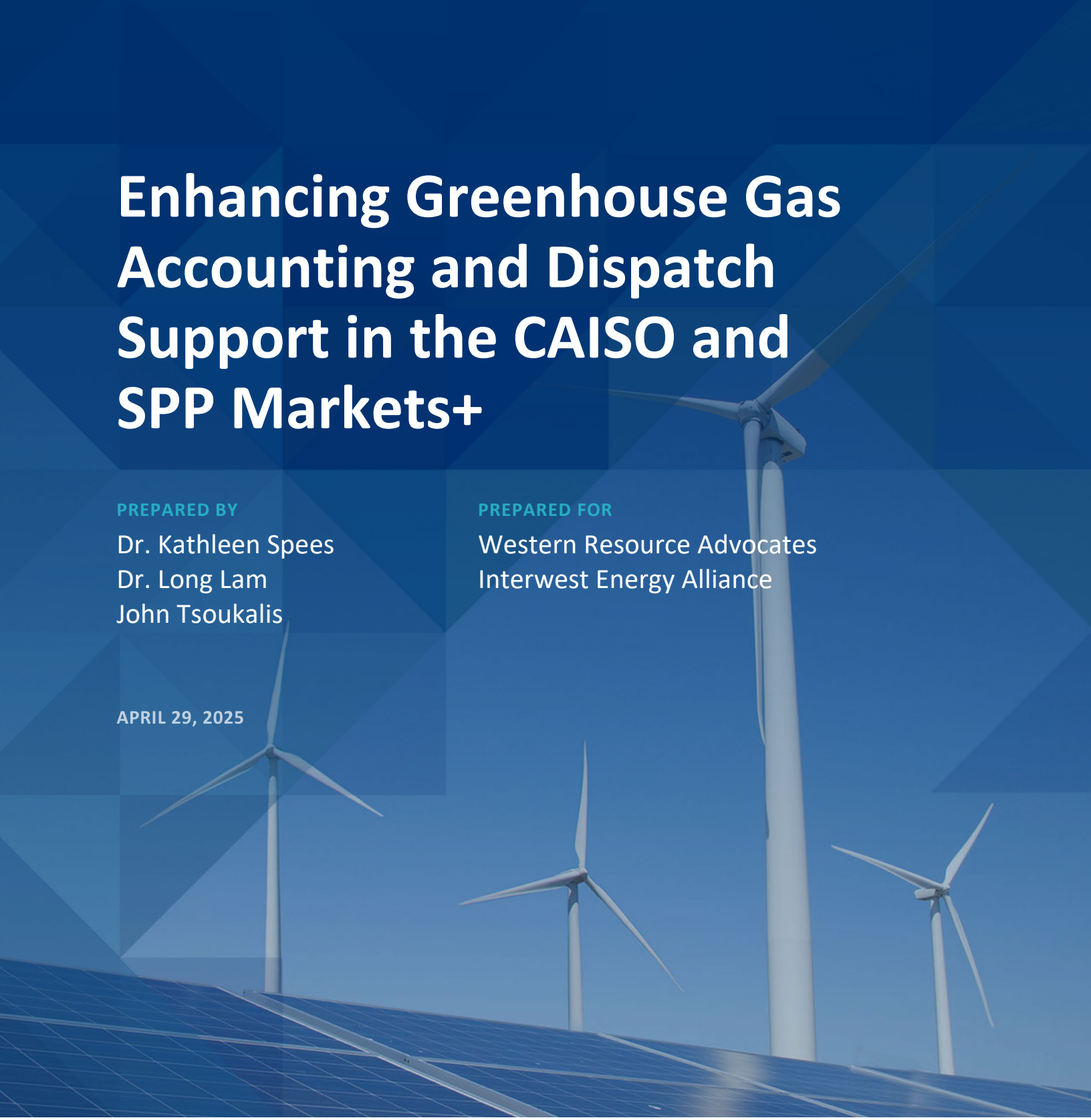

Enhancing Greenhouse Gas Accounting and Dispatch Support in the CAISO and SPP Markets+

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APRIL 29, 2025

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NOTICE

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TABLE OF CONTENTS

I. Introduction: Status of EDAM and Markets+ GHG Accounting Efforts

The coming decades pose innumerable challenges for policymakers and power markets that aim to support cost-effective and reliable investments and operations throughout the clean energy transition. To date, wholesale power markets have provided extensive economic value by focusing on their original mandate of supporting mutually beneficial power trade and reliability. States, utilities, and customers have pursued their own policy goals ranging from no greenhouse gas (GHG) requirements to 100% deep decarbonization targets, each at a different pace. They implement these policies using a variety of economic incentives and structures, including GHG pricing programs, clean energy mandates, and renewable portfolio standards (RPS). State programs also employ their own markets for GHG allowances and renewable energy certificates (RECs). Increasingly, states and utilities across the West see the need to engage more extensively with trade partners if they are to pursue policy goals cost-effectively, by leveraging the benefits of resource diversity and regional power markets for balancing supply. As the level of regional trade expands, so will the importance of building economic alignment between wholesale power market structures and the diverse policies and resource preferences of the participants. Market participants also require robust information and tracking of clean energy and GHG implications of their power market purchases, so they have the visibility to measure progress and manage economic trade-offs. We are optimistic that wholesale power markets can help states and market participants meet these challenges.

Originally, power markets were only able to reflect GHG preferences through supply-side offers that account for the cost of GHG allowances or the cost offset of REC sales. As the scale of decarbonization policies and commitments have expanded, however, it is clear that customers, utilities, and states need more support for tracking mutually exclusive and self-consistent clean energy claims and GHG attributions associated with bulk power trade. The most prominent and obvious disconnect is between the REC tracking system and GHG accounting needs, which currently cannot feasibly be aligned into self-consistent reports. We believe these can be made to align, though doing so will require a substantial exercise of multi-state coordination to articulate policy requirements to be supported through wholesale power market reform and tracking supports.

This report aims to contribute to that effort by providing an assessment of the current status of GHG accounting support provided in wholesale power markets in the West, and by offering

recommendations for future enhancements that could be pursued. We offer a high-level overview of GHG accounting support offered by a range of Independent System Operators (ISOs) and Regional Transmission Organizations (RTOs), and a more detailed discussion of the GHG accounting mechanisms in energy markets operated by the California Independent System Operator (CAISO) and Southwest Power Pool (SPP) Markets+.[1]

We review GHG pricing approaches as relevant at the publication of this report, considering:

- **CAISO's** current implementation of GHG pricing in the wholesale energy market as relevant for California and Washington under their economy-wide cap-and-trade regimes, which are already in place within the real-time Western Energy Imbalance Market (WEIM or EIM). This design will be adapted for implementation in the Extended Day-Ahead Market (EDAM), which has been approved by the Federal Energy Regulatory Commission (FERC) with a go-live date planned in Spring 2026.[2] We also review the additional market design and accounting support concepts under development within CAISO's GHG Coordination Working Group. These concepts are anticipated to expand support for GHG accounting and energy market participation, including enhanced support for non-pricing states.[3] Given the relatively early stage of several of these working group proposals, our assessment of potential outcomes is more speculative in nature.
- **SPP's** planned implementation of GHG pricing for **Markets+**, the tariff for which has been approved by FERC as of January 2025, with a targeted go-live date in 2027.[4] We also review the current proposal for cross-state and cross-utility attributional GHG accounting support for both GHG-pricing states and non-GHG-pricing states developed within the Markets+ GHG Task Force; this attributional GHG allocations approach is highly developed but subject to ongoing refinement.[5]

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1 See ISO/RTO sites at California ISO and SPP Markets+. Both initiatives are ongoing, and analyses in this report are based on information available as of January 2025.

2 For a description of the CAISO's current GHG-pricing approach already in place within the WEIM, see CAISO Energy Imbalance Market Business Practice Manual, Section 11.3.3. For the planned approach within the CAISO's EDAM as approved by the Federal Energy Regulatory Commission, see CAISO EDAM FERC Filing, Docket No. ER23-2686-000, August 22, 2023.

3 To review ongoing stakeholder discussions regarding refinements to the market design and accounting support, see meeting materials within the CAISO's GHG Coordination Working Group. For a discussion of the problem statement focus areas and potential reforms under consideration, see CAISO's Discussion Paper—GHG Coordination, September 16, 2024; and CAISO Accounting and Reporting Issue Paper—GHG Coordination, December 20, 2024.

4 See SPP filing on Markets+ as filed before FERC in Docket No. ER24-1658, March 29, 2024, including subsequent supplementary filings and responses; see FERC approval in Docket ER24-1658, January 16, 2025.

5 See meeting materials posted within the Markets+ GHG Task Force.

CAISO, SPP, and stakeholders in each market have taken substantial leadership roles in developing advances in their market designs and identifying innovative solutions for supporting state policy needs for states pursuing decarbonization goals. Each of the existing and proposed designs under development offers advantages that will support more cost-effective, reliable, and regionally coordinated investments and operations across a diverse portfolio of utility systems and policy mandates. However, in both contexts, we anticipate that it will be important for the market operators, stakeholders, and state policymakers to work together to continue advancing the market designs and data support structures, likely over a number of years of collaboration and continued evolution. Therefore, we caution that nothing in this report should be misinterpreted as a reason to select one ISO/RTO over the other, as several state and utilities are considering both market membership options. We anticipate that further evolution will help to improve all available alternatives.

Both SPP and CAISO have the expertise and technical capability to provide the needed information and market design structures enabling market participants to more cost-effectively and reliably meet state policy requirements, as long as there is a path to do so under the policy guidance and support of participating state regulators. The attractiveness of each new GHG accounting and market structure will also materially influence which states and market participants will ultimately participate—with accuracy, completeness and economic benefits increasing with the level of participation. For these reasons, we see substantial benefits from building alignment amongst a sufficient cross section of differently situated states to define guiding principles, establish evaluation criteria, and prioritize SPP's and CAISO's respective efforts to continue enhancing their market designs and GHG accounting support. Neither program will be able to meet the goals of states and participants in the most effective manner until they receive a sufficient level of alignment amongst the participating states on the optimal long-term path to support states across the region.

II. Jurisdictional Scan of Advances in RTO GHG Accounting Support

Currently, the CAISO WEIM/EDAM stakeholders, SPP Markets+ stakeholders, and other market operators across the world, as well as international standard bodies, are pursuing a number of efforts focused on advancing methods for GHG accounting in the power sector. These efforts are driven by a combination of factors, including the needs of states and utilities to meaningfully reflect deep decarbonization policy requirements. This is particularly important in regions that engage in substantial volumes of power trade and that may need to work together with neighbors

to pursue decarbonization policy in a reliable and affordable way. At the same time, customers and companies have adopted their own corporate sustainability goals and face increasing levels of accountability to investors and customers under both voluntary and mandatory reporting standards.[6]

A. Categories of Clean Energy and GHG Accounting Support Provided by RTOs

ISOs and RTOs can play a critical role in supporting GHG accounting and data-related activities, given their central role in operating large multi-state power markets, dispatching the transmission and generation infrastructure to cost-effectively and reliably meet customers' real-time power needs, tracking power flows, and settling financial transactions matched via the wholesale energy markets. RTOs have the experience and technical capability required to provide settlement-quality GHG data at scale across large power systems. We anticipate that market operators will need to play an increasingly important role in providing the primary "source of truth" in the context of certain GHG data, particularly as associated with : (a) information on real-time physical outcomes of the grid; and (b) tabulating the transfers of any GHG attributions or clean energy claims that may change hands alongside energy purchases and sales via the RTO markets. Such physical and settlement data could eventually be used as the basis from which to define contractual obligations, confirm fulfillment of state policy requirements, and support tradable products/instruments that enable compliance with those goals. The role that RTOs can play in providing settlement-quality GHG volume accounting may eventually need to be as meaningful as the role of settlement-quality energy megawatt-hour (MWh) volume accounting that is used to support both short-term power markets and long-term contract settlements. No other entity would have the scope and scale to provide a set of GHG and clean energy accounting data that is self-consistent with energy market transactions, nor support a coordinated marketplace for valuing the "green" side of these transactions in the day-ahead or real-time market timeframes.

