EIM Greenhouse Gas Enhancement

Revised Draft Final Proposal

June 23, 2017

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1 Introduction

California greenhouse gas regulations apply to imported electricity. Under these regulations, the California Air Resources Board (ARB) treats Energy Imbalance Market (EIM) transfers serving ISO load as electricity imports into California. ARB relies on the ISO's market results as reported by EIM participating resource scheduling coordinators to identify resources that supported those transfers and applies a specified source emission rate to those resources. ARB imposes reporting and compliance obligations on EIM participating resource scheduling coordinators representing these resources.

To address ARB's regulations, the ISO developed a mechanism to reflect greenhouse gas (GHG) compliance costs within locational marginal prices. Inside the ISO balancing authority area, the energy price includes GHG compliance costs of generation. Outside the ISO, the energy price does not include GHG compliance costs when external resources are serving load outside the ISO. However, external resources do receive a payment for GHG compliance costs when they are dispatched to serve ISO load. The ISO market can identify the price difference because resources outside the ISO balancing authority area bid a GHG compliance cost adder separately from their energy bids. When serving load outside the ISO, the market optimization considers only the energy bid. When serving load inside the ISO, the market optimization considers the energy bid plus the GHG compliance cost adder.

The ISO is currently working with ARB and stakeholders in ARB's rule making process to address a concern that the EIM GHG market design is not fully capturing the impact to the atmosphere that occurs in connection with EIM transfers into the ISO to serve ISO load. The ISO has reviewed several potential design changes and, based upon stakeholder comments, is proposing a two pass market optimization to identify which resources provide output to support an EIM transfer into the ISO to serve ISO load. The first pass would determine the optimal schedules across the EIM footprint while not allowing net transfers into the ISO. The second pass would allow transfers into the ISO and limit each EIM participating resource's GHG bid quantity to the difference between the resource's upper economic limit and its optimal schedule determined in the first pass.

The ISO is planning to implement the two pass solution only in the real-time market. The ISO, however, can extend this approach to the day-ahead market with some additional market design enhancements. The ISO describes the necessary design enhancements in this proposal.

2 Stakeholder Process and Timeline

Below is a proposed schedule for the policy development stakeholder process for this initiative:

Item	Date
Post Revised Draft Final Proposal	June 23, 2017
Stakeholder Conference Call	June 22, 2017
Stakeholder Comments Due	July 6, 2017
EIM Governing Body Briefing	July 13, 2017
Board of Governors Briefing	July 26-27, 2017
Report on GHG Attribution Accuracy	Q4 2017
EIM Governing Body Decision	Q1 2018
Board of Governors Decision	Q1 2018
Implementation	Fall 2018

Table 1 – Schedule

3 Changes from May 24 Draft Final Proposal

Modified the second pass optimization

In the draft final proposal, the ISO proposed to add a resource specific constraint that GHG attribution must be above the GHG allocation base determined in the first pass. Under the revised draft final proposal, the ISO is proposing to limit the GHG bid quantity to the difference between the resource's upper economic limit and the GHG allocation base determined in the first pass solution. This approach does not require additional constraints to be added to the market optimization.

No two pass solution can eliminate all secondary dispatch; therefore, the solution must balance the objective of minimizing secondary dispatch with optimization solution performance and price / dispatch consistency. An additional benefit of the two pass solution is that the GHG allocation base allows the ISO to provide data to ARB on the emissions of any residual secondary dispatch that remains after the GHG enhancement is implemented.

The ISO will implement the two pass solution described in this revised straw proposal in parallel operations and produce a report in Q4 '17 that evaluates the effectiveness of the design in minimizing seconday dispatch. In addition the ISO is investigating the potential for additional enhancements in the event that the Q4 '17 demonstration identifies the need for improved attribution accuracy.

4 Current GHG Design for ISO Energy Markets

Imports of energy into California and the generation of energy within California are subject to the California cap-and-trade program and mandatory reporting GHG regulations. The system marginal energy cost of the current ISO balancing authority area generally reflects the costs of compliance with these regulations by virtue of the fact that scheduling coordinators include the cost of this compliance in their energy bids. The ISO also allows for the inclusion of GHG compliance costs in start-up and minimum load costs for generators as well as their default energy bids. The market optimization then uses these energy bids to determine the least cost dispatch to serve ISO load.

