Study

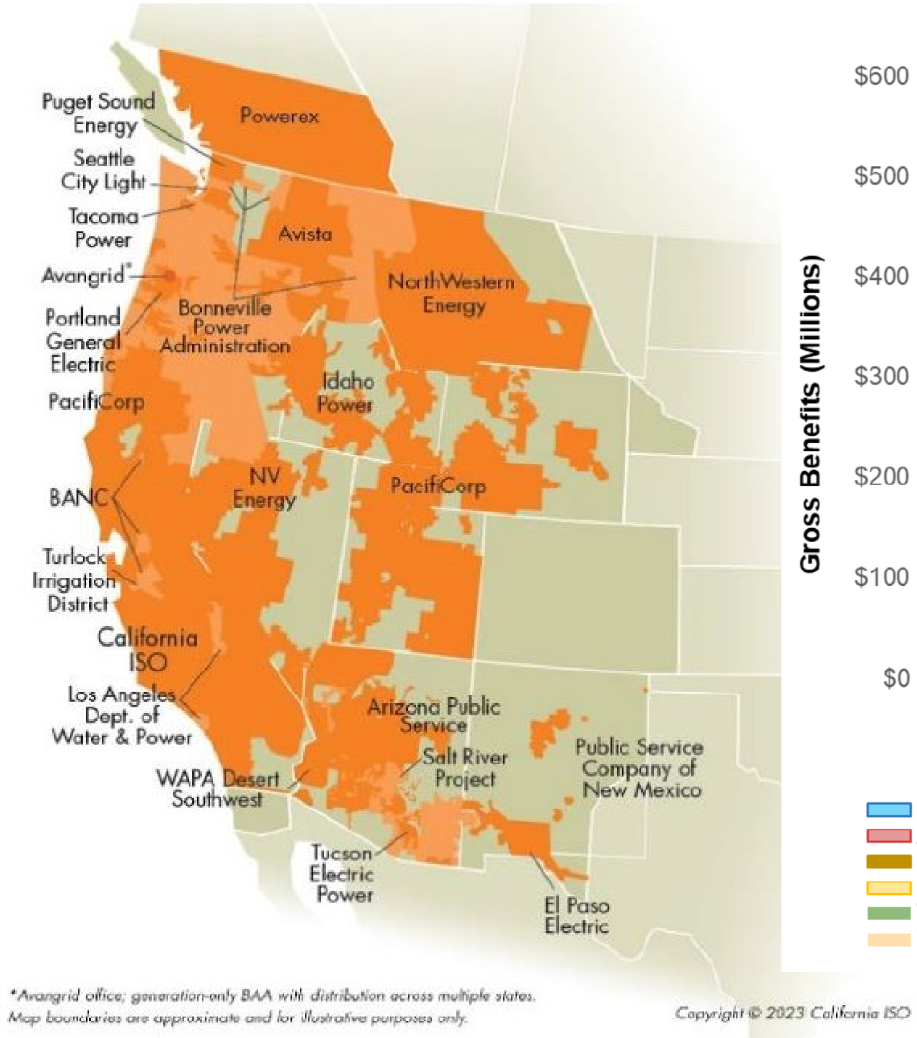
To simulate the specific EDAM design on a realistic footprint, not a simplified representation of a wholesale market across the entire WECC

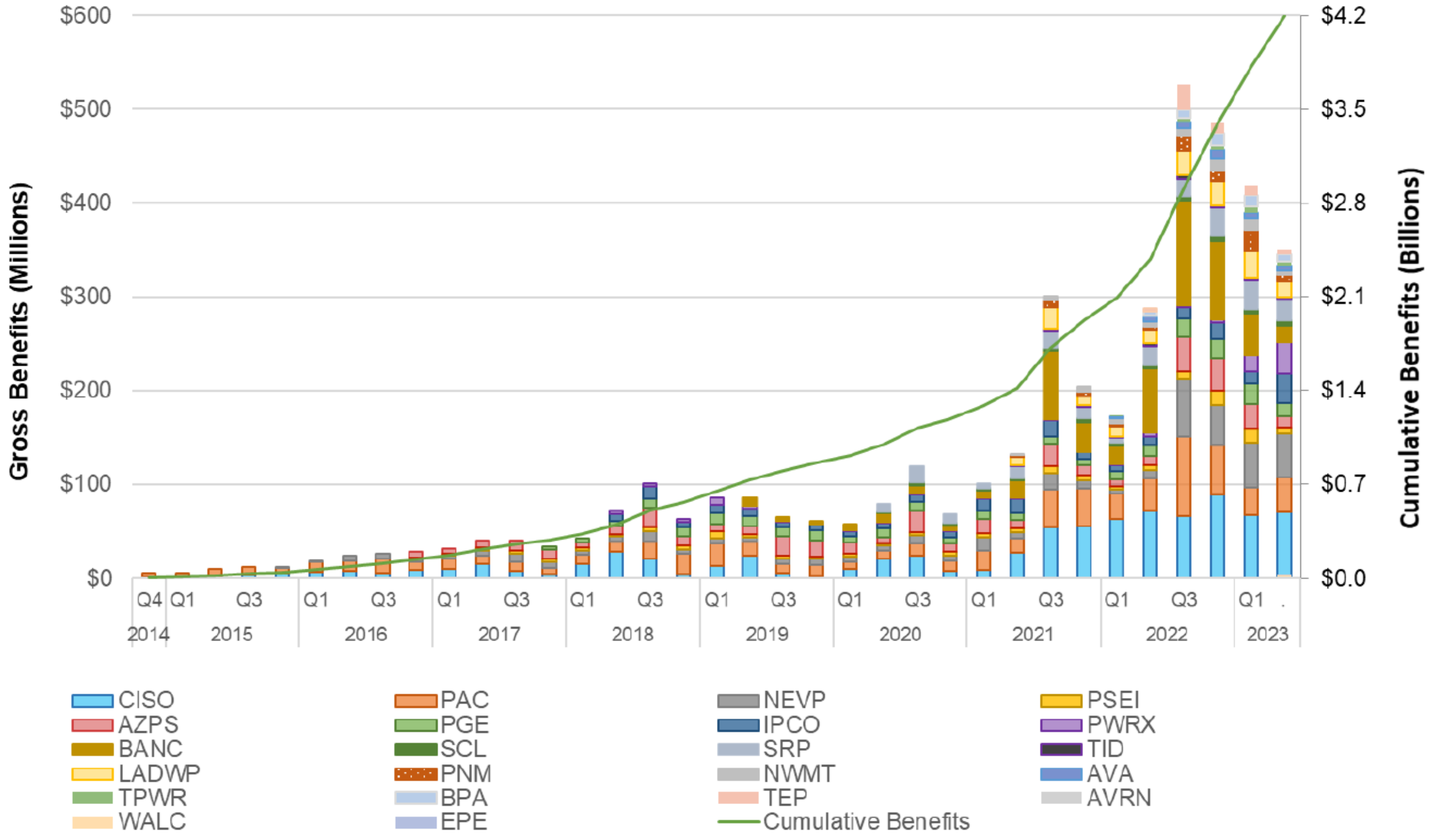
- **Calculate multiple benefit metrics:** (1) Adjusted Production Cost (APC), (2) impact on wheeling revenue, (3) loss of bilateral trading profits, and (4) EDAM congestion and transfer revenues
- **Model EDAM's GHG structure:** as specified in the EDAM design
  - Simulated the "GHG Reference Pass" to set limits on transfers into the GHG region (CA and WA)
  - Modeled resource-type specific GHG costs
- **Simulate existing real-time markets:** continued existence of the WEIM in parallel with the EDAM
  - Estimated the impact on existing WEIM trades and congestion revenues
- **Capture value of coupled day-ahead and real-time markets to manage unexpected imbalance:** modeled renewable and load forecast uncertainty between DA and RT
- **Realistically represent bilateral markets:** captured existing transmission rights, major trading hubs, block trading, CAISO intertie trades, hourly BA-to-BA trades, wheeling charges where applicable

Study participants: BANC, Idaho Power, LADWP, and PacifiCorp

- Communicated with CAISO about their system characteristics and the proposed EDAM design