On the one hand, many questions around what is technically feasible have already been answered and demonstrated through the various efforts pursued across the different U.S. and international regions. On the other hand, implementation progress has been slowed by challenges of scope and jurisdiction; states do not have uniform policy goals or structures, and the traditional mandate of RTOs has been widely seen as supporting reliability and economic efficiency rather than policy achievement.

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[6] See additional discussion of the mandatory and voluntary GHG and clean energy programs and voluntary reporting standards in standards in Spees *et al.,* *Greenhouse Gas and Clean Energy Accounting Methodology Catalog*, prepared for WEST Associates, May 2023.

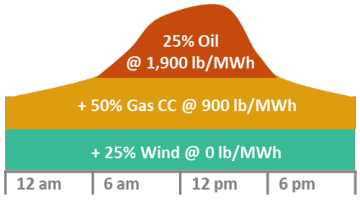
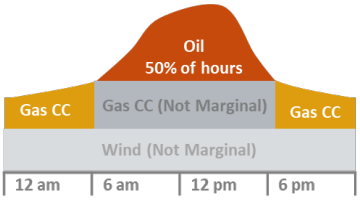
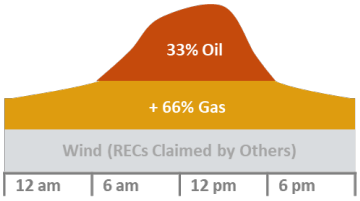
The GHG data and accounting needs of states and others generally encompass the following categories of GHG emissions rates:[7]

1. **Generation-based average** emissions rates, defined as the average rate of emissions divided by MWh of production in a defined region. This value is used for measuring Scope 1 direct GHG emissions accounting, and is typically the basis for states that assign GHG emissions responsibility to in-state generation asset owners;
2. **Consumption-based average** emissions rates, defined as the emissions divided by power consumption by customers in a defined region including accounting for power trade and transfer to/from the consumption area. This value is used for measuring Scope 2 emissions under the location-based accounting method, and is typically the basis for states that assign GHG emissions responsibility to retail providers and power importers;
3. **Marginal emissions rates,** defined as the marginal or incremental rate of emissions caused or avoided by the next MWh of power consumed or clean energy produced. This value is used to inform the most effective operating and investment decisions to address GHGs; and
4. **Residual grid mix rates,** defined as the consumption-based allocated GHG emissions relevant for residual or unspecified market purchases after accounting for the ownership and REC claims of other reporting entities across the relevant market footprint. This value is used for measuring Scope 2 emissions under the market-based accounting method and is the emissions rate that must be used if clean energy claims and GHG emissions responsibility are to be self-consistent on a system-wide basis.

All four of these categories of GHG data will be needed by states and consumers pursuing GHG commitments, given that they are used by differently situated entities and for distinct purposes as summarized in Table 1.

[7] For primary sources describing approaches to Scope 1, 2 and 3 emissions reporting, see World Resources Institute, *The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard;* and World Business Council for Sustainable Development and World Resources Institute, *The Greenhouse Gas Protocol, A Corporate Accounting and Reporting Standard*, Rev. 2004. For a description of the range of GHG and clean energy accounting standards in use by states and utilities across the US West, see Spees *et al.,* *Greenhouse Gas and Clean Energy Accounting Methodology Catalog,* prepared for WEST Associates, May 2023.

TABLE 1. CATEGORIES OF GHG EMISSIONS RATES DATA NEEDED BY STATES AND CUSTOMERS

	1 & 2. Average Emissions	3. Marginal Emissions	4. Residual Grid Mix
What is it?	Total GHG emissions produced by generators, divided by either: • Total generation MWh, or • Total consumption MWh (requires accounting for emissions associated with energy imports/exports)	Emissions rate of the marginal generator (last or highest-cost MW dispatched to serve demand)	Emissions rate of unspecified grid purchases, after subtracting out other entities claimed self-supply and clean energy purchases
Example	 = 925 lbs/MWh over the day (up to 1,220 lb/MWh in peak hour)	 = 1,400 lbs/MWh over the day (up to 1,900 lb/MWh in peak hour)	 = 1,233 lbs/MWh over the day (up to 1,567 lb/MWh in peak hour)
Used for:	• Tracking progress on total GHG emissions • Generation-based emissions accounting (i.e., Scope 1 accounting), as relevant for in-state cap-and-trade or enforcement • Consumption-based emissions accounting, as relevant for allocating GHG emissions responsibility to electricity consumers (i.e., Scope 2, location-based accounting)	• Measuring GHG that can be caused or avoided by specific interventions (build renewables, charge an EV or battery, pursue efficiency) • Setting the basis for contractual or policy incentives aimed at incentivizing GHG-abating investments or operations	• Tracking progress on total GHG emissions, while giving credit for clean energy claims (i.e., RECs) to entities that have paid a premium for clean supply (i.e., Scope 2, market-based accounting) • Goal is to support self-consistent measurement of RECs (for 0% emissions power) and residual market purchases (at the residual grid mix rate), so that total GHG obligations will equal total physical emissions

Sources and Notes: For a description of Scope 1, 2 and 3 accounting (including descriptions of consumption-based average emissions to be used in location-based GHG accounting and residual emissions mix to be used in market-based GHG accounting), see World Resources Institute, *The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard;* and World Business Council for Sustainable Development and World Resources Institute, *The Greenhouse Gas Protocol, A Corporate Accounting and Reporting Standard*, Rev. 2004. For a description of (locational) marginal emissions, see PJM Interconnection, Marginal Emissions Rate – A Primer; and Spees and Oates, *Locational Marginal Emissions*.

B. Cross-RTO Comparison of GHG Accounting Support

Though these different categories of GHG data have been defined and established for decades, the quality, availability, and granularity of these data have been relatively poor. To date, many states and customers have relied on a mixture of monthly renewable energy credit (REC) data with limited geographic granularity, such as state or RTO regional boundaries, as the basis for informing most contracting, investment, and policy decisions. Furthermore, states and customers have historically had limited or no feasible means to meaningfully track the GHG obligations associated

with power trading across state and utility boundaries, or to ensure self-consistency between REC vs. GHG accounting.[8]

Going forward, however, we see that RTO market operators have the potential to provide these same data in a highly granular and accurate manner, with the technical potential to eventually provide all four categories of data on the same 5-minute, nodal granularity that underpins the wholesale energy markets. Furthermore, once the volumes of GHG emissions and clean energy generation are tracked and allocated in the most accurate and meaningful way, they can provide the basis for market transactions and longer-term contractual arrangements both inside and outside the scope of RTO-operated wholesale markets. This effect is similar to the role that RTO markets play in supporting efficient energy transactions and trading in the real-time and day-ahead spot markets, which are also the basis against which mid-term futures and long-term contracts are settled.

Though no RTO has yet attempted to produce a comprehensive set of highly granular GHG accounting data, several RTOs are enhancing the breadth, granularity, and timeliness of GHG data provided on a public basis. Collectively, these efforts demonstrate the comprehensive suite of GHG data that can be provided:

- **New England**: The Independent System Operator of New England (ISO-NE) publishes marginal and average system-wide emissions rates, which are aggregated at various timescales (annual, monthly, on/off peak). Currently, each New England state uses the same REC tracking system, New England Power Pool Generation Information System (NEPOOL-GIS), to track resource attributes, but each determines its own methodology for calculating the residual grid mix relevant for tracking progress toward state compliance goals.[9]
- **New York**: The New York Independent System Operator (NYISO) has recently begun publishing more granular and transparent emissions rates for reporting hourly emissions rates, consistent with both day-ahead (hourly) and real-time (5-minute) energy market outcomes. NYISO's emissions reporting method includes both average emissions rates, considering two areas within the state, and accounting for emissions embedded in imports from outside of NYISO and associated with imports from upstate New York to the New York City import-constrained subregion (consumption-based average emissions, analogous to location-based Scope 2

[8] For additional discussion of GHG and clean energy accounting challenges faced by entities across the US West, see Spees *et al.*, *Greenhouse Gas and Clean Energy Accounting Methodology Catalog*, prepared for WEST Associates, May 2023.

[9] State policymakers recognize the challenges posed by inconsistent GHG measurement and allocation approaches and the benefits that would be shared from a commonly accepted approach. For example, see Rhode Island Commissioner Dr. Abigail Anthony, "Bigger meals require better receipts: A call for coordinated greenhouse gas emissions tracking," *Utility Dive*, July 12, 2023.

accounting); and implied marginal emissions rates, which are published separately for all eleven energy market zones.

- **PJM Interconnection (PJM):** As of 2023, PJM has begun publishing marginal GHG emissions rates, with a data granularity provided at the 5-minute, nodal level consistent with the real-time energy markets. The approach PJM uses to calculate nodal marginal emissions allows market participants to determine the incremental GHGs caused by power consumption (or GHGs avoided by power injections) at every time and place over the footprint. Policymakers in Illinois, the District of Columbia, and New Jersey have begun using these data to inform policies and incentive structures such as where to invest in renewables/transmission, how to remunerate batteries for operations, and how to evaluate the GHG benefits of electric vehicles that may be charged in consideration of GHG impacts.[10]
- **Midcontinent ISO (MISO)**: Provides a publicly available dashboard that can be used to review hourly average emissions (generation-based total and average emissions) provided for the entire US at the level of Balancing Authorities (U.S.-wide data provided with a time lag). In addition, MISO provides 5-minute, system-wide marginal and average emissions rates data on a near-real-time basis; and is in the process of developing nodal, 5-minute marginal and average emissions rates for publication. The GHG "flow tracing" approach that MISO will use to calculate nodal, 5-minute GHG emissions rates is the node-specific consumption-based average emissions rates (i.e., for granular Scope 2, location-based accounting).[11]
- **CAISO:** The CAISO has for a decade published an emissions dashboard on the current GHG emissions intensity of generation serving the CAISO Balancing Authority Area (BAA), as a function of California's Cap and Trade program history. The dashboard reports current and historical emissions within the state of California and imports from the EIM, including total emissions, average emissions rate, and emissions by resource type. [12] CAISO also publishes hourly, monthly, and annual data and reports covering California emissions.[13] The CAISO

[10] See Illinois Commerce Commission, Renewable Energy Access Plan, Section V.B.1; New Jersey Board of Public Utilities, Storage Incentive Program; and Public Service Commission of the District of Columbia, Strategic Electrification Roadmap.

[11] The MISO nodal flow-tracing approach tracks GHGs produced by fossil plants at each generator node where injected to the power system, and tracks GHG emissions across each transmission element before depositing the emissions in proportion to physical withdrawals. The result of the accounting approach is to ensure that all GHGs produced by fossil generators (Scope 1 emissions) are tracked through the system and allocated to customers in specific consumption nodes (Scope 2, location-based allocations), with GHGs produced equaling GHGs allocated within every 5-minute dispatch interval. The approach accounts for location-specific GHG emissions and obligations, including the implications of interstate and regional power trade (but does not account for individual entities' claims to RECs or clean energy, as would need to be done under a residual mix or market-based Scope 2 accounting).

[12] See CAISO Today's Outlook "Emissions."