Generators and importers can submit energy bids up to the $1000/MWh bid cap. In the event market power mitigation is triggered, the ISO replaces generators' energy bids with a mitigated bid. The floor for a mitigated bid is the generator's default energy bid. These are generally cost based bid curves are calculated by the ISO. When transmission elements are non-competitive, mitigated bids for some resources may be used by the market for determining dispatch and LMPs.[1] The ISO estimates the cost of GHG compliance and includes this cost in the default

[1] For additional information, please review section 6.5 of the ISO Business Practice Manual – Market Operations at https://bpmcm.caiso.com/Pages/BPMDetails.aspx?BPM=Market%20Operations

energy bid. For imports, the ISO does not use default energy bids since the ISO does not mitigate bids at intertie scheduling points.

5 GHG Design for EIM

5.1 Overview

In 2014, the ISO created the Energy Imbalance Market (EIM) which extended the ISO's real-time market to other balancing authority areas electing to participate in a joint dispatch with the ISO and other EIM entities. As a result, the real-time market dispatch simultaneously met demand in California and other states in the West. The ISO designed the EIM so that the GHG compliance costs will not affect the price in an EIM balancing authority area when load is met from generation external to the ISO. Through its market optimization, the ISO calculates the marginal cost difference between EIM generation serving load in the ISO balancing authority area and EIM generation serving load outside of the ISO. This difference reflects the marginal GHG compliance cost component of the LMP.[2] It is also the rate the market uses to calculate a payment to each generator in an EIM balancing authority area for its output that is determined to serve ISO imbalances. This payment is funded through the price paid within the ISO for imbalance energy embedded in the system marginal cost of energy.[3]

In the ISO, all generation and imports embed the cost of GHG compliance within their energy bid. For resources in an EIM entity's balancing authority area, there are no GHG compliance costs when the resources serve load outside the ISO. These resources, therefore, cannot include GHG compliance costs in their energy bids. The design allows EIM participating resources to submit two bids: (1) an energy bid and (2) a GHG bid adder. The combination of the energy bid and the GHG bid must not exceed the $1000/MWh energy bid cap.

The market optimization minimizes the total cost to serve load across all balancing authority areas in the EIM, this includes the ISO. When evaluating the least cost dispatch to serve load in the ISO, the optimization considers the energy bids which can include GHG costs of generation in the ISO and the GHG cost of attributed resources for the EIM transfers into ISO to serve ISO load. When serving load outside the ISO, only the energy bid, both ISO resources and EIM participating resources, will be considered by the market optimization.

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[2] As discussed above, the system marginal energy cost component is the same across all nodes in the EIM footprint. Since the system market energy component is based upon the ISO balancing authority area, it includes GHG compliance costs. Therefore, the GHG compliance cost component of the LMP is a negative value and is only included in the LMP of nodes in the EIM footprint outside of the ISO balancing authority area if there is an EIM transfer into the ISO; otherwise, the value is zero.

[3] The EIM draft final proposal includes detailed examples on how the GHG compliance costs are reflected in prices in the EIM footprint. Although changes were made to the bidding rules for GHG compliance costs, the fundamental market optimization has not changed since the EIM went live on November 1, 2014. See section 3.9 of the draft proposal available at http://www.caiso.com/Documents/EnergyImbalanceMarket-DraftFinalProposal092313.pdf

The initial EIM design allowed an EIM participating resource to submit a GHG bid adder price to reflect its willingness to be deemed delivered to the ISO when there is an EIM transfer into the ISO. The GHG bid adder was independent of the energy bid curve submitted, thus the total output of the EIM participating resource was eligible to be deemed delivered to the ISO. The GHG bid adder was not mitigated, with the only restriction being that the combined energy bid and GHG bid adder must be less than or equal to the $1000/MWh energy bid cap. A participating resource could submit a high GHG bid adder to reduce the probability that the output of the resource will not be deemed delivered to the ISO. However, a high GHG bid adder did not guarantee that the resource would not be deemed delivered to the ISO and as a result subject to the California Cap-and-Trade Program. In FERC's June 19, 2014 Order[4] approving the EIM design, FERC directed the ISO to include a flag which would allow an EIM participating resource to opt out completely from consideration for EIM transfer into the ISO. In addition, FERC directed the ISO to design the GHG bid adder to be based upon the expected cost of GHG compliance obligations.