The Study Estimates EDAM Benefits Incremental to EIM Benefits



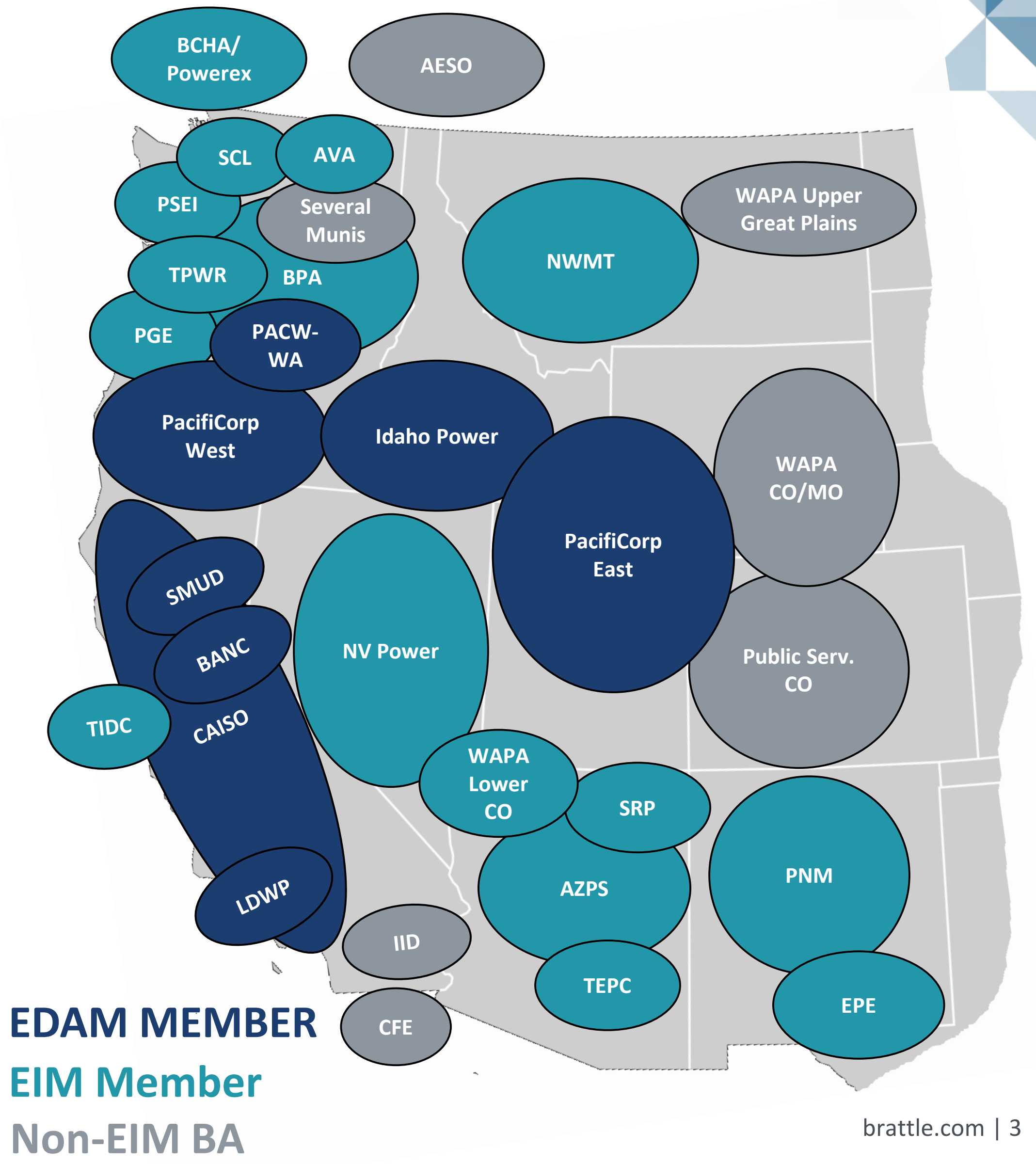


Modeled EDAM Footprint and Study Year

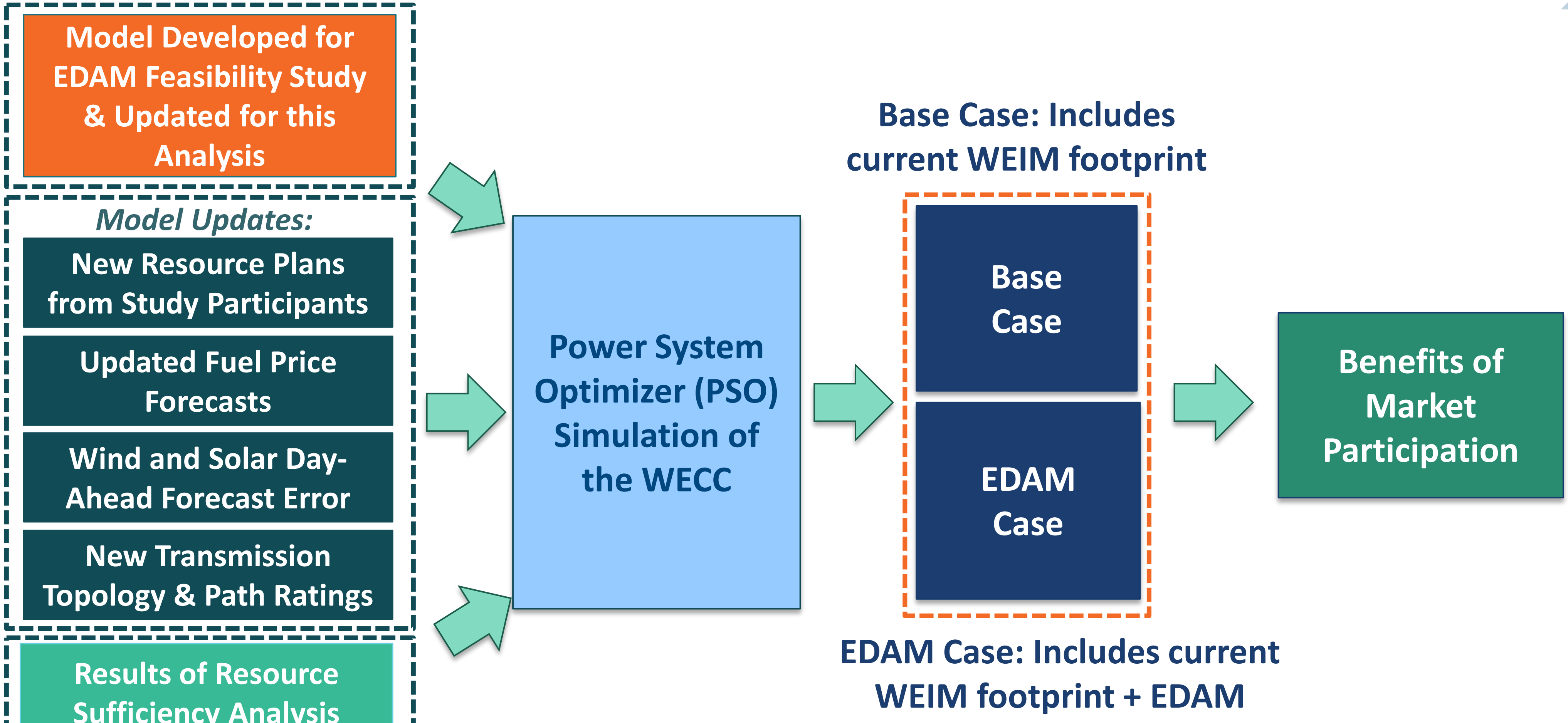
Simulations are based on 2032 as a proxy year to represent annual benefits for the first decade of EDAM operations

The simulated EDAM footprint includes:

- **PacifiCorp**, broken into PAC-East (PACE), PAC-West (PACW), and PAC-West in Washington (PAWA)
- The **California ISO** (CAISO)
- **Idaho Power** (IPCO)
- **Los Angeles** Department of Water and Power (LADWP)
- The **Balancing Authority of Northern California**
  - Broken into SMUD and "Rest of BANC"



Study Approach and Framework



Summary of EDAM Study Results

The results document significant benefits offered by the proposed EDAM design:

- **Over $800 million in annual cost savings to EDAM participants, with net benefits of over $430 million**
  - Savings associated with 50 TWh in EDAM transactions, representing a 27% increase in trade between EDAM participants
  - Every one of the assumed EDAM participants benefits (even after considering reduced bilateral trading gains and wheeling revenue losses, if any)
  - Results are incremental to benefits from EIM membership (i.e, based on difference of “EDAM+EIM” benefits and “EIM” base-case benefits),
    - The study finds that EIM trading declines slightly, reflecting that day-ahead optimization under EDAM more efficiently takes on a portion of the role played by EIM today
- **2.4 TWh in reduced renewable generation curtailments and reduced overall emissions**
  - The EDAM design’s reference pass methodology successfully prevents any significant resource reshuffling, resulting in EDAM-, EIM-, and WECC-wide decreases of GHG emissions, with lower renewable generation curtailments, reduced fossil fuel generation, and a displacement of less efficient generation with increased output from lower-cost resources

Summary of 2032 EDAM Footprint-Wide Benefits

The assumed EDAM footprint is estimated to see gross benefits of $810 million/year, with net benefits estimated at $438 million.

Benefits driven by 50 TWh increase in day-ahead trades between the assumed EDAM participants, with significant EDAM congestion and transfer revenues

EDAM Benefits ($ millions/year)

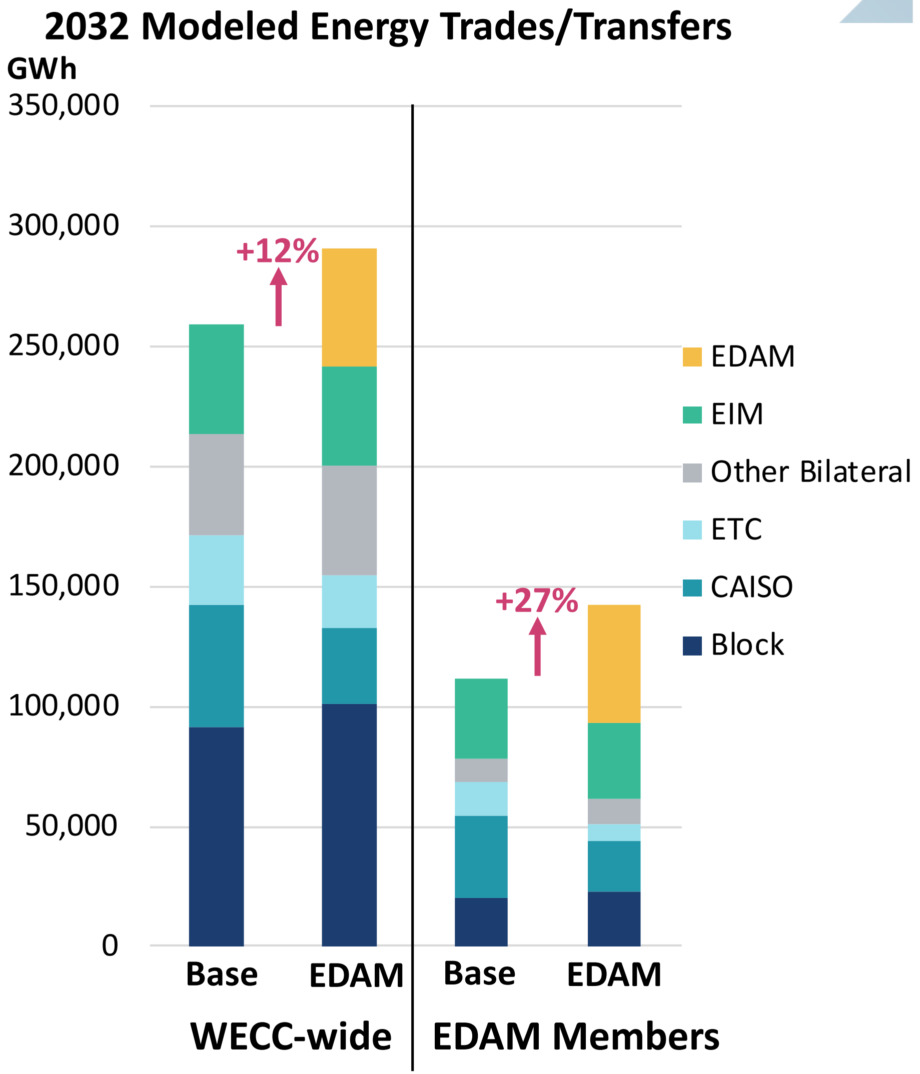
Benefit Metric	Modeled EDAM Footprint
EDAM Benefits	
Adjusted Production Cost Savings	$134
EDAM Congestion Revenues	$269
EDAM Transfer Revenues	$409
Total EDAM Benefits	**$813**
Other EDAM Related Impacts	
Impact on Wheeling Revenues	-$103
TRR Settlements *[1]*	$0
Impact on EIM Congestion Revenues	-$16
Impact on CAISO DA Tieline Trading Value	-$57
Reduced Bilateral Trading Value *[2]*	-$199
Net EDAM Benefits	**$438**