[13] See CAISO Greenhouse gas emissions tracking reports.

recently started publishing an average emissions rate report which covers the WEIM footprint and provides the emissions intensity of WEIM transfers into California.[14] The CAISO also publishes GHG shadow prices and the GHG component of nodal power prices for each market interval.[15]

- **European Association of Issuing Bodies (AIB):** The pan-European AIB has for several years coordinated a Europe-wide, multi-governmental effort to provide a common set of residual GHG mix calculations accounting for supply, demand, and import/export dynamics across 34 countries that are heavily interconnected through extensive cross-border trade and a common electricity market.[16] Though only calculated and provided on an annual basis, the residual mix rates produce a self-consistent and mutually accepted set of residual GHG emissions rates and self-supply resource claims (i.e., consistent with "guarantee of origin" tracking, equivalent to REC tracking in the U.S.). Over time, the accuracy of the calculated residual mixes has increased as more entities participate in resource tracking and the AIB has adopted improved methods for accounting for GHGs associated with energy trade.
- **Hourly REC Tracking and Markets:** In a separate but highly interacting set of efforts, several renewable energy tracking systems are beginning to provide more granular support for hourly REC tracking. The Midwest Renewable Energy Tracking Systems (M-RETS) began supporting hourly REC transactions in 2021, while the PJM Environmental Information Services (PJM-EIS) hourly tracking system launched in 2023 (retroactive support to 2022).[17] In the West, the Western Renewable Energy Generation Information System (WREGIS) tracks and manages RECs for renewable energy generation and has plans to do so on an hourly basis in the near future.[18] These hourly REC markets are responsive to increasing interest in 24×7 clean energy tracking and matching by corporate buyers, and will become required by some policies such as the hydrogen incentives under Section 45V of the Inflation Reduction Act (hourly matching will be required starting 2029).[19] Though these hourly REC systems have demonstrated the potential to expand support for more time-granular supports, they still face a substantial limitation associated with the lack of locational (i.e., zonal or nodal) granularity in accounting for transmission limits and power flows that underpin wholesale RTO energy markets. Unlike wholesale power markets, REC markets have been developed without considering the transmission limitations that may prevent supply from being deliverable, individually or

[14] See WEIM average emissions rate report.

[15] See nodal market prices and GHG shadow pricing data.

[16] See European Residual Mix | AIB.

[17] See PJM-EIS Generation Attribute Tracking System: Hourly Certificate.

[18] See CRS, Readiness for Hourly: U.S. Renewable Energy Tracking Systems.

[19] See U.S. Department of the Treasury, IRS Release Guidance on Hydrogen Production Credit to Drive American Innovation and Strengthen Energy Security | U.S. Department of the Treasury.

collectively, to buyers under varying system conditions. The lack of a means to signal time-dependent locational deliverability in REC markets can in some instances result in less efficient or higher-emission outcomes. For example, a state with a 100% clean energy goal may over-procure renewables that are not fully deliverable, and insufficient local supply of renewables or storage. For these reasons, we anticipate that a comprehensive long-term solution for self-consistent clean energy and residual GHG tracking will eventually require a more complete alignment or integration with RTO energy markets than what has been previously considered in REC markets.

Overall, we observe that the breadth of GHG and clean energy data support provided by U.S. RTOs is rapidly expanding, both geographically and substantively. Together, these examples illustrate that a full suite of comprehensive data supports is feasible to provide, including 5-minute, nodal coverage for all four categories of data (see Table 1), but will require substantial guidance and engagement from policymakers and market participants to provide data that align with the variety of use cases. We offer further thoughts on data needs in Section VI below.

III. CAISO WEIM & EDAM

Since 2014, the CAISO-operated real-time WEIM has incorporated the capability to reflect GHG emissions costs in wholesale energy market dispatch and pricing. The approach was initiated with the capability to support only one GHG-pricing state (California) in the real-time market timeframe. The approach will be extended with the functionality to apply to multiple states (currently, California and Washington have GHG pricing policies) and will also apply in the day-ahead market timeframe with the roll-out of the EDAM in 2026.[20] For the purposes of this discussion, we describe and examine the GHG pricing and dispatch treatment consistent with full EDAM implementation (which is similar, but not identical, to the approach already supported in the WEIM).

Beyond the support for GHG-pricing states included in the WEIM and EDAM, the CAISO and stakeholders have since August 2023 been engaged in an extensive process to further examine and refine support for a variety of GHG reporting and market dispatch needs for states and entities in both GHG-pricing states and non-GHG-pricing states. Given the early stages of these

[20] The EDAM Tariff was approved by FERC on December 20, 2023, with a planned go-live date in Spring 2026. See CAISO, EDAM Market Initiative.

stakeholder discussions, our analysis of potential outcomes is relatively more speculative and forward-looking in nature.

A. How it Works

The CAISO real-time WEIM and forthcoming day-ahead EDAM support economic dispatch and price formation that differentiate between resources serving demand in states with vs. without GHG-pricing policies. Among the participating states, California and Washington both have GHG cap-and-trade programs, each of which having a distinct program of GHG allowances that may be traded at different $/tonne pricing levels.[21]

The CAISO, WEIM and EDAM allow GHG-emitting generators through their scheduling coordinators to incorporate the costs associated with purchasing GHG allowances into their energy market offers.[22] For resources inside GHG-pricing states and external pseudo-tied resources, these resources incur a GHG obligation whenever they produce power, and so the GHG costs are always in their energy market offer price.[23] The seller's anticipated cost of purchasing the required GHG allowances translates from a $/tonne into a $/MWh GHG cost and is incorporated into the generator's offer price, alongside other $/MWh cost components including fuel and other variable costs.

Scheduling coordinators of other external resources have the option to offer their resources for dispatch either with or without a GHG-pricing adder. The offer format of external resources can be submitted by: (1) considering only the $/MWh fuel and traditional variable costs, which is the offer price considered if the external resource is dispatched to serve customers outside of a GHG-pricing state; or (2) in addition, these same external generations have the option, on an opt-in basis, to offer their generation for sale/export into a GHG-pricing state by submitting a GHG adder to the energy offer price. For external resources, GHG allowance obligations and associated offer price adders are only incurred by the scheduling coordinator if CAISO market dispatch selects them to serve demand in a GHG-pricing state. External resources that do not submit a GHG offer price adder cannot be selected to serve imports into a GHG-pricing state.

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[21] The same energy market dispatch approach could be used to support other types of GHG-pricing policies, such as an emissions tax or emissions price applied to generators producing GHG emissions.

[22] For a description of the CAISO's current GHG-pricing approach already in place within the WEIM, see CAISO Energy Imbalance Market Business Practice Manual, Section 11.3.3. For the planned approach within the CAISO's EDAM as approved by the Federal Energy Regulatory Commission, see CAISO EDAM FERC Filing, August 22, 2023, Docket No. ER23-2686-000. To review ongoing stakeholder discussions regarding ongoing refinements to the market design and accounting support, see meeting materials within the CAISO's GHG Coordination Working Group.

[23] External pseudo-tied resources refer to resources that are physically located outside a given BAA but are operated in real-time as if they are inside that BAA.

The CAISO energy market dispatch optimization seeks to jointly minimize the total cost of supply across all GHG-pricing and non-pricing regions, subject to various constraints intended to reflect physical transmission limits and mitigate the potential for emissions leakage and "secondary dispatch."[24] The two dispatch steps relevant to GHG dispatch and pricing in the day-ahead market include:

1. **Optimized Reference Pass** (Used as Input to Step 2, Energy Market Dispatch). As the first step in the day-ahead energy market process, CAISO conducts an optimized dispatch of energy market schedules that would be realized if external resources were not eligible to sell energy into GHG-pricing states. This reference pass establishes a baseline volume of energy output that would be expected under separate dispatch for GHG-pricing and non-GHG-pricing regions.[25] This baseline is a counterfactual approximating the MW capacity external to the GHG-pricing region that would be needed to serve demand in non-GHG-pricing states. In the subsequent step 2, only MW output above this baseline dispatch is considered as potentially available for and serving export into the GHG-pricing states.
2. **Energy Market Dispatch** (Used for Final Dispatch and Settlements). In energy market dispatch, CAISO conducts an optimization to minimize total cost of production jointly across all GHG-pricing and non-GHG-pricing regions. As summarized in Table 2 below, market dispatch optimally selects which combination of internal and external resources should be dedicated to supply customers in the GHG-pricing region. Price formation from the energy market includes standard components of the locational marginal price (LMP), including marginal costs of energy, congestion, and losses. In addition, the CAISO produces a marginal GHG cost component of the energy price that is paid by customers in GHG-pricing states. The GHG-pricing component is paid out to only the external generators that are attributed as dispatched to serve customers in the GHG-pricing state. External customers and external generators

[24] Under each state's regulatory regime, state policymakers have authorities to define what constitutes "emissions leakage," a generalized term indicating that the quantity of GHG emissions accomplished is less than what is measured by policy, often because the emissions reduction measured is partly or fully offset by increases in GHG emissions from other sources that are not measured or enforced (e.g., because they are outside jurisdictional authority). A common concern in power markets is the possibility of emissions leakage due to the reduction of GHG emissions from covered (e.g. in-state) fossil resources, only to have equal or greater emissions produced by non-covered fossil supply that are not covered by the policy. In the context of CAISO-administered power markets, one measure of emissions leakage is "secondary dispatch," which is the amount of GHG increases from non-covered fossil supply that is arguably attributable to market redispatch compared to a specified but-for scenario. The proper way to measure and mitigate the potential for secondary dispatch is one of the areas of substantial recent and go-forward focus in the EIM and EDAM markets.

[25] For external resources that are dedicated to sell energy into the GHG-pricing state, their baseline output is set to zero so the entire resource capability is eligible for export to the GHG-pricing state. For resources participating in both the EDAM and WEIM, the day-ahead baseline remains the baseline through real-time operations. For resources that participate only in the real-time WEIM, baseline schedules are submitted by scheduling coordinators, informed by each participant's plans for resource operations and transmission scheduling prior to the start of the real-time market.

serving non-GHG-pricing regions are not affected by the marginal GHG component of the energy price.

TABLE 2. INCORPORATION OF GHG PRICING INTO CAISO ENERGY MARKET DISPATCH OPTIMIZATION

	Energy Market Formulation
Objective Function: Minimize Costs	Minimize Total System-Wide Generator Production Cost = Sum of: • Fuel and other generator production costs, plus • GHG allowance costs in GHG pricing states (included as part of generator offer price), plus • GHG allowance costs for external generators (only if selected to export supply to the GHG-pricing state)
Decision Variables	Establish dispatch MW schedules including: • Generator physical MW output (both inside & outside of GHG-pricing regions) • MW share of external generators' physical output allocated to serve demand in GHG-pricing region
Subject to Constraints	Standard economic dispatch constraints: • Observe all physical generator limits and transmission limits • MW of imports to attributed GHG-pricing state cannot exceed total import capability Constraints tailored to limit the potential for secondary dispatch: • Resource-specific limits on external MW that can be attributed to the GHG pricing state (i.e., only MW above the baseline dispatch can be considered as potentially attributable) • BAA-specific "Net Export Constraint" that limits the MW that can be attributed to the GHG pricing state (i.e., only MW of generation exceeding local consumption within each BAA can be considered as potentially attributable)
GHG Component of Energy Price	• GHG component of locational market price is derived from shadow price of serving customer demand in GHG-pricing zone (i.e., transmission-limited, supply-demand balance of specified external MW) • External resources are paid the GHG component of LMP if selected as specified importers to the GHG-pricing region • Resources internal to the GHG pricing state naturally recover GHG costs, considering that the in-state LMPs account for the in-state fossil generators total offer price (inclusive of any GHG allowance costs they may occur)

The CAISO's market design incorporates two primary mechanisms intended to prevent and mitigate the potential for "secondary dispatch" and the impact of leakage:[26]

- **GHG Reference Pass Baseline,** which establishes a counterfactual to estimate what dispatch would have occurred in the non-GHG-pricing state, and without offers to serve demand in

[26] As used in the WEIM and EDAM markets, "secondary dispatch" refers to the risk that lower or non-emitting external resources could be optimally reshuffled so that their clean MW are attributed to serve customers in the GHG-pricing state, even if those resources may have operated regardless to serve customers in their home utility area. For example, secondary dispatch could occur if some low-emitting supply that would have operated regardless of the CAISO dispatch may be allocated to serve GHG-pricing states, and at the same time other higher-emitting supply could be assigned to backfill energy production to serve customers in non-GHG-pricing regions. If the GHG-pricing state would claim non-emitting MW from these external resources, this would overstate the GHG reductions accomplished compared to a sensible counterfactual baseline in which low-cost external clean resources would be operated to serve external customers.