In response to FERC's order, the ISO and stakeholders developed several modifications to the bidding rules for GHG compliance costs as part of the *EIM Year 1 Enhancements Phase 1* stakeholder initiative. After FERC approval, the ISO implemented these modifications on November 1, 2015. The changes allowed an EIM participating resource to submit a single MW quantity and single bid price expressing its willingness to be deemed delivered to the ISO on an hourly basis. The MW quantity bid is independent of the energy bid curve submitted, thus the total output of the EIM participating resource up to the MW quantity bid is eligible to be deemed delivered to the ISO.[5]

The ISO did not propose an explicit flag that would prevent an EIM participating resource's output from supporting an EIM transfer to the ISO. However, an EIM participating resource can, through its bid, accomplish the same objective of not being considered for EIM transfers into the ISO by submitting a zero MW GHG bid. In addition, the ISO sets the default MW quantity of the GHG bid to zero. If an EIM participating resource does not submit a GHG bid, the ISO market will not consider energy from the resource for EIM transfer into the ISO because the MW quantity will be set to zero. This design satisfied FERC's directive for a flag and allowed participants enhanced flexibility to make adjustments on an hourly basis.

To address FERC's requirement that bid caps for GHG bid adders be cost based, the ISO uses a process similar to establishing the GHG costs included in the default energy bids of ISO resources.[6] This includes a variable cost option and a negotiated rate option[7]. However, rather

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4 See pages 86-89 of the order available at http://www.caiso.com/Documents/Jun19_2014_OrderConditionallyAcceptingEIMTariffRevisions_ER14-1386.pdf

5 The market optimization will limit EIM transfers into the ISO to the bid-in MW quantity from all EIM participating resources in the EIM footprint even if transmission to support EIM transfers is available.

6 For additional information, please review section 39.7.1 of the ISO tariff available at http://www.caiso.com/rules/Pages/Regulatory/Default.aspx

than calculating a GHG cost curve, the ISO calculates a single daily value based upon the maximum heat rate of the EIM participating resource.

Under the variable cost option for calculating the GHG bid adder cap, the ISO will calculate a single GHG compliance cost for each resource each day. The ISO calculates each resource's GHG emissions cost based on the resource's heat rate characteristics, as registered with the ISO, the applicable GHG allowance price, and the resource's GHG emission rate. Similar to the default energy bids of ISO resources, there will be a 10% adder to the calculated cost.

An EIM participating resource must submit a GHG bid price equal to or less than its daily maximum GHG compliance cost, but not less than zero. If an EIM participating resource submits a GHG bid price above the GHG cost of the EIM participating resource, the ISO sets the GHG bid to the calculated daily GHG cost. If a resource submits a MW quantity, but fails to submit a GHG bid price, the ISO rejects the bid.

Although economic bidding on interties of an EIM entity balancing authority area is not currently allowed, the EIM GHG design includes rules for the cost based GHG bids of imports on EIM interties with surrounding balancing authority areas. Importers on these interties would submit an hourly GHG MW quantity and bid price similar to participating resources within an EIM balancing authority area. Currently, if the import is registered as a resource specific resource, the ISO will use the GHG emissions rate authorized by ARB for the specific resource to calculate the daily maximum GHG cost that may be bid. If the import is registered as a system resource, the ISO will use the GHG emission rate of the highest emitting resource outside the EIM footprint to calculate the maximum GHG cost that may be bid.

5.2 Concerns Raised by ARB with Existing EIM Design

After NV Energy joined the EIM in November 2015, EIM transfers occurred across multiple EIM balancing authority areas. Under the ISO's market optimization, an EIM transfer from NV Energy balancing authority area to the ISO could be scheduled and tagged while no transfers occurred from PacifiCorp West balancing authority area to the ISO. However, the resource identified as supporting the EIM transfers from the EIM footprint to the ISO may be located within the PacifiCorp West balancing authority area. The reason for this outcome is that the optimization solves for the lowest cost resources – including the cost of GHG bid adders – to serve ISO load and EIM balancing authority load based on transmission capability made available to the EIM. A physical explanation for this outcome is that the energy from the resource in the PacifiCorp West balancing authority area is routed through the NV Energy balancing authority area to serve ISO load, whereas energy from the NV Energy balancing authority area is routed in the opposite direction to serve PacifiCorp West balancing authority area load.

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[7] The negotiated rate option, which has not been used to date, is for resources that either can't file the necessary input data or can prove to Department of Market Monitoring that the calculated GHG bid cap is not a reasonable measure of their GHG compliance cost.