Notes:
[1] TRR settlements (hold harmless for lost wheeling revenues) are zero for footprint
[2] Reduced bilateral trading values of exports and imports from the BAs of EDAM members, includes impacts on trades by third-party marketers.

Total BA-to-BA Transfers by Trade Type

The EDAM market **enables a 12% increase in overall WECC transfers/trades**, and a 27% increase directly for the EDAM members

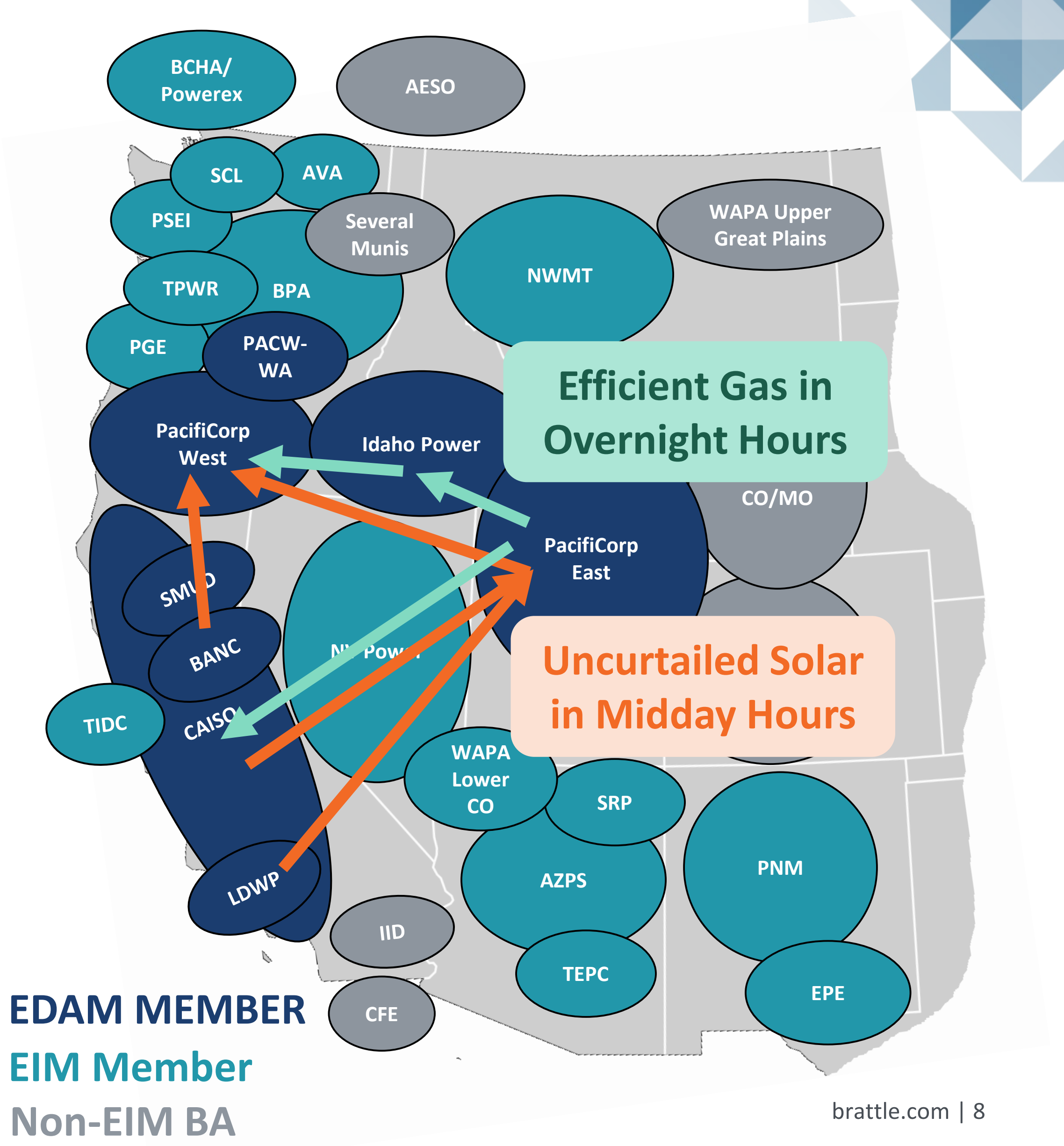
- Total WECC trading increases ~30 TWh due to the EDAM market
- New WECC trading comes from block trades (+11%), and hourly bilateral trading (+7%)
- Trading volumes decrease in EIM (-9%), for CAISO intertie trades (-39%), and hourly trades on long-term ETCs (-23%)
- **Total EDAM transactions: 51 TWh**



Trading Patterns in EDAM

We observe two key patterns the simulated in EDAM transactions:

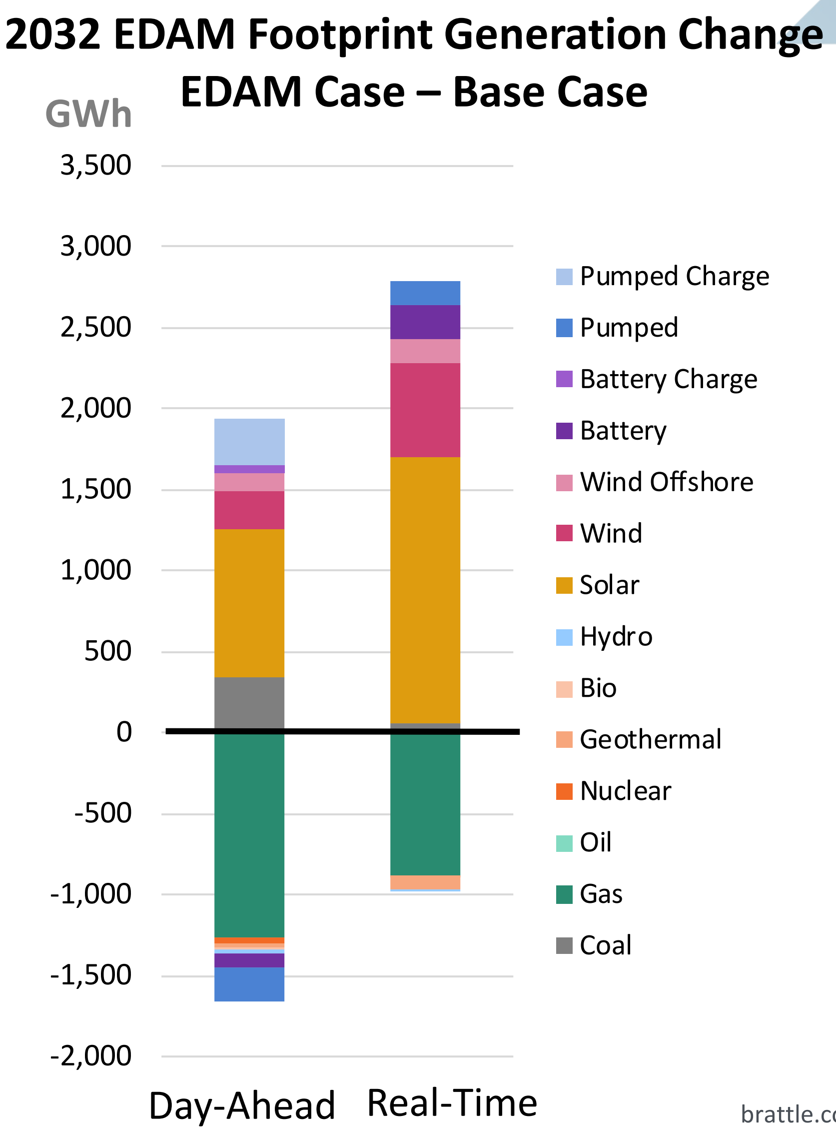
- During midday hours, the market uses excess solar in CAISO, which would get curtailed without EDAM, to back down thermal generation in PACE, PACW, and IPCO
- In the overnight hours, the most efficient gas-fired generation (usually in PACE) displaces less efficient (i.e., higher cost and higher emitting) gas generation in CA, OR, and WA
- Trading patterns would likely become more efficient as new members join the footprint
  - Our EDAM footprint has little PNW hydro and no AZ/NV solar with a different profile than CA solar