GHG regulation areas. It creates an energy market dispatch baseline to approximate the resource-specific MW that would hypothetically be operated regardless of demand from a GHG-pricing state. MW volumes below this baseline are considered as non-attributable to the GHG-pricing state (only MW above each resource's baseline dispatch can be assigned as imports into GHG-pricing states). Note that this mechanism prevents the majority of any reshuffling that could otherwise occur with respect to intermittent renewable resources, since their supply offers at zero/negative cost will be dispatched to serve external customers unless their output is curtailed, usually due to local transmission limits. This resource-specific baseline mechanism has a more complex interaction with mid-merit dispatchable resources such as batteries, hydro, and lower-emitting fossil supply, whose output is more likely to change between steps 1 and 2.

- **Net Export Constraint**, which allows external balancing authority areas to export to GHG-pricing states only to the extent that their physical energy production exceeds total demand within the same balancing area. This constraint is intended to ensure GHG attribution reflects the physical and reliability realities of the transmission system, including within each balancing area.

Both of these mechanisms limit the extent to which the energy market can reallocate dispatch of energy resources to be assigned as imports to the GHG-pricing zone, but each also introduces the potential for economic inefficiencies associated with a more constrained energy market dispatch (see additional discussion below).[27]

B. Key Features

The CAISO approach to supporting dispatch outcomes for GHG-pricing states offers a number of advantages, including:

- Capability to support both GHG-pricing states and non-pricing regions in a jointly optimized market setting that supports economic trade and achieves economic savings to customers and

[27] In general, the need for a two-pass approach is less efficient than a one-pass approach to market clearing, and is an indicator that the market is missing some element of supply, demand, value, or price formation. Common issues include missing markets/products; incomplete or asymmetric information; inconsistencies between cleared prices and volumes (i.e., prices that misalign with marginal costs, thus creating incentives for sellers to deviate from dispatch instructions); or unpriced positive/negative externalities. Though identifying a first-best, one-pass solution to address the root cause of any such market failures is not always feasible or practical, it is preferred to do so whenever possible to avoid the follow-on inefficiencies that can be induced by second-best approaches that may involve imposing quantity rationing (supply or demand side), incentivizing inefficient operating behavior, incentivizing sellers to offer in ways that do not reflect their true marginal costs, or imposing the costs of additional constraints on market outcomes.

society (achieving large economic efficiencies from RTO dispatch across many states, even if they have different GHG policies);

- Flexibility in accommodating different state energy policies, where the GHG component of prices may be higher/lower between GHG-pricing states while remaining at zero for non-GHG-pricing states;
- A decade of implementation experience and lessons learned in the real-time WEIM, which will be enhanced to support the implementation of EDAM;
- Demonstration of concept regarding competitive selection of external MW supply to specific customer regions endogenously within the wholesale energy markets, with sufficient granularity in attributing MW responsibility for serving customers that can be used for attributional purposes (attributing both the MWh of energy sales sufficiently to support a differently priced energy transaction, and attributing the GHG compliance responsibility to the affected generator and customer region);
- A time-granular approach to tracking allocated MW and GHGs associated with energy imports, consistent with the hourly and 5-minute timeframes relevant for dispatch and settlement in the day-ahead and real-time markets;
- Production of the transparent marginal GHG cost component of GHG emissions, signaling the times when there may be the greatest value of attracting and dispatching more low-emitting supply to GHG-pricing states;
- Incorporation of baseline and net export mechanisms to quantify and mitigate (though not eliminate) potential for emissions from secondary dispatch;
- Demonstration of concept regarding alignment with real-time transmission system capability and MW of resource attribution between areas, including with total impart limits to GHG pricing areas and through the BAA net export constraints;
- Demonstration of wholesale market design and outcomes in alignment with state-defined policy obligations; and
- Obligation of scheduling coordinators of GHG-emitting resources to fulfill state-defined reporting and compliance obligations if resources are selected by the wholesale market to serve energy imports to GHG-pricing states. This creates an opportunity to transition away from a generic and potentially less accurate emissions rate that would otherwise need to be applied to “unspecified emissions” and utilize more accurate accounting of emissions associated with imports from specified resources as associated with their physical emissions rates.

C. Ongoing Stakeholder Efforts

Though the CAISO's GHG-pricing approach has a number of advantages, it has been designed primarily to support the needs of GHG-pricing states and does not yet support the needs of all the differently situated customers and states that the WEIM and EDAM will serve. To expand support for these needs, the CAISO has been engaged in a GHG coordination working group since July 2023.[28] In two discussion papers in September 2024 and December 2024, CAISO staff laid out future reforms and solutions that will be pursued including:[29]

- **Enhancing the current approach to GHG pricing in WEIM and EDAM**, including to further mitigate the potential for emissions associated with secondary dispatch;
- **Development of additional GHG-related metrics** that may be valuable to a subset of states or market participants;
- **Developing GHG reporting supports for attributional and residual mix accounting,** through an out-of-market allocational GHG accounting and reporting. The approach was originally described by the Western Power Trading Forum (WPTF) and proposed in both the CAISO and SPP Markets+ forums, with the SPP variation farther along in detailed development, as discussed further in Section IV below.[30] The CAISO's initial assessment of the concept is described in the December 2024 discussion paper and would include features such as pre-market resource claims (based on ownership and contracts) and alignment with time-granular wholesale market outcomes. Many other aspects of the concept are in early stages of specification, including the tradeoff between implementation timeline and granularity of reporting entity, BAA level reporting being more feasible to implement sooner than load serving entity level reporting; and
- **Reflecting the needs of non-pricing states endogenously within the energy market,** such as through an in-market emission-constrained dispatch approach, though these efforts are anticipated to be pursued at a later stage given the later target implementation timeline (approximated for 2030 implementation, considering the indicative timeframe to align with Oregon policy deadlines.)

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[28] See CAISO: California ISO - Greenhouse gas coordination working group.

[29] See CAISO, *Greenhouse Gas Coordination: Discussion Paper: Recommendations for Policy Development*. September 16, 2024; and CAISO Accounting and Reporting Issue Paper – GHG Coordination, December 20, 2024.

[30] See WPTF, "Energy and GHG Accounting Framework Illustration," April 2024.

IV. SPP Markets+

We evaluate here the Markets+ proposal for GHG pricing and allocations including both:

- **SPP Markets+ GHG Pricing Program approach that was approved by FERC in January 2025**,[31] with a targeted go-live date in 2027, which includes mechanisms to incorporate GHG-pricing adders into seller offer prices and attributes the MW of generation associated with imports to states with GHG pricing or cap-and-trade mechanisms; and
- **SPP Markets+ proposed GHG Tracking and Reporting Program approach that is subject to ongoing refinement in the GHG task force**,[32] which includes additional resource tracking and attributional GHG accounting mechanisms to support reporting entities consumption-based GHG emissions obligations (applicable to entities either inside or outside of GHG-pricing states).

The approach that will be used to support allocational GHG reporting and otherwise support entities in non-pricing states is under active refinement through SPP stakeholder processes.

A. How it Works

The SPP Markets+ approach to supporting GHG attribution and representation in market dispatch is implemented across distinct timeframes before, during, and after market dispatch, as summarized in the following Table 3. The GHG Pricing Program is utilized within energy market dispatch to attribute certain supply resources as delivering power to GHG pricing states. The GHG Tracking and Reporting Program is primarily a post-market activity utilized to support reporting entities and state regulators with self-consistent resource claims and associated GHG allocations reporting.

For narrative clarity, we describe pre-market, in-market, and post-market activities in three steps in the following discussion, in order to allow for discussion of the complementary nature of the pricing and reporting programs. However, we note that the pricing program has already gained

[31] See SPP filing on Markets+ as filed before FERC in Docket No. ER24-1658, March 29, 2024, including subsequent supplementary filings and responses; see FERC approval in Docket ER24-1658, January 16, 2025.

[32] See meeting materials posted within the Markets+ GHG Task Force. For discussion of the current proposed approach to GHG allocational accounting, we reference the Markets+ Tariff Attachment K, GHG Programs, working draft version current as of September 16, 2024.

FERC approval alongside the initial SPP Markets+ Tariff filing, while the reporting program is still under refinement within the Markets+ GHG Task Force.

TABLE 3. OVERVIEW OF SPP MARKETS+ GHG PRICING AND REPORTING PROGRAMS

	GHG Pricing Program (In-Market Dispatch)	GHG Tracking & Reporting Program (Post-Market GHG Allocations)
Step 1: Pre-market Registration of Resources & Contracts	• Resource registration, including resources inside GHG pricing zone and those outside GHG pricing zone eligible to be attributed to supply demand in a GHG pricing zone	• Reporting Entities confirm self-supply resources
Step 2: Market Clearing & Dispatch	• Market dispatch, including in-market attribution of MW of imports from specified resources into (accounting for GHG cost for resources attributed to GHG pricing zones)	• Not applicable (though Reporting Entities have opportunities to adjust in-market participation to align with post-market reporting needs)
Step 3: Post-Market GHG Allocation & Reporting	• State policymakers may assign responsibilities (e.g., GHG allowance obligations) to importers as an outcome of MW imports attributed in market dispatch	• Outcomes of market dispatch used to tabulate hourly GHG allocations for self-supply (contracts and ownership) as well as GHGs from net market purchases/sales relative to the system-wide residual mix

STEP 1: PRE-MARKET REGISTRATION OF DEMAND AND SUPPLY IN ANTICIPATION OF GHG DISPATCH AND ACCOUNTING TREATMENT

Under the GHG Tracking and Reporting Program, utilities or other buy-side entities ("load responsible entities") purchasing electricity through Markets+ will have the opportunity to participate as "Reporting Entities" receiving attributional GHG accounting data/reports developed by SPP. Geographic boundaries used for load registration will be aligned with the already-defined load settlement locations, in alignment with distribution utility territories that must be separately metered for wholesale market settlement purposes, which may be smaller than a balancing authority area. Each load settlement location can be treated as either:

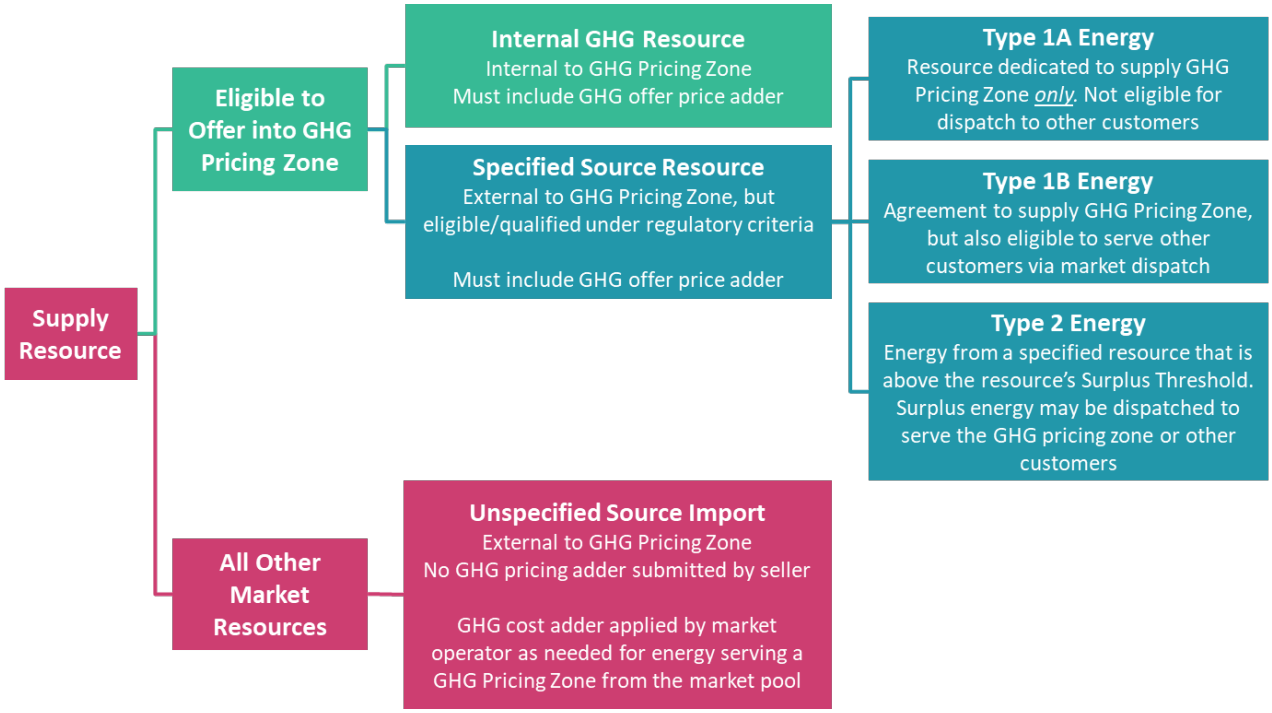
- **Reporting Entities with GHG-pricing Zone Load**, relevant for states with cap-and-trade or other explicit GHG costs imposed on GHG-emitting generators;
- **Reporting Entities with Non-GHG-pricing Zone Load,** relevant for buy-side market participants that are not subject to a policy that applies GHG emissions costs to generators, but that wish to receive a report of GHG accounting allocations responsibility, for example to track compliance with state GHG policies, corporate goals, or support the needs of end use consumers; or
- **Non-Reporting Entity Load**, for which GHG emissions allocations will not be reported.

On the supply side, market participants also have the opportunity to register supply resources in the market and qualify them under different categories. Relevant to the GHG Tracking and

Reporting Program, the primary pre-market activity is for participating "Reporting Entities" to claim or confirm the self-supply resources (see additional discussion under Step 3 below).

Relevant to the GHG Pricing Program which can produce different market dispatch outcomes, supply resources may be registered under multiple alternative energy market participation models as summarized in Figure 1.

FIGURE 1: SUPPLY RESOURCE REGISTRATION OPTIONS



Source: Adapted from SPP meeting materials, FERC filing, and working draft (dated September 16, 2024) of *Tariff Attachment K: Markets + GHG Programs* (under active revision).

Each of these resource categories has a somewhat different treatment in GHG pricing and reporting programs, as follows:

- **GHG Zone Internal Resources,** whose offer prices are always subject to a GHG-pricing adder associated with complying with the GHG emissions policy (e.g., cost of purchasing allowances under Washington's GHG cap-and-invest program).
- **Specified Source Resources** that are external to a GHG-pricing zone but are qualified to sell into a GHG-pricing zone under the relevant state policy, and whose MW of output (and hence associated emissions) can be individually tracked and attributed to buyers within GHG-pricing zones. Specified Source Resources have three sub-categories:[33]

[33] A resource offering Type 1A Energy cannot simultaneously offer any portion of the resource MW capability as Type 1B or Type 2 Energy. A resource *can* be dual-listed to offer both Type 1B and Type 2 Energy, but the MW volume of Type 1B Energy must be below the Surplus Threshold.

- Type 1A Energy is from supply resources that are exclusively dedicated to serving customers within GHG-pricing zones, and that cannot be dispatched to serve other customers outside the GHG zone. These resources are anticipated to include generation that is owned or contracted by buyers within a GHG-pricing zone, such as clean resources outside the GHG-pricing state that a utility wishes to incorporate into its verifiable GHG-free electricity supply. These external resources are also confirmed to have a certain level of resource deliverability to the relevant customers, given that one requirement for registering Type 1A Energy is a precondition that the parties have either already arranged transmission service or demonstrated the capability to arrange transmission service.
- Type 1B Energy is from supply resources contracted or owned by a reporting entity within a GHG-pricing zone, but whose supply capability can also be made available for sale to customers outside the GHG-pricing zone. The GHG offer price adder is included as a cost of dispatch only when the resource is dispatched to serve the GHG-pricing zone.
- Type 2 Energy is from supply resources that do not have a prior contractual commitment to serve customers in the GHG-pricing zone, but that can be made available to serve a GHG-pricing zone through the outcomes of market dispatch. Type 2 Energy is only available for dispatch to GHG-pricing zone customers if output exceeds the resource's Surplus Threshold. The Surplus Threshold can be set in one of two ways. A Surplus Threshold may be submitted by the asset owner to ensure that the MW of green power *below* the threshold can be retained and claimed by the asset owner as GHG-free self-supply, rather than being assigned to support the needs of other customers in the GHG-pricing zone). Alternatively, if the asset owner does not set a Surplus Threshold, then the market clearing process will determine that threshold in a merit order approach that presumes low-cost resources are utilized for self-supply up to the asset owner's load obligation.

- **Unspecified sources** are external to a GHG-pricing zone, will not include any GHG price adder in their offers, and will never face GHG-related emissions charges. Usually, these resources are expected to be dispatched to serve customers outside of GHG-pricing zones, subject to standard economic dispatch and pricing rules. However, these resources do contribute to the general pool of unspecified resources that can be indirectly assigned to serve customers in GHG-pricing zones in the post-market GHG allocations and reporting program, with these unspecified sources being considered in dispatch relative to a pre-determined, state-defined GHG emissions rate and GHG emissions cost index, or a default GHG adder of $0/tonne if the relevant state authority does not specify a price that should be applied to unspecified market purchases. This treatment is akin to treatment under several states' "unspecified market purchases" rules that apply a generic, pre-defined emissions rate to any grid purchases that cannot be traced to a specified power source. Currently, many states use a generic emissions

rate, such as consistent with a gas combined-cycle plant, as a rough approximation of the emissions rate that may apply for unspecified market purchases. The introduction of an hourly, market-wide residual mix emissions rate as anticipated under the Markets+ GHG reporting program will provide a substantially more accurate and time-dependent measure of GHGs associated with unspecified market purchases.

Each category of supply resources will have a different treatment in optimized energy market dispatch as well as in the subsequent follow-on GHG allocational reporting activities.

STEP 2: MARKET CLEARING AND DISPATCH OF DIFFERENTLY SITUATED RESOURCES

Under the in-market GHG Pricing Program, energy market clearing for supply resources within or allocated to supply GHG-pricing zones has several elements in common with and building upon the approach for GHG-pricing states that the CAISO first adopted in 2014 (described above). Similarities to the CAISO approach include the following:

- GHG offer price adders apply to resources inside the GHG-pricing zone, as well as to external resources allocated to serve resources within the GHG-pricing zone.
- Optimized energy market clearing seeks to minimize the joint costs of serving customers in both GHG-pricing zones and non-pricing zones, subject to relevant dispatch constraints.
- Market-clearing prices in the GHG-pricing zone are commensurately higher to account for the GHG component of generators' offer prices, though only customers within the GHG-pricing zone must pay the GHG component of market prices. Surplus GHG revenues collected from customers in GHG-pricing zones are returned to that state.[34]
- Customers outside the GHG-pricing zones do not pay any GHG-related costs; generators not dispatched to serve customers in GHG-pricing zones also do not incur GHG-pricing adders.

However, the Markets+ approach has several distinctions from the CAISO approach, with a common theme that the Markets+ proposal has more categories of resources with different treatment within market dispatch. Several of these distinctions allow for different ways of managing resources in the post-market GHG Tracking and Reporting Program (as discussed in Step 3 below). With respect to Type 2 Energy, the volume available for sales/attribution into a GHG-pricing zone is determined by the Surplus Threshold. For example, a 100 MW resource with a Surplus Threshold of 75 MW is only eligible to sell up to 25 MW of supply into a GHG-pricing zone.

[34] A nuance under SPP's approach is that the entity receiving the surplus GHG revenues associated with purchases from unspecified sources is specified by state regulatory authority that administers the GHG program. For example, the surplus GHG revenues may be returned to the relevant load responsible entity or to the entity otherwise identified by the relevant state regulatory authority as responsible for paying associated GHG compliance costs.

An asset owner may elect to submit their own Surplus Threshold or may utilize the default merit-order process conducted by SPP in advance of market dispatch. Under the merit order approach, the market participant's supply offer stack (without GHG cost adders) is sorted from low-cost to high-cost resources, with self-committed resources treated as the lowest cost. A pre-market algorithm determines the volume of low-cost resources that would be needed to serve that market participant's own load obligations. Any volumes of Type 2 Energy MW higher in the merit order are presumed to be beyond what is needed for self-supply and can be offered into the market as available for dispatch to GHG-pricing zones. The merit order approach seeks to approximately determine which supply resources would be prioritized for self-consumption and presumably would be dispatched regardless of GHG costs. Low-emitting and zero-emitting resources will often be at the lowest-cost portion of the merit order and would be unlikely to be made available for sales to GHG-pricing states, mitigating the potential for leakage. Given that the merit order process is conducted on a pre-market basis, it does not consider the extent to which the presumed self-supply vs. surplus MW available are mutually physically feasible and deliverable while establishing surplus thresholds. However, these physical and transmission limits are respected in physical flows in the subsequent steps of market dispatch.

For GHG-pricing zones, the outputs of market dispatch include attribution of MW supply resources as attributed to serve the loads located in GHG-pricing zones. Type 1A Energy is always treated as assigned to GHG-pricing states, while remaining net purchases may be optimally assigned from specified source resources (Type 1B or Type 2 Energy at resource-specific GHG adders) or from unspecified market purchases (with costs considered at generic, state-defined GHG price adders). The MW of attributed imports/purchases into a GHG-pricing zone is a concept separate and distinct from the physical MW of power flows. Attributed MW of imports to GHG zones are not directly limited by available transmission endogenously in market dispatch, though the physical power flows are limited by transmission limits.

For Reporting Entities without GHG-pricing policies, the clearing optimization engine does not directly assign or optimize the cleared volume of attributed self-supply vs. net market purchases/sales. However, these Reporting Entities do have the option to utilize Type 2 Surplus Thresholds in combination with the post-market GHG allocations and reporting (see Step 3 below) to achieve dispatch outcomes that could improve alignment between dispatch and GHG goals—for example, by ensuring that its own GHG-free power sources are not made available for dispatch/export to GHG-pricing zones.

STEP 3: POST-MARKET GHG ACCOUNTING ALLOCATIONS UNDER THE GHG TRACKING & REPORTING PROGRAM

SPP Markets+ participants are actively developing and refining a proposed approach for supporting market participants by providing allocational GHG accounting reports on an opt-in basis.[35] Reporting Entities may be within GHG-pricing states, states with non-priced GHG mandates, or without any GHG policy. As an expansion of the registration of specified source resources described in Step 1, Reporting Entities can register their list of owned and contracted resources with SPP (subject to mutual confirmation for cross-entity arrangements). The market operator will facilitate the process by preventing duplicate registration claims and will apply a presumption of self-supply applicable to all non-Reporting Entities.

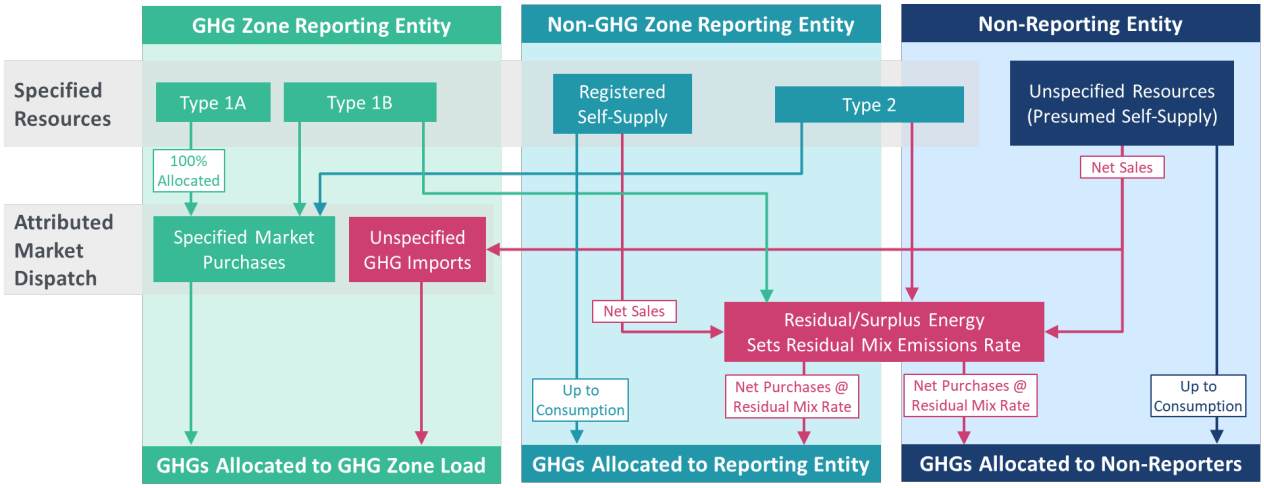
Hourly GHG emissions will also be reported out for non-participating, non-Reporting Entities, and their emissions will be accounted for in the system-wide residual mix. GHG emissions reports will be issued on an hourly basis, aggregated to monthly and annual values, and will include extensive data on volumes of both MW and GHG emissions. Non-public versions of the reports will include granular data relevant to a specific entity that can be viewed only by the market participant and state regulatory authorities. Public versions of the same report will also be issued on an hourly time-granular basis, and with state and zonal locational granularity.[36]

The general concept of the reporting approach is to tabulate all emissions produced across the system and allocate the emissions to customers, as summarized in Figure 2 below. All GHG and MW tracking is conducted on an hourly basis as derived from market dispatch. Reporting Entities will have visibility on generation-based emissions from their registered self-supply resources; they will also have visibility into how their supply resources' MW and associated emissions are allocated to customers whether for self-supply, net sales into GHG-pricing zones, or net market sales rolled into the residual mix. Similarly, net purchases may be tabulated on a specified source resource basis (only for GHG-pricing zones) or derived from the residual grid mix rate.