Generation Change: Base Case to EDAM (DA and RT)

EDAM enables beneficial shifts in the generation mix to achieve production cost savings and emissions reductions

- Renewable curtailments fall ~1,200 GWh in day-ahead, ~2,400 GWh in real-time
- In day-ahead, reduced renewable curtailments displaces mostly gas
- In real-time, the simulated EDAM footprint exports more renewables (due to lower curtailments) and gas generation to the non-EDAM portion of the EIM footprint
  - Overall, gas generation is lower due to implementation of EDAM
- Emissions fall in EDAM, EIM, and WECC

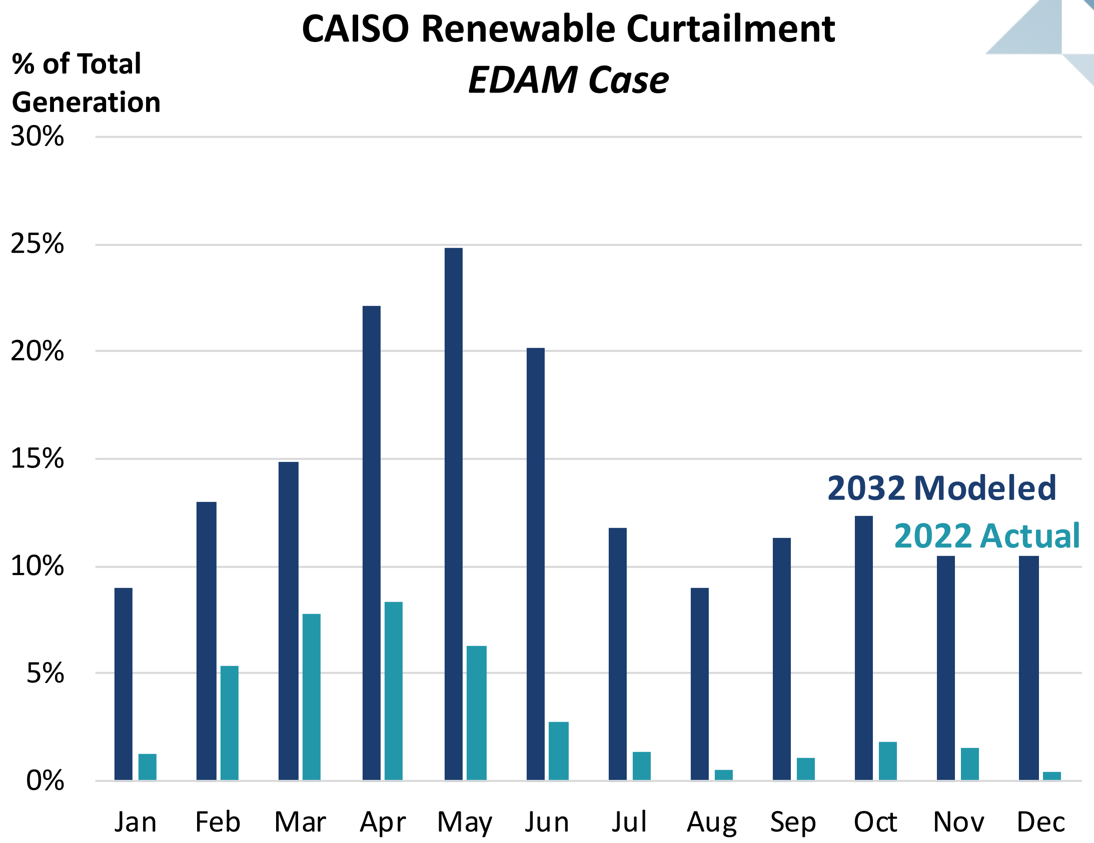


CAISO Renewable Curtailments: 2032 model vs. 2022 actual

While EDAM reduces curtailments by ~2.4 TWh, curtailed renewable energy in CAISO still amounts to over 10% of all renewable generation in the BAA

- In spring shoulder months, over 20% of renewable energy is curtailed in the CAISO BAA
- There remains over 20 TWh of curtailments in CAISO in our 2032 EDAM Case

This result highlights the potential for increased benefits as more BAAs join EDAM, particularly BAAs with additional transmission rights into CAISO/California



Note: Includes solar, wind, and offshore wind for CAISO.

GHG Emission Reductions: EDAM vs. Base Case

EDAM reduces emissions: both within the GHG-regions of EDAM and the remaining EDAM footprint, as well as within EIM and WECC-wide

Simulations show that EDAM's GHG design (incl. its reference pass methodology) successfully prevents significant resource reshuffling, resulting in:

- Reduced renewable generation curtailments, particularly in high-renewable areas such as CAISO
- Switching from less efficient gas units to more efficient gas units within the EDAM footprint
- WECC-wide, coal generation falls by 200 GWh
- PacifiCorp-, EDAM-, EIM-, and WECC-wide decreases of GHG emissions

Total Emissions in Million Metric Tons (2032)

	EDAM			WECC	
Case	**EDAM GHG Region**	**EDAM Non-GHG**	**Total EDAM**	**Total EIM**	**Total WECC**
Base Case	16.31	19.31	35.62	125.37	170.70
EDAM Case	15.78	19.20	34.98	125.13	170.42
EDAM - Base	***-0.54***	***-0.11***	***-0.65***	***-0.24***	***-0.29***

Comparison with other Recent WECC Market Benefit Studies

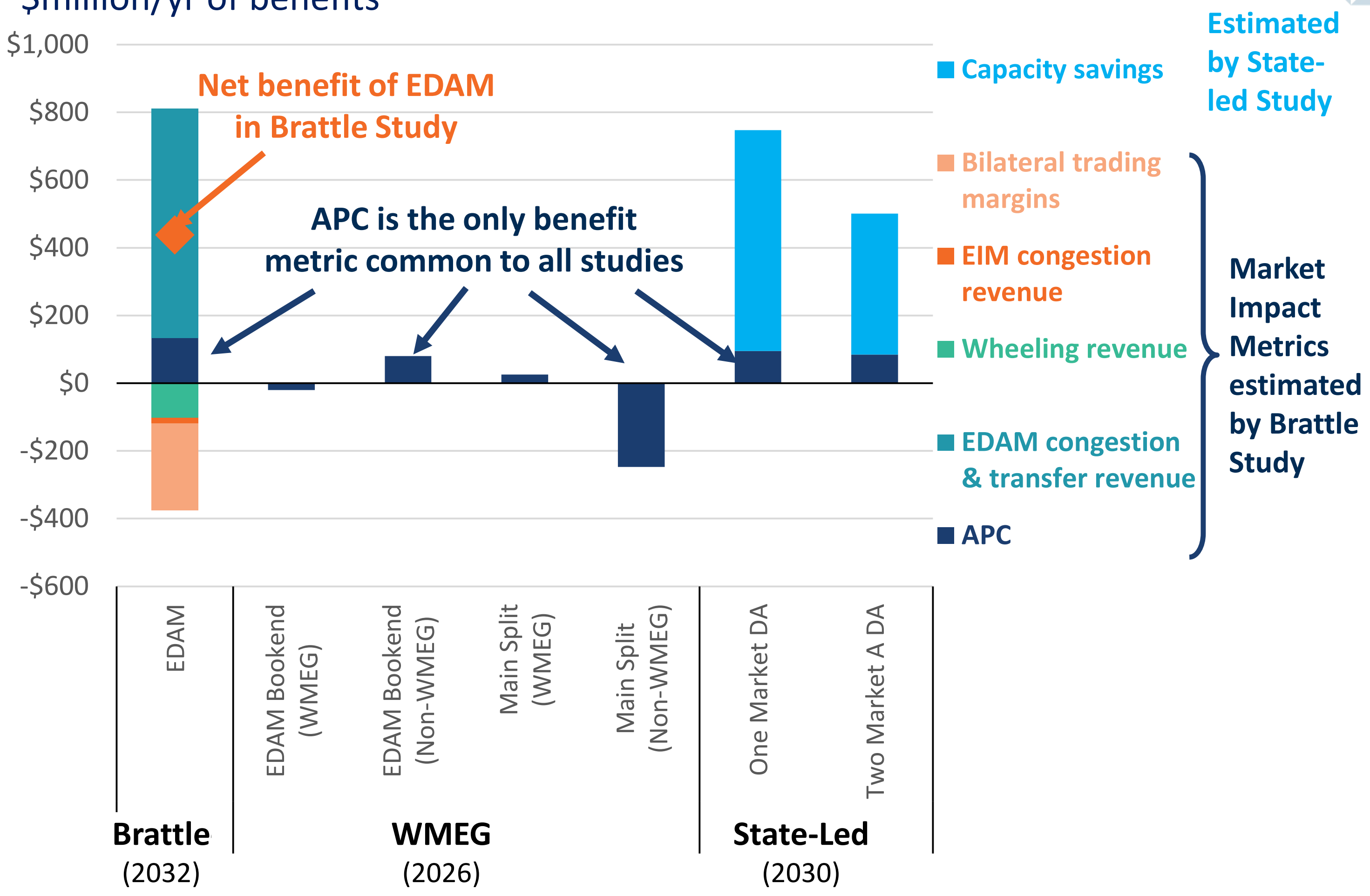
Recent market studies focus on APC benefits and may not have reflected the specific characteristics, likely footprints, and payments associated with the EDAM

It is difficult to compare the benefit estimates across studies, because each estimated different metrics

- The WMEG and State-led studies show lower Adjusted Production Cost (APC) benefits from a day-ahead market than our study
- Brattle's is the only study to quantify congestion and transfer revenues, wheeling fee losses, loss of bilateral trading profits
- The State-led study estimated resource adequacy related investment benefits (capacity savings), which do not apply to EDAM but would apply to a WRAP or RTO

Summary of Market Benefits Results Across Studies

$million/yr of benefits



Note: State-led study doesn't include a Two Market case for DA (not full RTO) that includes CAISO, but benefits for such a case would likely fall between those of the One Market DA and Two Market A DA cases.

Estimated EDAM Benefits are Conservatively Low

The estimated benefits are likely understated due to several factors:

- **Overstated base-case efficiency:** our simulation of the status quo is more efficient than reality.
  - The Base Case assumes that balancing authorities have optimal security-constrained unit-commitment and dispatch (SCED) in both DA and RT, making the simulated dispatch more optimal than in reality.
  - Inefficient utilization of transmission due to bilateral scheduling and trading is not fully modeled, understating the extent EDAM will be able to make better use of available transmission.
  - Transmission outages are not modeled, which would magnify the benefit of SCED-based congestion management in EDAM compared to the status quo
- **Normalized loads and fuel prices:** the model uses weather-normalized loads and averaged monthly natural gas prices without daily volatility.
  - Challenging market conditions, such during as the 2022 gas price spikes, will magnify EDAM benefits. Illustrated by the WEIM experience in 3Q of 2021 and 3Q-4Q of 2022.
  - The Base Case does not reflect the limited liquidity of bilateral market during such challenging market conditions.
- **No capacity benefits quantified:** we have not quantified the extent to which EDAM may reduce investment costs associated with lower operating reserve requirements.
- **Limited EDAM footprint:** like in EIM, EDAM benefits will increase as more parties join EDAM

Model Overview and Assumptions

Overview of Modeling Approach

We utilize the WECC ADS nodal production cost model as a starting point imported into Power System Optimizer (PSO), as refined during the EDAM feasibility study and follow-on engagements

Utilized the Polaris Power System Optimizer (PSO), an advanced market simulation model

- Nodal mixed-integer model representing each load and generator bus in the WECC
- Licensed through Enelytix
- Detailed operating reserve and ancillary service product definition
- Detailed representation of the transmission system (both physical power flows and contract paths)
- Sub-hourly granularity (but used hourly simulations due to limited data availability)
- Designed for multiple commitment and dispatch cycles (e.g., DA and RT) with different levels of foresight
- EDAM feasibility study assumptions updated to reflect the most recent utility resource plans and forecasts of system conditions and costs

ENELYTIX®
powered by PSO

PSO is uniquely suited to simulate bilateral trading, joint dispatch, imbalance markets, and RTOs, reflecting multiple stages of system operator decision making

Independent Simulation of Multiple Time Horizons

PSO simulates multiple independent decision cycles to capture day-ahead vs. real-time unit commitment and dispatch

D-1 (am)	D-1 (~noon)	D-1 (pm-D)	D
DA Bilateral Markets	**Day-Ahead Market**	**Intra-Day Markets**	**EIM (RT Balancing)**
• DA block trades on long-term transmission rights and incremental transmission	• CAISO, EDAM, and RTO market clearing • Hourly intertie trading • Hourly trading with long-term transmission rights	• Hourly bilateral trades on remaining transmission	• EIM/CAISO trading of economic energy • Transmission released for EIM • RT balancing in BAAs

Independent real-time decision cycle used to simulate EIM functions

DA Unit Commitment Cycle → **DA Economic Dispatch Cycle** → **Real Time Cycle**

Decision cycles capture bilateral trading, market clearing, BAA functions in DA and RT, and market cycles (incl. EDAM "GHG reference" pass, EDAM market, and EIM)

Independent real-time decision cycle used to simulate DA vs. RT, including forecast errors for wind and solar

Multi-Functional Simulation of WECC

Markets/RTO Functions & Configurations

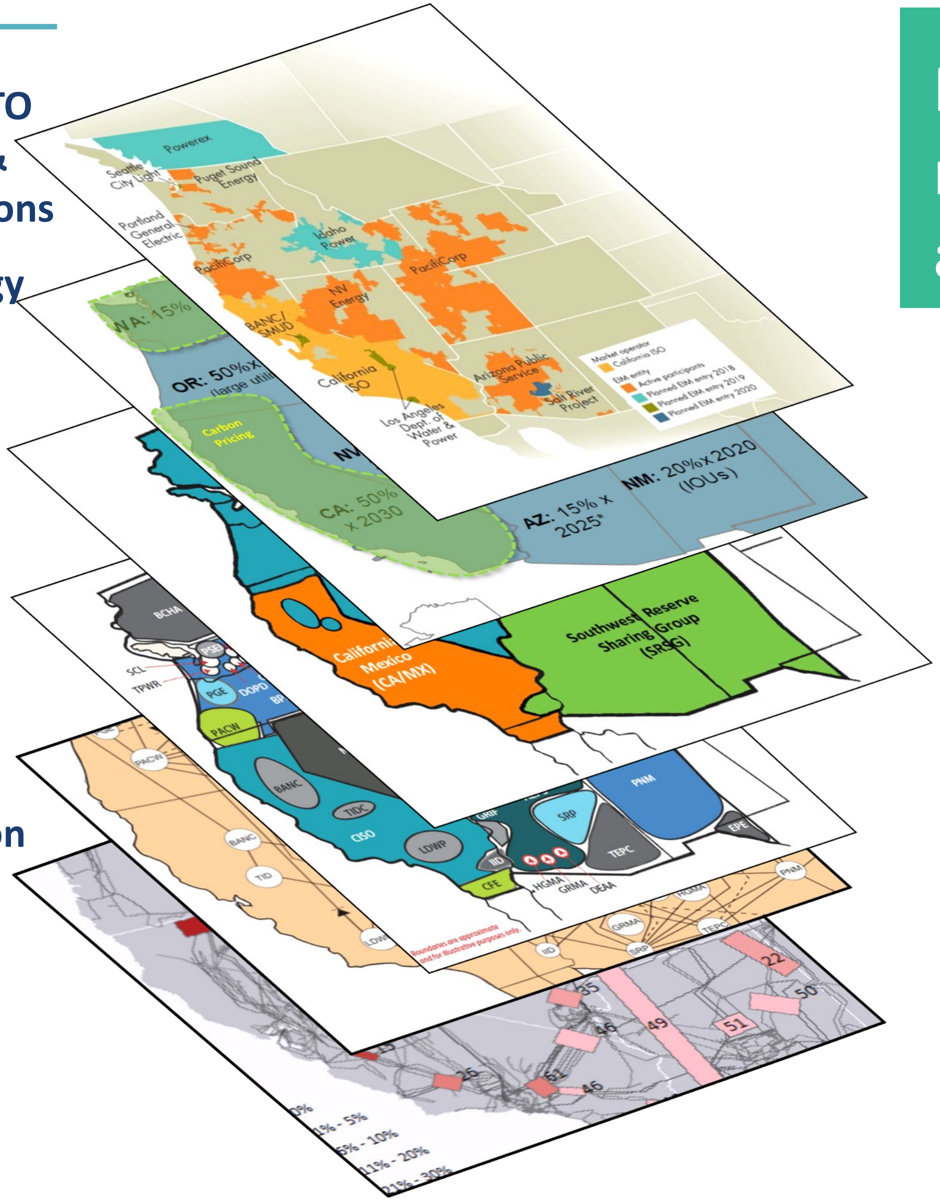
Clean Energy Policies

Reserve Sharing

BAA Functions

Contract Paths and Transmission Rights

Physical Flows and Constraints



PSO’s multi-layer simulations represent the various physical, policy, and operational facets of the WECC

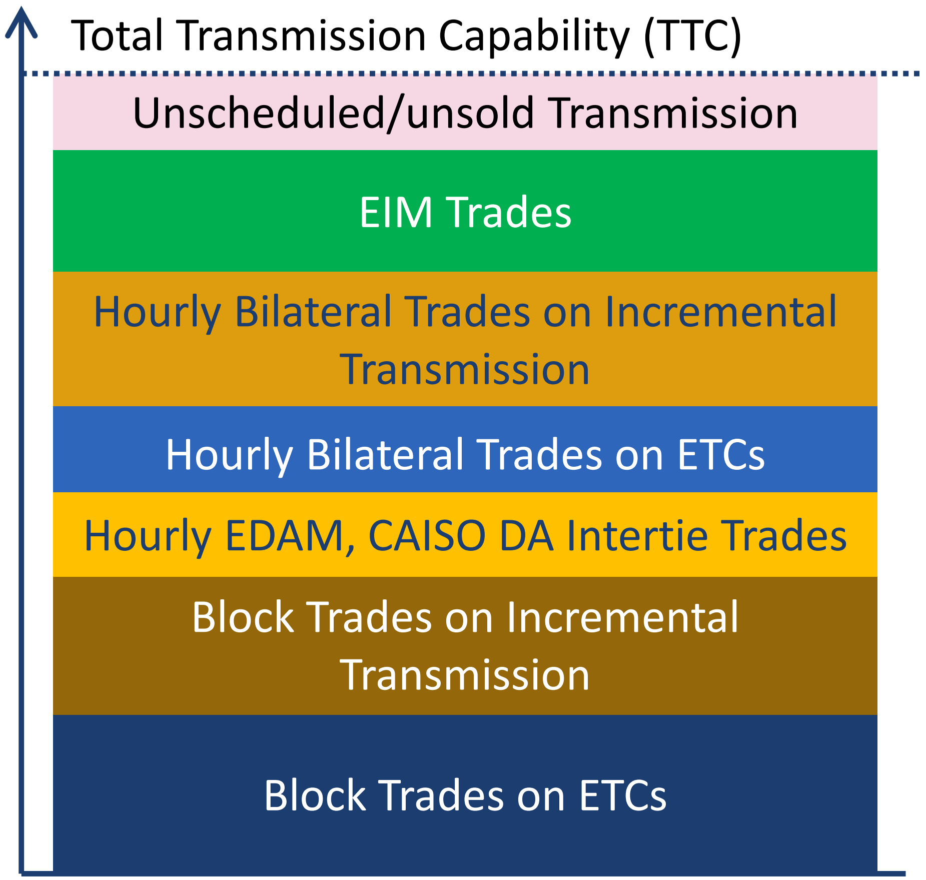
- Physical grid with ~20k buses, ~25k lines and ~5k generators represented as DC power flow
- 38 Balancing Authority Areas (BAAs) and contract paths
- The WECC reserve sharing groups
- Diverse state clean energy policies
- Major trading hubs (e.g., Mid-C, Malin, PV)
- Bilateral transmission rights
- Renewable diversity, day-ahead forecast uncertainty, real-time operations
- CAISO and WEIM footprints