[35] Approach description is consistent with the Markets+ Tariff Attachment K, GHG Programs, working draft version current as of September 16, 2024. The approach is subject to active and ongoing refinement within stakeholder processes.

[36] Subject to confidentiality restrictions that require 3+ entities to be aggregated for public data reporting.

FIGURE 2: GHG EMISSIONS TRACKING AND ALLOCATIONS BY RESOURCE AND ENTITY TYPE



The GHG emissions allocation approach develops a self-consistent accounting that tabulates on an hourly basis the total emissions produced and allocates the associated emissions to customers in consideration of self-supply volumes. For entities engaged in substantial volumes of net purchases or sales, one of the most impactful aspects of the approach is the determination of which supply volumes are assumed to be applied for self-supply versus treated as net sales. For specified source resources that are explicitly allocated via market processes (Step 2), there is a relatively direct allocation of GHG responsibility, consistent with the in-market attribution of supply MW, to customers in GHG-pricing states.

However, for other Reporting Entities, there are several options for how their volumes would be attributed to self-supply vs. allocated into the residual energy mix. They have the option to claim:

- Self-supply at their portfolio average emissions rate in that hour;
- Economic resource stack, with the lowest-cost resources retained as self-supply. This approach would often result in claiming low-emitting supply as self-supply, with higher-emitting resources attributed for sale;
- Manual stack, where the participant uses their own preferred resource claim order for self-supply; or
- Another method mandated by the state regulator.

Regardless of which of the above options is used to determine the resources and associated emissions applied for self-supply, the remaining resources are deemed to be the ones that have been allocated for net sales into the residual resource mix. Non-Reporting Entities are similarly treated as first engaged in self-supply (defaulting to the average portfolio mix approach), with net sales tabulated in the residual mix. The result is a tabulation of the residual mix rate in every hour,

from which net purchasers can derive an hourly emissions rate for unspecified market purchases.[37]

An area of ongoing refinement is associated with the definition and treatment of "null power," or supply for which the RECs or other attributes have been retained by the market participant or sold to a separate third party. Options under consideration include the possibility of excluding null power resources from registering as specified source resources or simply tracking null power as a separate category in emissions reporting.

B. Key Features

The proposed approaches in Markets+ to supporting GHG-pricing states and attributional GHG accounting for all types of reporting entities offer a number of advantages, including:

- Incorporation of GHG-pricing policies into jointly optimized dispatch and price formation, including a common market that can dispatch power to serve demand across states with or without GHG-pricing programs;
- Mechanisms to mitigate (but not necessarily eliminate) the potential for leakage, including through the merit-order Surplus Threshold method, the requirement that specified source resources be qualified in GHG-pricing states, and the option for state regulators to apply a GHG adder to discourage non-specified resources;
- Comprehensive and expansive support for time-granular attributional GHG allocations accounting for a wide variety of differently situated entities with both net purchase and net sale positions. The proposal offers a step change improvement and a model for other RTOs seeking more advanced, time granular, and self-consistent allocational GHG accounting methods;
- Providing several avenues for state regulatory authorities to customize the treatment of their own policies and accounting rules including by applying state-specific residual emissions and GHG adders for unspecified purchases, and potentially for applying different rules to GHG accounting practices for entities under their jurisdiction; and

[37] The methods for calculating and applying the residual mix are subject to active revision. We note that the presumed rate for market purchases utilized within market dispatch is a pre-defined rate set by policymakers in GHG-pricing states and could deviate from the *ex post* calculation of residual emissions derived after market dispatch. The two emissions rates should theoretically be aligned to the same value for self-consistent market dispatch and resulting GHG reporting, but this would not be feasible to accomplish unless the market dispatch is further enhanced to endogenously calculate and apply the residual mix rate.

- Despite allowing for somewhat different treatment for different states, both within market dispatch and in deciding which resources are considered as self-supply, the approach regardless has the potential to produce a self-consistent tabulation of the residual mix and residual emissions rates that can be utilized by all purchasers.

C. Ongoing Stakeholder Efforts

The SPP Markets+ approach to the GHG Pricing Program that will support pricing and dispatch for GHG-pricing states has been approved by FERC as of January 2025 with a targeted go-live date in 2027, assuming that sufficient member participation is confirmed for market launch.[38] The post-market GHG Tracking and Reporting Program is relatively fleshed out, including draft Tariff and Protocols language, but is undergoing ongoing refinement in the stakeholder process through the SPP Markets+ GHG Task Force.[39]

V. Recommended Areas for Future Enhancement

We anticipate that CAISO's WEIM/EDAM, SPP's Markets+, and other ISO/RTO markets will have to substantially expand their support for market participants and state policymakers with diverse GHG and clean energy goals. These parties will need to engage in increasing levels of trade in order to cost-effectively and reliably pursue their goals, even while they become increasingly focused on the GHG obligations associated with their market purchases and sales. However, at the present moment there are at least two market failures that limit the capability of regional power markets to support all mutually beneficial trades, namely:

- *Insufficient information* available to power market participants and policymakers, specifically to help them accurately measure and report GHG responsibility associated with wholesale market purchases, including on a time and transaction-granular basis that is consistent with reliable operations of the grid; and
- *Insufficient access to well-defined products and property rights*, specifically related to the ability to exclusively claim (or transfer the claim) of non-GHG-emitting supply, in a fashion that

[38] See SPP filing on Markets+ as filed before FERC in Docket No. ER24-1658, March 29, 2024, including subsequent supplementary filings and responses; see FERC approval in Docket ER24-1658, January 16, 2025.

[39] See Markets+ GHG Task Force and associated meeting materials.

is self-consistent with allocated GHG responsibility and consistent with reliable grid operations.

We believe that ISO/RTO market operators will be able to unlock substantial economic value through ongoing reforms to meaningfully address these market barriers by:

- **Expanding reporting support for physical system emissions data** (marginal, average, and location-based consumption rates) on a time-granular and locationally granular basis.[40] Because these data are fact-based and readily derived from physical system data, they should be viewed as low-hanging fruit that can be provided in an expedited fashion (unlike most of the other enhancements we describe, which may take substantially more time to develop and implement).
- **Tracking and reporting support for allocated GHG emissions responsibility**, relevant for calculating residual mix emissions associated with market purchases and developing market-based GHG accounting. Over time, allocational GHG emissions reporting should become increasingly self-consistent with REC markets, GHG allowance markets, and state clean energy program compliance if these mechanisms are to be mutually beneficial and affordable.
- **Enhancing RTO energy market dispatch to endogenously track and optimize** market participants' diverse preferences to utilize non-emitting MW of power supply and avoid relance on GHG-emitting power supply.

It is neither realistic nor necessary for different states and market participants to arrive at a singular approach to defining and driving progress on decarbonization and clean energy goals. For example, we anticipate that states will continue to use a variety of programs including GHG cap-and-trade, renewable portfolio standards, utility net-zero GHG planning standards, and fossil phase-out requirements in service of their goals. It would not be realistic to require that all states conform to a common approach of defining their policy structures as the precondition to participate in markets and gain the benefits of trade.

Instead, we would describe the roles of regional power markets as: providing the information transparency needed to inform decision-making and policy; supporting the clarification of property rights associated with the transfer of clean energy claims and allocated GHG responsibility associated with energy purchases made through the RTO markets; and enabling mutually beneficial trade of these same property rights amongst willing buyers and sellers.

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[40] As described in more detail below, we anticipate that most data can and should be provided on the same time granularity as market transactions, including down to the 5-minute or hourly timeframe and nodal locational granularity.

A. Physical System GHG Data

We recommend expediting the development of a comprehensive suite of physical system GHG data on a time-granular and locationally granular basis. We distinguish physical system data as substantially simpler to implement compared to the allocational GHG reporting and market design support that are the primary subject of this paper. Physical system GHG data play the more straightforward role of providing transparency into grid realities, and hence do not require the same level of policy guidance and stakeholder engagement to define them.

Physical system GHG data are those related to data categories 1-3 in Section II above, including: (1) generation-based emissions; (2) consumption-based emissions, developed consistent with regional power flows under location-based accounting approaches; and (3) marginal emissions rates. These data would be provided on an aggregate basis (total emissions) as well as on a rate basis (emissions per MWh of generation or consumption). The data can also be provided at the most granular basis relevant to RTO power markets (nodal, hourly or 5-minute) and aggregated.

We provide more detail on how these data can be provided, including examples of markets where they are already being produced, in Section II above and Section VI below.

B. Allocational GHG and Residual Mix Reporting

The much more challenging, and ultimately more valuable, exercise is to provide a robust set of allocational GHG tracking and reporting data, including developing an accurate residual mix emissions rate that can be used to measure the emissions associated with net market purchases (data category (4) from Section II above). These reporting needs will be supported by both the SPP Markets+ GHG Tracking and Reporting Program proposal, which has been relatively fleshed out, and the initial CAISO approach for GHG accounting and reporting (in early development stages).[41] In our view, these efforts correctly focus on the central concept of creating value by providing a common fact basis against which to measure and report GHG responsibility, but they will face a number of analytical complexities in developing the most accurate and feasible implementation.

We offer our recommendations for how these reporting mechanisms could be structured to most meaningfully inform and align with state policymakers informational and compliance needs, including accounting for the differences amongst states. We anticipate that state policymakers will gain the most value from the resulting GHG emissions reports if they include the following:

[41] See Markets+ GHG Task Force, specifically Markets+ Tariff Attachment K, GHG Programs, working draft version current as of September 16, 2024 and CAISO Accounting and Reporting Issue Paper—GHG Coordination, December 20, 2024.

- **Essential GHG Data Categories for Each Entity**: Including MW and GHG associated with: (1) self-supply MW (owned or contracted, confirmed prior to market dispatch); (2) emissions and MW associated with market sales (attributed to other buyers via RTO dispatch); and (3) emissions and MW associated with market purchases at the most accurate residual mix rate. When provided by resource type and reported separately for gross and net market purchases and sales, these data can be used to support the primary measures needed to demonstrate progress against all or nearly all types of policy goals (such as generation-based compliance, clean energy goals measured on a consumption basis, GHG goals measured on a consumption basis, and any combination).
- **Comprehensive and Complete Data:** All GHG emissions produced by any generator should be allocated to consumers in the same time dispatch interval, including accounting for the emissions from fossil resources owned by non-reporting entities. Even if a particular entity or state chooses not to participate in the reporting program, these emissions would need to be accounted for if the subset of participating states/entities is to have an accurate measure of emissions responsibility to avoid the natural problem that many entities would tend to opt in to self-supply claims and sales participation with the cleanest supply resources while leaving highest-emitting supply out of the program.
- **Granular Accounting:** Eventually, the granularity of the GHG reporting and attribution can and should become as granular as energy market transactions to allow reporting entities to most accurately capture the emissions associated with individual purchases and sales. If the foundation of reporting is at the most granular level, it can always be aggregated to any higher level that is useful for individual entities, policymakers, and the public. The reverse is not true. The most granular accounting would be:
  - *Hourly or 5-minute time granularity*, which is already the time granularity contemplated in the SPP Markets+ proposal;
  - *Nodal locational granularity,* though initial reporting is likely to be limited to system-wide granularity (SPP Markets+) or possibly by BAA (noted as feasible by the CAISO in its initial assessment); and
  - *Transaction-level granularity,* which enables alignment with individual entities' pre-market self-supply reporting, as well as allowing for post-market aggregation (to the level of entity, zone, state, or system). This level of granularity is also aligned with the granularity of energy market settlements required to implement any of the complementary market reforms that could be used by participating entities to manage their GHG and clean energy positions in trade.
- **Consistency with Transmission Capability and Physical System Dispatch:** To date, the allocational GHG reporting mechanisms have been relatively less focused on ensuring

consistency with transmission deliverability compared to the granular representation of the transmission system accounted for in nodal power markets. We anticipate system-wide (and probably even BAA or state-wide) GHG reporting will eventually be insufficient to support states' needs, given the importance of transmission limits that prevent some low-cost renewables from being fully deliverable to consumers at different times. Ultimately, we anticipate that states and utilities will need the visibility into more locationally and transmission-consistent GHG reporting to inform their ability to plan and operate enough local dispatchable resources to compensate for transmission limits.

- **Self-Consistency Between REC Markets, Self-Supply Claims, In-Market Dispatch and GHG Reporting.** Currently, there is no alignment between REC markets (monthly, non-locationally granular) and GHG reporting. But these mechanisms can be *made* to be more self-consistent and complementary if this is adopted as a design goal. We recommend aligning clean energy claims and GHG allocations to improve economic efficiency and help states to ensure that these separate programs, both within a state and across state borders, have a meaningful association with mutually exclusive clean energy claims and comprehensive GHG attributions. To enhance alignment between REC/clean energy claims and GHG reports, the reporting can separately track multiple categories of non-emitting supply resources:
  - *Claimed Non-Emitting Self-Supply* would be those resources that a reporting entity plans to claim as clean energy by retiring a REC or claiming the clean attributes under state compliance. In market dispatch, these MW would be attributed as self-supply by default, though surpluses above self-supply MW in interval could be incorporated into the residual system mix.
  - *Certified Non-Emitting Supply, Available for Sale via the RTO Market*, would be any renewable or non-emitting resource that is offered for sale as a zero-emission resource that can be attributed to another buyer through the wholesale power market. CAISO and SPP Markets+ both have mechanisms to support such sales to GHG-pricing states by attributing MW within market dispatch, though neither yet has a proposal to offer a similar opportunity for a market sale of clean energy to non-pricing states. Currently, neither the CAISO proposal nor SPP Markets+ proposal includes a mechanism to ensure that attributed MW of non-emitting energy supply are backed up with a certification of a non-exclusive REC claims, which is one of the reasons that other mechanisms to prevent leakage are needed. A more meaningful attribution and sale of clean energy MW could be accomplished if the seller were required to surrender RECs (or at least have the organization certify that they have not otherwise sold or claimed the unbundled attributes) as a requirement to offer these MW for sale via the RTO market. This would prevent the non-mutually exclusive claim or re-attribution of the non-emitting supply either directly (through RTO market attribution) or implicitly (through post-market GHG

accounting). Certified non-emitting supply would be directly attributed to specific buyers or states (assuming the in-market mechanisms exist to support the attribution), or included in the residual mix if they remain non-attributed.

  - *Null Power* (adopting the term from SPP Markets+) would be any non-emitting supply for which the unbundled REC or clean energy attributes have been separately sold or claimed, or for which the asset owner has not made any certification. Null power resources would be presumed as self-supply by the asset owner in the first instance. However, even if the volume of null power exceeded the asset owner's demand, it would not be included in the calculation of the system-wide residual mix emissions rate (to avoid the potential for reporting entities to double-count the non-emitting value of those null power resources).

- **A Focus on Time and Locational Accuracy in the Residual Emissions Mix:** Many reporting entities are likely to focus most extensively on the large volume of MW and GHGs associated with self-supply reporting, with a lesser focus on the accuracy of the residual mix used to tabulate the GHGs associated with a smaller volume of net market purchases and sales. For example, utilities will naturally be concerned that they receive "full credit" for their self-supply choices and pre-market planning and resource decisions (and we agree entirely with the importance of accurately capturing self-supply). However, as economists, we also emphasize the criticality and importance of an accurate and granular measure of the residual emissions mix as a central driver of go-forward adjustments to resource operating profiles and investment/contracting decisions. For example, the operations of batteries and hydro resources across the West are greatly influenced by the incentives produced in ISO dispatch. If these resources are to be operated in a fashion that helps to create value by avoiding emissions for the relevant reporting entities, then the accuracy of the residual mix, along with the nodal power price, is a critical factor that should be accounted for in operating decisions and charge/discharge profiles. Striving to measure the residual emissions mix on both a time-granular and locationally granular basis will make the accounting support substantially more valuable signal for driving operating and planning decisions. Over time, we recommend that for states that currently utilize a generic rate to account for market purchases, these can be replaced by the more accurate and granular residual mix rate tabulated in each dispatch interval.

Overall, the outcome of a granular and accurate GHG reporting mechanism can support increasingly robust measurement of entities' progress against GHG goals and for policymakers to confirm compliance. The more carefully these mechanisms align with REC markets and clean energy claims, the more meaningfully they can also provide the basis for transfer of property rights (i.e., clean energy claims) in RTO dispatch.

C. In-Market Dispatch Support for GHG-Pricing & Non-Pricing States

Both the CAISO and SPP Markets+ designs described above have developed in-market mechanisms to support the dispatch and attribution of supply for GHG-pricing states, including both MW of supply internal to those states and external resources attributed for import to those states. Neither market has yet proposed a similar and compatible mechanism to support enhanced dispatch outcomes for non-GHG-pricing states and other entities with strong GHG goals, though the CAISO GHG Coordination stakeholder group will eventually begin looking at solutions with a potential target for implementation by approximately 2030.[42]

We are optimistic that the next phase of enhancements for in-market dispatch can incorporate mechanisms to support the needs of entities in non-pricing states, as well as leverage the advances in GHG reporting programs. One proposal that has been described in both the CAISO and SPP Markets+ stakeholder contexts is the potential for "emissions constrained dispatch" to support the needs of GHG-pricing states.[43] Though we do not fully restate and describe that proposal here, we acknowledge that we draw on several of the concepts presented in that paper in developing our own suggestions for enhancing in-market dispatch solutions for both pricing and non-pricing states.

To enhance in-market support for both GHG-pricing states and non-GHG-pricing states, we suggest considering options including:

- **Aligning qualification requirements for attributable non-emitting MW with exclusive clean energy claims and REC-based accounting.** As discussed in Section V.B above, the introduction of GHG reporting support creates an opportunity to improve the mutual compatibility of RTO markets with REC-based accounting and measuring policy compliance. Currently, both the CAISO WEIM/EDAM and SPP Markets+ approaches to supporting GHG-pricing states allow those states to receive "attributed" MW of supply from any resources that are qualified as importers to the state in question. For GHG-emitting resources, this would mean that the seller must accept state requirements to surrender GHG allowances in the volumes needed to fulfill a compliance obligation. For non-emitting resources such as renewables and nuclear, we suggest that the requirement for qualifying to make such an attributed non-GHG-emitting, clean energy sale through the RTO market should be that they make an exclusive sale of clean energy attributes, meaning the RECs are not unbundled or remarketed, and clean energy

[42] See CAISO, Accounting and Reporting Issue Paper – GHG Coordination, December 20, 2024.

[43] See Howe, "*Emission Constrained Dispatch: Technical Documentation,*" May 21, 2024; as well as the earlier June 2023 paper by the same author developed in the SPP context.

attributes are not otherwise claimed by the asset owner under a state clean energy program or GHG policy. A more robust version of the same requirement would require follow-on activities via the ISO or under the receiving state's regulations for the surrender of the appropriate volume of qualified RECs or clean energy certificates to cover the in-market clean energy sales volume. Under this approach, only resources that have committed to the exclusive sale of clean energy to the receiving state or GHG-pricing region would be eligible to receive the GHG component of pricing relevant for specified importers.

- **Applying the in-market-calculated residual mix for any unspecified market purchases.** Rather than waiting until post-market activities to calculate the residual emissions mix, endogenously calculate the residual emissions mix as market of the RTO day-ahead and real-time market clearing. Using the same methods relevant for GHG reporting (see prior discussion), calculate the residual mix applicable for in-market unspecified market purchases. If the residual emissions mix rate applicable for unspecified market purchases can be calculated endogenously in market clearing, it would be a parameter that can be issued to the marketplace in real-time and used to inform dispatch and operating decisions.
- **Expanding the use of in-market attribution of MW to apply to both GHG-pricing and non-pricing states.** Already, both the SPP Markets+ and CAISO WEIM/EDAM market designs apply the concept of "attributing" MW of specified imports to describe the specific resources that are assigned as imports to GHG-pricing zones. We recommend that the same concept be extended to support the needs of non-GHG-pricing states and other buyers that prioritize the purchase of non-emitting supply. There are several ways that this could be accomplished in market dispatch, but the central idea is that the "decision variable" that the market clearing engine can decide upon is to determine which customer (or state) should be assigned which MW of attributed supply. Elements of the concept would include:
  - *Introducing a participation model for voluntary clean energy buyers* that would opt in to participating for in-market purchases of non-emitting clean energy supply. Individual market participants with a buy-side or load position in the RTO markets would be eligible as clean energy buyers. The concept could be extended to a state-wide level as well, with a state regulatory authority setting the parameters for demand on behalf of all customers in the state.
  - *Extending the concept of in-market attributed MW to apply to both GHG-pricing states (as now) and also to other voluntary buyers or non-GHG-pricing states.* Already, the CAISO and SPP Markets+ approaches include the capability for the market to assign attributed MW from specific resources to serve a portion of the demand for GHG-pricing states. The concept would be extended to also define a volume of attributed MW of cleared supply of from specified sources to other voluntary clean energy buyers.

- *Designating attributed MW of supply as an explicitly defined product that can clear via the RTO market as "specified clean energy" purchases.*[44] The volumes of attributed MW would then be elevated in prominence as a clearly defined product, the value of which is derived from the importance that voluntary buyers place on ensuring that their market purchases can be certified as GHG-emissions-free. By procuring GHG-free power from specified resources via the RTO market, buyers would benefit by: (a) avoiding the application of GHG emissions at the residual mix rate in the RTO reporting program; and (b) earning the right to make exclusive claims to the non-emitting nature of the supply. To qualify as supply, sellers would be required to certify their clean energy attributes have not been separately sold or claimed, or, in a more stringent variation, would have to eventually surrender the associated volume of RECs to the RTO or the relevant state regulator.
- *Allowing buyers and sellers to submit bids and offers for specified clean energy*, alongside other RTO energy market bid parameters. Buyers wishing to procure specified clean energy through the RTO marketplace would express their willingness to pay as a maximum $/MWh price premium for a specific MWh demand volume.[45] Sellers would express an offer price adder, also in $/MWh, reflecting the minimum price they are willing to accept for making specified clean energy sales. For example, if a solar resource offers unbundled energy for sale at $0/MWh, they may offer to make a specified clean energy sale at a price premium of $10/MWh (the price premium reflecting the fact that the seller forgoes the opportunity of selling the REC to another buyer).
- Optimizing the clearing of attributed specified clean energy sales alongside other energy market parameters, so as to minimize total system costs and maximize the benefits of

[44] Note that the markets already incorporate a somewhat one-sided variation of this market product in support of GHG pricing states, in that the sell side of the specified resources market opts in to compete for sales into the GHG pricing zones and can earn compensation at the GHG component of the price outside the GHG zone. The buy side of the market is created indirectly through the application of the GHG premium paid for by customers in the GHG pricing zone. The approach that we describe above aims to more explicitly describe the preferences of the buy-side of the market.