Types of Trades and Transmission Reservations Modelled

Our model simulates the use of different types of contract-path transmission reservations for bilateral trading across DA and RT

- Existing long-term transmission contracts (ETCs) and incrementally purchased transmission
- Total reservations on each contract path is limited by the total transfer capability (TTC)
- Trades are structured as blocks or hourly
- Bilateral trades between BAs, at major hubs, or across CAISO interties
- Account for renewable diversity and day-ahead forecast uncertainty vs. real-time operations
- Unscheduled transfer capability released for EIM trades in real-time

Types of Trades Modeled



Modeling Assumptions: Generation Mix, Gas Prices, Reserves

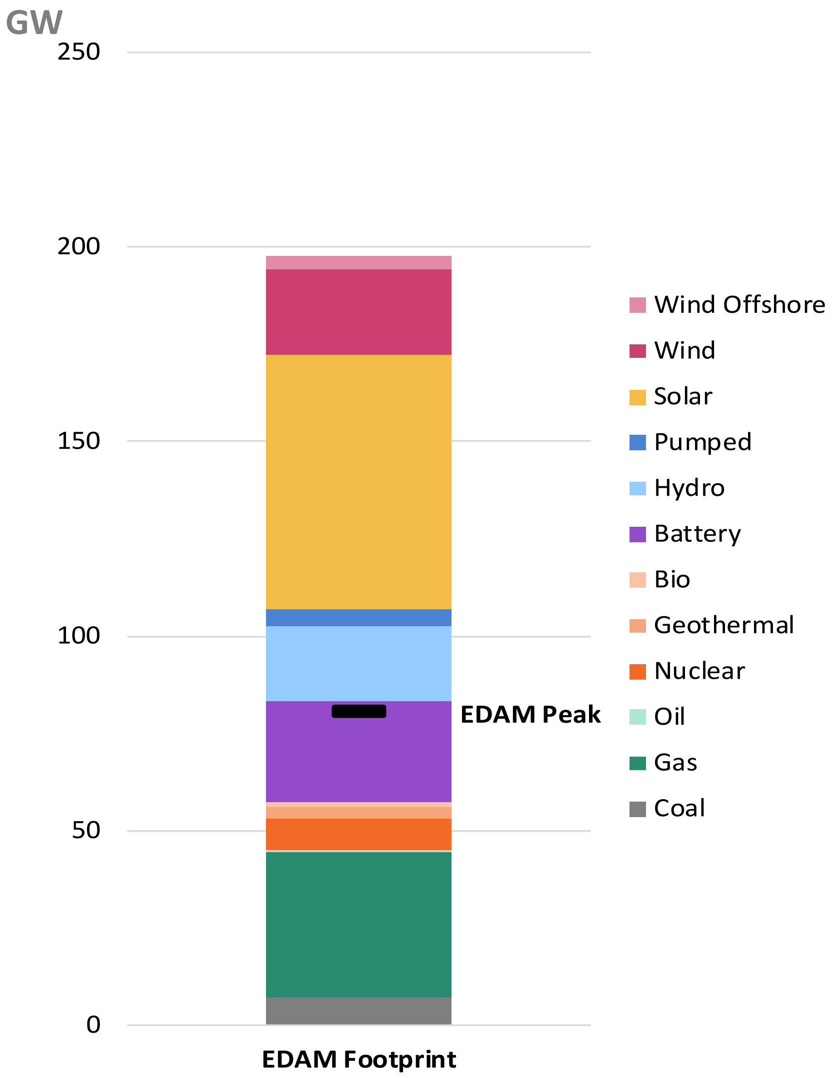
Total capacity in assumed EDAM footprint: nearly **200 GW**

- Resource mix based on published plans as of Fall 2022
- Dispatchable capacity (including battery and hydro) exceeds EDAM peak by ~40 GW
- Solar capacity by 2032 is nearly 100 GW, with a significant portion from CAISO

Gas Price Forecast

- Compared the data from multiple participants at SoCal, Kern, Malin, and Sumas, and are using the middle forecast of the group, which shows prices between $4-5/MMBtu (2022$)

2032 Capacity Mix in EDAM Footprint

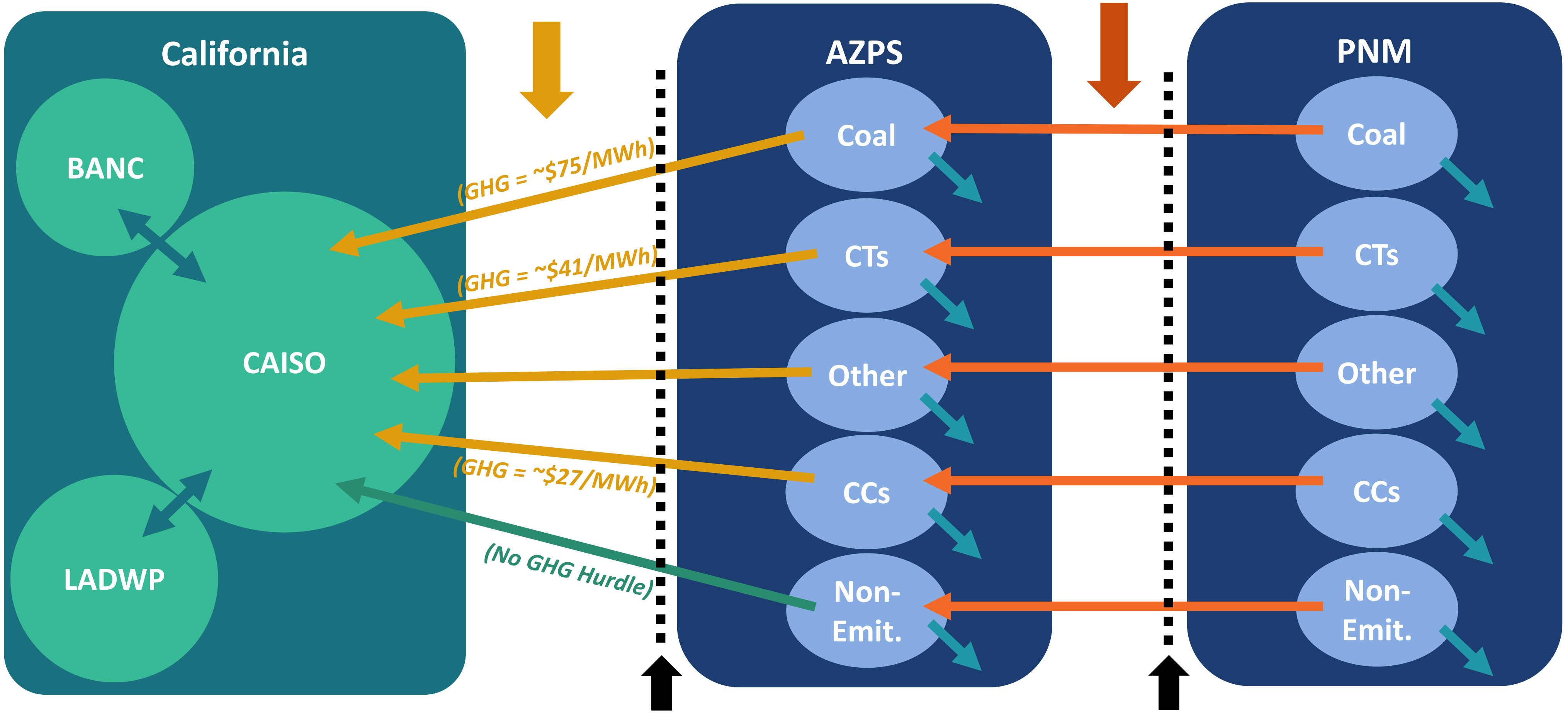


EDAM GHG Structure: Illustration

Sales incur unit GHG cost, relevant hurdles, and are limited by attributions from the GHG Reference Pass

Resources can sell into neighboring BAAs by paying applicable fees:

- Bilateral market: OATT fee, trading margin
- EIM: no hurdle on available transmission
- EDAM: no hurdle on Buckets 1,2, & 3



Resources serve load in their own BAA with no hurdle

Flows restricted to BAA export limit
+ BAA Net Export GHG Attribution Limit

A nomogram restricting total BAA-to-BAA flows to export limit, which varies by market type – bilateral, EIM, and EDAM

EDAM GHG Structure: "Reference Cycle"

Our GHG modeling structure accounts for two constraints specified in the EDAM design for GHG attributions relative to a baseline from EDAM's "reference pass" cycle, which we simulate as well