[45] These demand bid parameters could be structured in multiple ways, but would always be possible to translate into a $/MWh value and associated MWh volume that is relevant in each dispatch interval and is tied to a specific quantity of physical demand purchased through the RTO energy market. The volume of demand for clean energy would be equal to or less than the volume of unspecified purchases that they would otherwise make at the residual mix rate. Some buyers or states may opt to place a standing bid, for example $5/MWh as the maximum willingness to pay to secure non-emitting supply for all net market purchases, and leave that willingness-to-pay as a constant with few updates over time. Other players that are actively considering tradeoffs in procurement of clean supply relative to other options such as on-site storage, running high-emissions local backup supply, or deploying high-cost demand response might develop a more dynamic strategy for updating their willingness to pay to procure certified clean supply from the RTO market.

trade.[46] The clearing price for specified clean energy would be set at the intersection of supply and demand.[47]

- **Enhancing representation of transmission system limitations to limit the maximum quantity of market-attributed MW supply.** We recommend more fully representing major transmission system limitations within in-market attribution of specified resources, including applying these limits both for GHG-pricing states and non-GHG-pricing states. For example, the MW of attributed clean energy sales between BAAs would be described as a portion of the physical power flows between the same BAAs, and would not be allowed to exceed the physical transmission limits.[48]

The overall result of these enhancements to in-market dispatch support would be to produce market clearing outcomes that are fully aligned with post-market GHG reporting and allocations, while enhancing the ability of market participants to manage their own GHG and clean resource positions as a function of market dispatch. Buyers would have the ability to dynamically observe the real-time residual emissions rate of GHGs they would have to accept if making unspecified market purchases, and be able to compare the associated obligations against the real-time price of securing certified non-emitting supply. Batteries and hydro resources would be incentivized by the combination of energy prices and also by clean energy value. They could dynamically shift their output to absorb non-emitting supply when the cost of doing so is low, and sell the non-emitting supply (minus efficiency losses) back to the marketplace at a later time. Over time, the resulting patterns of prices and residual mix rates would inform improved resource planning and policy choices, such as how heavily to prioritize local resources over remote supply and when to

[46] In the optimization objective function, the market clearing engine would continue to be formulated as the minimization of total system-wide production costs and GHG costs. On top of that would be added the minimization of the sum of: (a) costs of cleared specified clean energy supply (measured as sellers' offer prices times cleared volumes); minus (b) value of cleared clean energy demand (measured as buyers' bid price times cleared volumes). Note that the new components of the objective function work to maximize the benefits of trade created by clearing the new product (i.e., maximize the economic surplus = consumers' value − producers' cost).

[47] Translated into the terms of optimization formulation, the clearing price for specified clean energy would be backed out as the shadow price on the supply-demand constraint, similar to how prices are set based on the supply-demand balance constraints on energy, ancillary services, and MW of specified energy attributed to GHG pricing states. The supply-demand balance constraint for specified clean energy would stipulate that: Cleared Demand MW of Specified Clean Energy ≥ Cleared Supply of Specified Clean Energy. The result ensures that there is a cleared seller for each buyer, and also ensures that incremental volumes can only clear the market if the value to the marginal customer is equal or greater than the cost to the marginal seller. If there are multiple classes of cleared clean energy supply, either because states have different qualification criteria or because transmission constraints are applied in the market, then there may be differences in the marginal clearing price by resource class and/or by location.

[48] At this stage we do not take a view on the most appropriate level at which to apply such transmission limits, other than noting that node-level granularity is likely more granular than is needed and relevant at this time and that a full system-wide representation without transmission representation is likely insufficient to ensure that attributed MW are sufficiently aligned with physical dispatch outcomes.

invest in on-site batteries (rather than relying on market purchases as the most cost-effective source of low or non-emitting balancing energy).

VI. Takeaways

We hypothesize that over time, states will require an increasing level of support from market operators to provide transparent, settlement-quality data and energy market participation mechanisms for entities pursuing GHG reduction targets. The data and market participation needs likely will eventually need to be as granular in time and place as the wholesale energy markets, such that clean energy accounting and residual mix GHG allocations can be supported on the same 5-minute, nodal basis that underpins energy market LMPs. Furthermore, GHG reporting and REC instruments will likely need improved alignment with each other over time to support mutual consistency and align economic incentives.[49]

Both CAISO WEIM/EDAM and SPP Markets+ have developed or implemented industry-leading approaches to support GHG accounting needs and incorporate GHG values into market dispatch, and the supporting RTOs are actively engaged in efforts to expand their methodologies to serve entities in both GHG-pricing and non-pricing states. We summarize their respective approaches below and compare them to our view of the potential long-term needs to support states' and consumers' diverse range of GHG policies, inform clean energy resource planning, and provide settlement-quality GHG data that can be used to settle contracts and demonstrate compliance.

[49] Total alignment between the two systems will not be feasible unless market operators have access to and incorporate into their dispatch granular information associated with the REC instruments, including the associated resources and their sales volumes across applicable timeframes.

TABLE 4. CURRENT STATUS & RECOMMENDED LONG-TERM SUPPORT FOR GHG POLICIES

	CAISO WEIM & EDAM	SPP Markets+	Long-Term Needs
GHG Emissions Rate Reporting			
Average Generation-Based Emissions Rate	• Hourly emissions, provided for California & WEIM system-wide	• Proposed as part of entity reports (hourly, locational, entity)	• Total emissions and average generation emissions rate, hourly or 5-minute granularity • Zonal, state, and system-wide
Average Consumption-Based Emissions Rate (i.e., for Location-Based Scope 2 Reporting)	• For California: GHGs produced to serve CAISO customers from ISO dispatch (CAISO internal & net imports); monthly aggregation of 5-minute data	• Not included in initial proposal (focus on attributional accounting)	• Flow-based accounting of GHGs produced and allocated to loads (i.e., nodal equivalent of Scope 2, location-based accounting) • Nodal allocations aggregated to zonal, state, and system levels; 5-minute granularity • Example: MISO flow-based allocations
Marginal Emissions Rates	• Not yet provided (not prioritized in ongoing GHG Working Group)	• Not included in initial proposal	• Node-specific locational marginal emissions, 5-minute granularity • Example: PJM marginal emissions
Residual Mix Emissions Rates	• Not yet provided, but prioritized for ongoing development in CAISO GHG Working Group	• Approach proposed & in refinement in Markets+ GHG Task Force (hourly)	• Node-specific residual mix rates; 5-minute granularity • Consistent with entity-specific reporting
Energy Market Integration			
Market Timeframes Supported	• WEIM: 5-min real-time market (in place since 2014) • EDAM: Hourly day-ahead (implementation 2026)	• 5-min real-time market & hourly day-ahead market (FERC approved, target implementation by 2027)	• 5-min real-time & hourly day-ahead (same timeframes as energy market dispatch & settlement)
Dispatch Support for GHG-Pricing States	• In-state supply: GHG costs included in gen offer prices • Imported supply: out-of-state supply may incur GHG allowance obligation & price if dispatched to serve demand for pricing states (supply must opt in for eligibility to serve GHG-pricing state demand). GHG component of LMP paid to out-of-state sellers dispatched to serve customers in GHG-pricing state	• Internal resources in GHG zones subject to GHG adder • Specified source resources can serve GHG-pricing zones with GHG cost adder, different treatment for dedicated self-supply (Type 1A), self-supply available for net sales (Type 1B), and specified purchases (Type 2) • Unspecified purchases subject to state-defined emissions rate and GHG adder	• Similar to current SPP & CAISO approaches, ongoing enhancements to align with entity reporting, mitigate leakage, and enable/align with other green buyers' needs • Update MW attribution to allow buyers in GHG pricing & non-pricing states to compete for non-emitting supply (see below)
Supply Participation Models	• Fossil Resources: can offer GHG adder if selling to GHG-pricing state • Clean Resources: Can sell into GHG-pricing state and earn GHG adder	• Fossil Resources: can offer GHG adder if qualified and selling to GHG zone • Clean Resources: can sell into GHG zone if qualified and earn GHG adder	• Fossil resources: Current CAISO & SPP approaches; plus • Clean resources: Ability to offer unclaimed REC/environmental attributes for sale via real-time energy market dispatch ($/REC offer price offered alongside brown power energy offer price)

	CAISO WEIM & EDAM	SPP Markets+	Long-Term Needs
Buyer Participation Models: Non-GHG-Pricing States	• Preliminary discussions (currently deferred). One proposed option is emissions-constrained dispatch to apply GHG quantity limits to be respected in energy market dispatch (up to a maximum GHG price)	• Not endogenously supported within market dispatch (but can avoid sales to GHG-pricing states and participate in allocational GHG accounting)	• Allow all buy-side market participants to express willingness-to-pay alongside nodal energy market bids, for example through $/MWh willingness-to-pay for specified supply from certified clean energy supply resources
Geographic Granularity & Reflection of Transmission Limits	• Imports allocated to GHG-pricing states limited to physical transmission availability (endogenous to market dispatch)	• Self-supply resources indicate deliverability prior to market operations based on confirmation of transmission service or ability to acquire transmission (not explicitly enforced in market dispatch)	• Implied volumes of real-time clean energy deliveries simultaneously feasible across RTO footprint in all intervals with all transmission limits respected (e.g., attributed clean energy flows equal to or less than physical energy flows realized in market dispatch)
Mechanisms to Mitigate GHG Leakage and GHG Backfill	• Market "reference pass" establishes baseline level of output for external resources, only higher-MW output can be considered in final market pass • GHG net export constraint allows only energy exports from a BAA that is net exporting to be allocated as export to GHG-pricing state	• Sales of Type 2 energy to GHG-pricing states only above Surplus Threshold. If using merit-order approach, low-cost renewables unlikely offered for sale as specified source resources	• Continue evolution toward full accounting of attributed self-supply MW and net purchase sale within market dispatch for all reporting entities and net purchases at the residual mix rate (ideally in one-pass solution) • Consider requirements to back net purchases of GHG-free power with REC deliveries
Attributional GHG Accounting (i.e., Allocated During or After Market Clearing)			
Generator Emissions Coverage	• Supply in GHG-pricing states + specified imports • Ongoing efforts: expand coverage to track emissions from supply serving non-pricing states and reporting entities	• Proposal for full coverage of all entities (reporting and non-reporting entities)	• 100% of supply-side GHG emissions included in reporting across RTO footprint • Include accounting of emissions from non-participating, non-opt-in supply in residual emissions mix allocations
Allocational GHG Reporting Provided	• Today: GHG-pricing states, state-wide • Ongoing Efforts: Expand support for non-GHG-pricing states and reporting entities	• Proposal to support reporting entities in pricing states, non-pricing states, and public reporting for aggregated system-wide allocational reporting	• Market Participants: Nodal GHG attributions (at load nodes), consistent with energy market withdrawals & settlement volumes • States: Nodal & entity-specific allocations aggregated to state level. States opt in to public reporting at relevant level (e.g., retail provider or distribution utility) • Public Reporting: GHG allocations at the zone, state, and system levels

List of Acronyms

AIB	Association of Issuing Bodies
BAA	Balancing Authority Area
CAISO	California Independent System Operator
EDAM	Extended Day-Ahead Market
EIM	Energy Imbalance Market
FERC	Federal Energy Regulatory Commission
GHG	Greenhouse Gas
GIS	Generation Information System
ISO	Independent System Operator
ISO-NE	Independent System Operator of New England
Lb	Pound
LMP	Locational Marginal Price
M-RETS	Midwest Renewable Energy Tracking Systems
MISO	Midcontinent Independent System Operator
MW	Megawatt
MWh	Megawatt Hour
NEPOOL	New England Power Pool
NYISO	New York Independent System Operator
PJM	PJM Interconnection
PJM-EIS	PJM Environmental Information Services
REC	Renewable Energy Certificate
RPS	Renewable Portfolio Standard
RTO	Regional Transmission Organization
SPP	Southwest Power Pool
WEIM	Western Energy Imbalance Market
WREGIS	Western Renewable Energy Generation Information System

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