1. **Resource Specific GHG Attribution (resource-type attribution under proposed approach) =**

max{0, min{GHG Bid, UEL – Reference Pass, Optimal Dispatch}}

Simulations assume resources bid all their capacity into the GHG Region

Calculated using results of our GHG Reference Pass run

GHG attribution cannot exceed final dispatch of resource

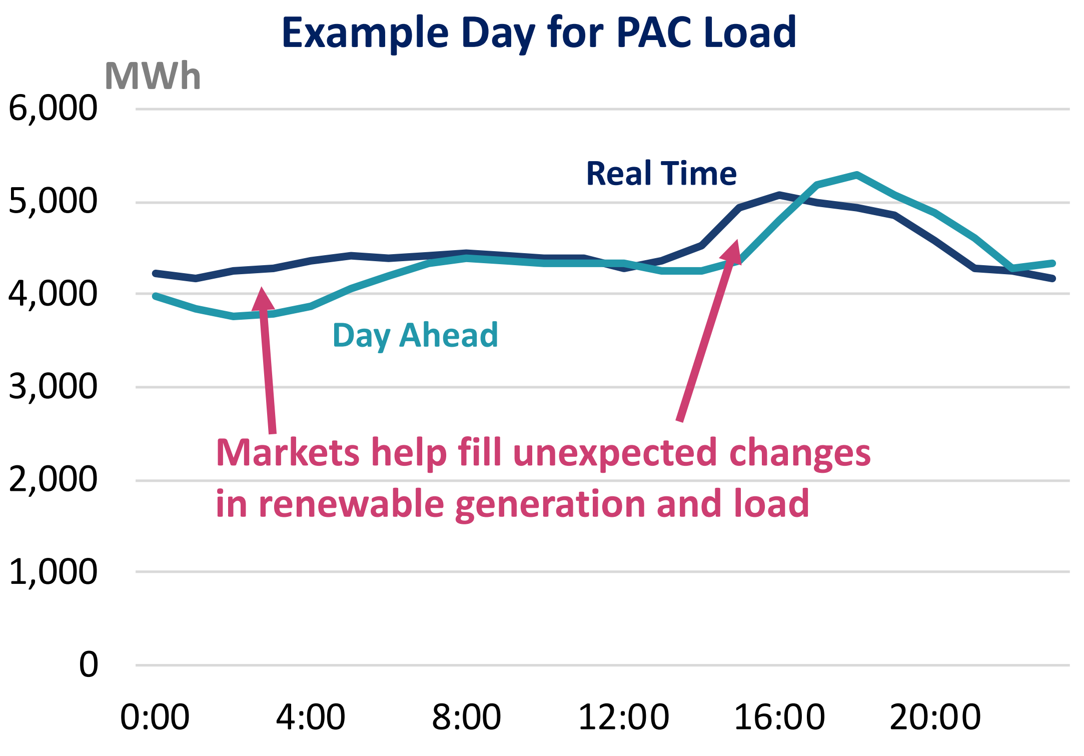
2. **BAA Total GHG Attribution <= (Net TTC Difference - BAA Net Exports hourly in reference pass)**

These reference pass results set **hourly export limits** that are enforced in the actual EDAM case for EIM and EDAM members for sales to GHG balancing authorities

Day-Ahead Load & Renewable Forecasting Errors

Historical utility load and renewable data was used to develop a representation of 2032 DA/RT forecast error

- Different load profiles applied in the DA and RT cycles of the model to capture forecast error
- Used for all EDAM members, including CAISO
- Allows for a **better estimate of the value of markets**, which helps BAs react to forecast errors



EDAM Modeling Assumptions: Resource Sufficiency, Transmission

Resource Sufficiency Test

- The EDAM Straw Proposal applies the Resource Sufficiency Test to each EDAM member the day prior to real-time, before day-ahead market operations
  - In the 2019 EDAM Feasibility Study, E3 conducted an hourly analysis of Resource Sufficiency for each proposed EDAM member at that time
    - In that analysis, failure of the test was extremely rare
    - In fact, all current study participants (BANC, CAISO, IPCO, LADWP, SMUD, and PAC) previously passed the resource sufficiency test in all hours
  - For this study, conducted ex-post check and confirmed that all assumed EDAM members are resource sufficient in all hours

EDAM Transmission

- All three buckets of EDAM transmission are modeled and assumed to be hurdle-free:
  - Bucket 1: Transmission to Support Resource Sufficiency
    - Includes existing long-term transmission contracts (“ETCs”) for energy used for sufficiency accounting purposes
  - Bucket 2: “Donated” Transmission Contracts
    - Existing transmission contracts (ETCs) made available (“donated”) to the EDAM by participants
  - Bucket 3: Unsold Firm Transmission
    - Remaining transmission made available for EDAM (participants might hold back from transmission for block trading)
- Simulated Bucket 1 and 2 EDAM transmission equals total ETC capacity; Bucket 3 transmission equals the remaining transfer capability (i.e., TTC less ETC) between the assumed EDAM members

Imbalance Reserve Requirement

EDAM reserve requirement estimated to fall about 2 GW/hr in the EDAM Case (relative to Base Case) due to the diversity benefit achieved by the EDAM footprint

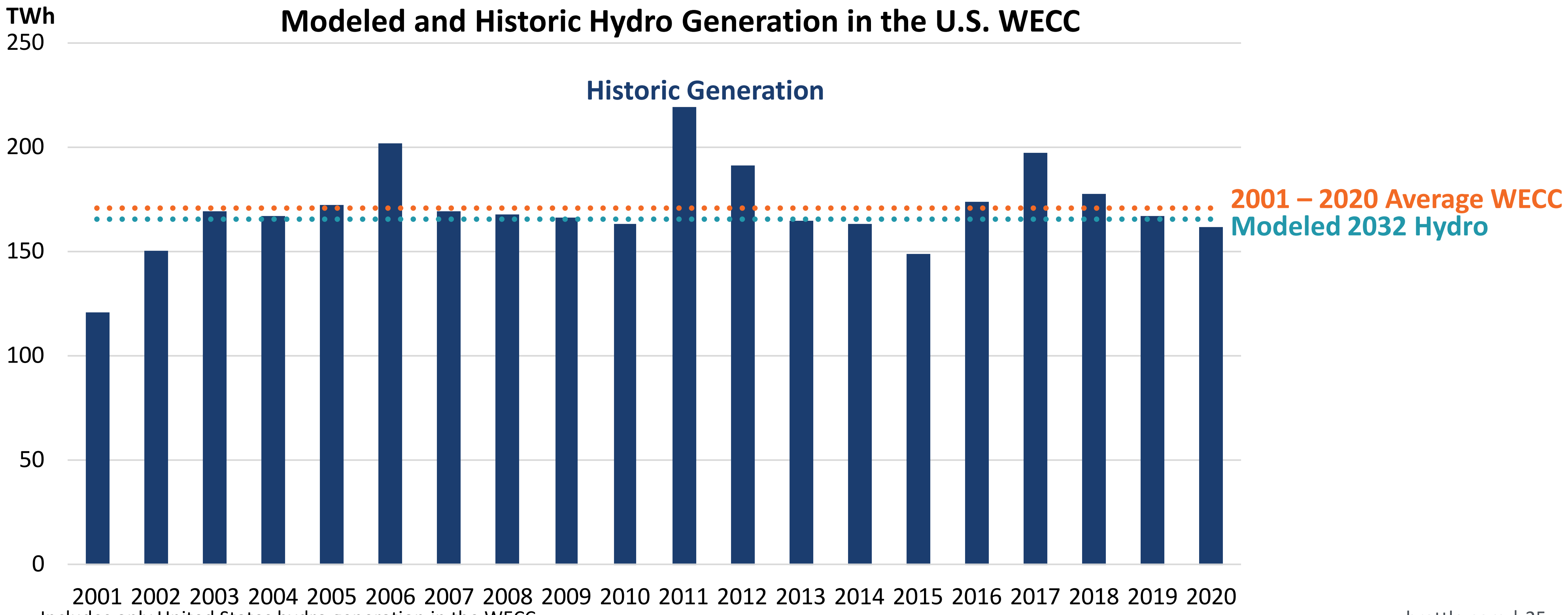
Imbalance Reserve is a new reserve product being implemented by the CAISO as part of their DA Market Enhancements (DAME) initiative, and will apply to EDAM

- The Imbalance Reserve requirement (up and down) will be set to meet the 97.5 percentile of each BAAs historical net load variability
- In EDAM, participants' Imbalance Reserve Requirement will be reduced by the diversity benefit created by pooling commitment and dispatch across the regional footprint
- Does not impact other operating reserve types – regulation, contingency, etc.
- **Brattle Assumption:** we calculated each EDAM participants Imbalance Reserve Requirement and the EDAM diversity benefit to reduce each member's requirement

EDAM Modeling Assumptions: Hydro Generation

Modeled hydro generation reflects an “Average year” in the WECC, with **total generation at 165 TWh**

- Most hydro generation is “load following”; smaller share of hydro resources is able to follow the market



Includes only United States hydro generation in the WECC.

Detailed Explanation of Benefit Metrics

Benefit Metric: Adjusted Production Cost

Adjusted Production Cost (APC) is a standard metric used to capture the direct variable energy-related costs from a customer impact perspective

The APC is the sum of production costs and purchased power less off-system sales revenue:

(+) Production costs (fuel, startup, variable O&M, emissions costs) for generation owned or contracted by the load-serving entities

(+) Cost of bilateral and market purchases valued at the BAA's load-weighted energy price ("Load LMP")

(−) Revenues from bilateral and market sales valued at the BAA's generation-weighted energy price ("Gen LMP")

The APC is calculated for the Status Quo Case and the RTO case to determine the RTO-related reduction in APC

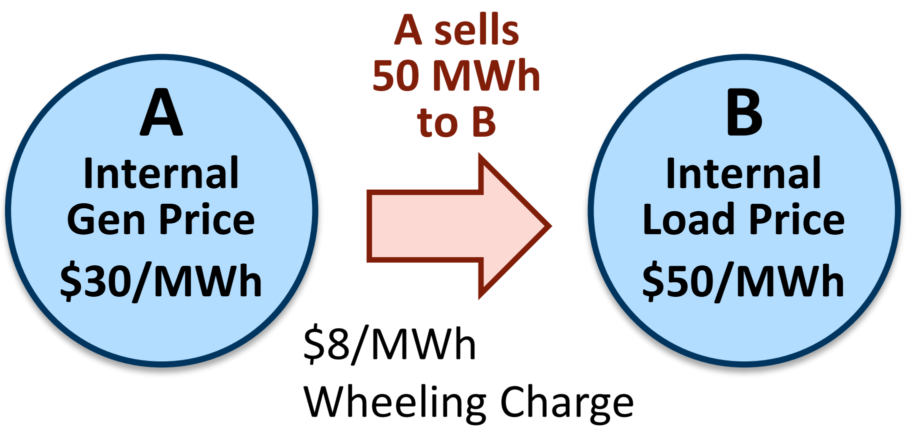
- By using the generation price of the exporter and load price of the importer for sales revenues and purchase costs, the APC metric does not capture wheeling revenues and the remaining portion of the value of the trade to the counterparties (see next slide)

Operational Benefit Metrics: Wheeling Revenues, Trading Gains

Based on the simulation results, we also estimate several additional impacts from increased trading facilitated by the market reforms, which is not fully captured in APC.

- **Wheeling Revenues:** collected by the exporting BAAs based on OATT rates
- **Trading Gains:** buyer and seller split 50/50 the trading margin (and congestion revenues in EIM/EDAM)

EXAMPLE: Bilateral Trade



The APC metric only uses area-internal prices for purchase cost and sales revenues, which does not capture part of the value:

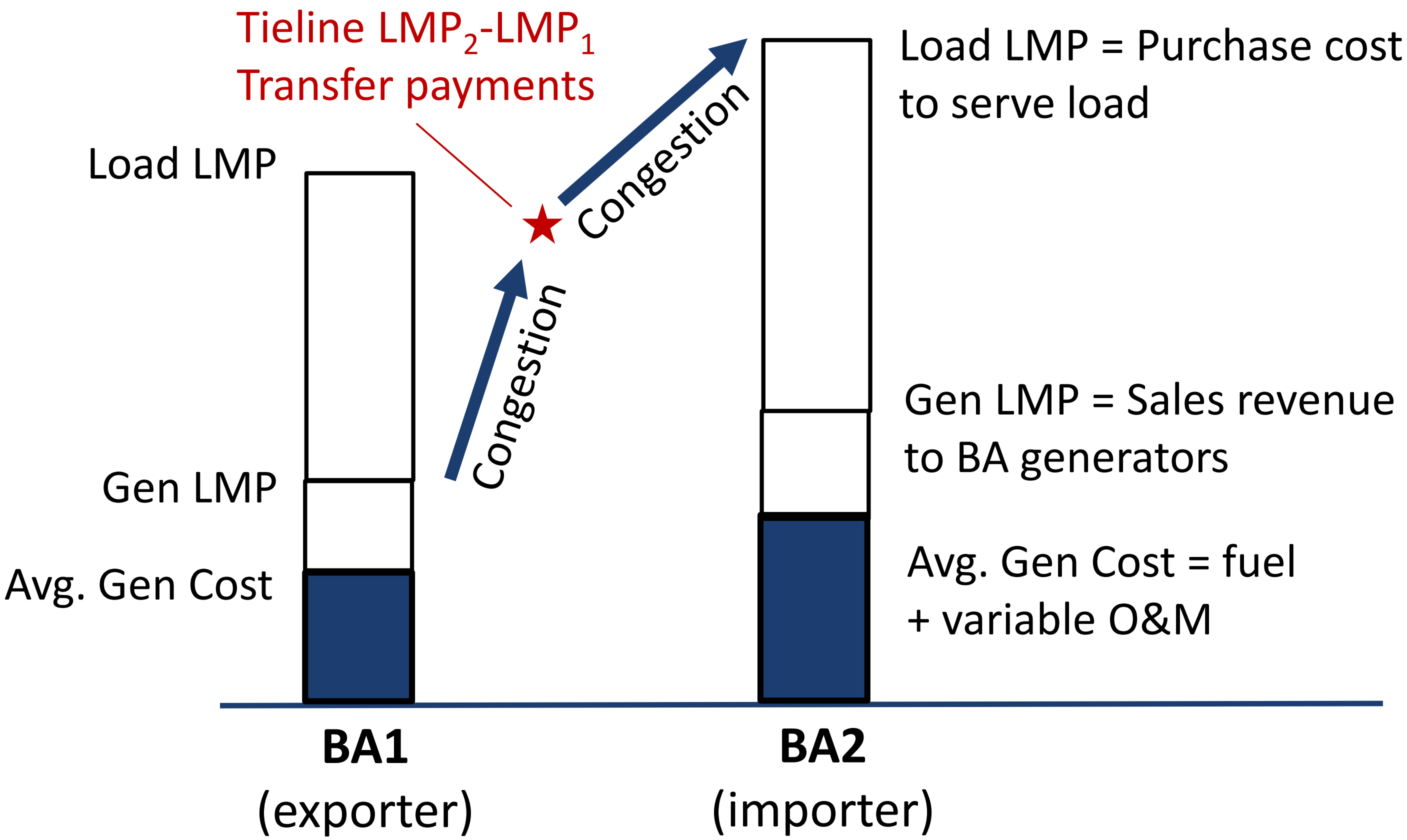
- A receives $30×50MWh=$1,500 in APC sales revenues
- B pays $50×50MWh=$2,500 in APC purchase costs

➔ $1,000 of trading value not captured in APC metric

Trading value = $20/MWh Δprice x 50 MWh = $1000

- Exporter A receives wheeling revenues: $8/MWh x 50MWh = $400
- Remaining $600 trading gain split 50/50: both A and B receive $300

Illustration of APC and EDAM Congestion and Transfer Revenues



EDAM congestion and transfer revenues estimated based on individual tieline LMPs:

- **Congestion Payment (to exporter) = MW x (Tie LMP_1 – Gen LMP_1)**
- **Congestion Payment (to importer) = MW x (Load LMP_2 – Tie LMP_2)**
- **Transfer Payment (split 50/50) = MW x (Tie LMP_2 – Tie LMP_1)**

Presenter Bio

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John has broad experience helping clients address a range of issues related to wholesale power markets. He is an expert in electric market modeling, analyzing regional market participation, transmission benefit-cost analysis, transmission rate design, market design, detection of market manipulation and damages analyses, and strategic planning.

John has worked with electric utilities, cooperatives, public power authorities, transmission developers, generation owners, power traders, and ISO/RTO staff. He has assisted clients in developing whole market rules, ancillary service product, designing market power mitigation regimes and auction clearing mechanics, leading strategic planning initiatives, and modeling the power system to assess the benefits of new transmission, the benefits of participating in wholesale power markets, and the value generation assets.

John has provided expert testimony to FERC, provincial regulators in Canada, and in U.S. Federal Court related to transmission rate cases, alternative transmission rate designs, cost allocation, and contracts for wholesale power.

Acronyms

ADS	Anchor Data Set (WECC)
AESO	Alberta Electric System Operator
APC	Adjusted Production Costs
AVA	Avista Corporation
AZPS	Arizona Public Service Company
B2H	Boardman to Hemingway Transmission Line
BA	Balancing Authority
BAA	Balancing Authority Area
BANC	Balancing Authority of Northern California
BCHA	British Columbia Hydro and Power Authority
BPA	Bonneville Power Administration
CAISO	California Independent System Operator
CC	Combined Cycle generator
CFE	Comision Federal de Electricidad (Mexico)
CO/MO	Colorado/Montana
CT	Combustion Turbine generator
DA	Day Ahead
DAME	Day Ahead Market Enhancement
EDAM	Extended Day Ahead Market
EIM	Energy Imbalance Market
EPE	El Paso Electric Company
ETC	Existing (long-term) Transmission Contract
GHG	Greenhouse Gas
GW	Gigawatt
GWh	Gigawatt Hour
GW/hr	Gigawatt/Hour
IID	Imperial Irrigation District
IPCO	Idaho Power Company
ISO	Independent System Operator
kW	kilowatt
LADWP	Los Angeles Department of Water and Power
LMP	Locational Marginal Price
MMBtu	Million British Thermal Units
MWh	Megawatt Hours
NOx	Nitrogen Oxides
NV	NV Energy (Nevada)
NWMT	Northwestern Energy (Montana)
O&M	Operations & Maintenance
OATT	Open Access Transmission Tariff
PAC	PacificCorp
PACE	PacificCorp East
PACW	PacificCorp West
PAWA	PacificCorp West in Washington
PGE	Portland General Electric Company
PNM	Public Service Company of New Mexico
PSEI	Puget Sound Energy
PSO	Polaris Power System Optimizer
PV	Photo Voltaic
RT	Real Time
RTO	Regional Transmission Organization
SCED	Security Constrained Economic Dispatch
SCL	Seattle City Light
SMUD	Sacramento Municipal Utility District
SRP	Salt River Project
TEPC	Tucson Electric Power Company
TIDC	Turlock Irrigation District
TPWR	City of Tacoma, Department of Public Utilities
TTC	Total Transmission Capability
TWh	Terrawatt Hour
UEL	Upper Electrical Limit
WAPA	Western Area Power Administration
WECC	Western Electricity Coordinating Council
WEIM	Western Energy Imbalance Market