ARB expressed concern that this outcome did not fully reflect the atmospheric effect of ISO load relying on resources external to the ISO balancing authority area in all instances. ARB's concern is the market optimization's least cost dispatch can deem or attribute low emitting resources to the ISO, but not account for the resulting "secondary" dispatch or backfill of other, possibly higher emitting, resources to serve external demand. ARB and the ISO have been discussing how to address these concerns resulting from a "secondary" dispatch.[8] ARB, through its rulemaking process, is proposing changes to address these concerns. The ISO discussed the issue and at ARB's June 24 workshop[9] and at an ISO technical workshop[10] held on October 13.

5.3 Options to Address ARB's Concerns

The ISO has discussed several options with stakeholders to address concerns about the atmospheric impacts of EIM transfers into the ISO to serve ISO load. However, each option has legal/regulatory risk and market inefficiency impacts that need careful evaluation. In addition to the ISO's stakeholder initiative, the ISO is working with ARB and its stakeholders through the ARB rulemaking process to consider alternatives to address the concerns identified with the EIM GHG market design. Three principal options were considered:

1. Calculate the overall GHG impact based on a comparison to counter-factual dispatch outside the market optimization.

2. Modify the ISO optimization to attribute transfers to resources that have upward dispatch capability after serving non-ISO load and maintain resource-specific cost and attribution. This requires a two pass market optimization to (1) determine the optimal dispatch outside ISO and then (2) allow EIM transfers into the ISO from EIM participating resources.

3. Modify the ISO optimization to include a residual emission rate for EIM transfers into ISO. The compliance obligation resulting from the residual emission rate does not result in a resource specific attribution.

The ISO discussed these options at a technical workshop held on October 13, 2016. During the workshop, the ISO stated that option 1 may not be a feasible long term solution because ARB's regulations do not recognize GHG reductions that may occur across multiple operating intervals

8 The market optimization simultaneously solves to serve load in the ISO and the other balancing authority areas in the EIM footprint. The term "secondary" dispatch is used to illustrate the backfill effect of lower GHG cost resources to support EIM transfers to the ISO with higher GHG cost resources, and should not be used to infer that the market optimization has multiple distinct steps.

9 See presentation for June 24, 2016 Public Workshop on Mandatory GHG Reporting and Cap-and-Trade Program Electricity and Natural Gas Sectors http://www.arb.ca.gov/cc/capandtrade/meetings/062416/arb_and_caiso_staff_presentations_updated.pdf

10 The presentation is available at http://www.caiso.com/Documents/UpdatedAgenda-Presentation-RegionalIntegrationCaliforniaGreenhouseGasCompliance-TechnicalWorkshop.pdf

based on both electricity imports and exports. With regards to option 2, this approach may be the most accurate means to align the market optimization with ARB's GHG accounting objectives. However, this option would require the ISO to perform a second market run for each five minute real-time dispatch interval in order to optimize resources serving non-ISO loads in the first instance before assessing incremental dispatches from those external resources to serve ISO load.

Lastly, option 3 has the disadvantage of muting the price signal to lower GHG emitting resources outside the ISO. However, the ISO could implement this approach in the near term while exploring option 2. ARB discussed variants of option 2 and option 3 at a workshop[11] held on October 21, 2016.

Based on stakeholder comments, the ISO focused its efforts on developing option 2 since it is the long-term solution for GHG tracking for both the EIM and a multi-state balancing authority area. As stakeholders pointed out, option 3 has the drawback that it applies the same additional GHG emission rate to all resources. Consequently, the residual emission rate does not consider individual resource's GHG emission rate in the dispatch, mutes the GHG emissions price signal, and could be viewed as inequitably disadvantaging low-emitting resources not located in California. However, since it will take the ISO sometime to develop and implement option 2, there will likely be the need for a bridge solution to fully account for EIM GHG emissions until it is implemented. Since the straw proposal was posted, ARB has proposed a bridge solution that will retire the allowances to cover the difference between the ISO's GHG attribution and the system emission rate.[12]

In selecting option 2, the ISO used the following principles:

- Track emissions impacting the atmosphere as a result of generation outside California dispatched by the ISO market to serve California load.
- Reflect those emissions in ARB's GHG regulations.
- Allow suppliers selling power to serve California load to recover their costs to comply with ARB's greenhouse gas regulations from the ISO market.
- Mitigate the impact of the ISO market's GHG tracking mechanism on the ISO market's prices for electricity to serve load outside of California.
- Ensure solution is scalable to a regional ISO balancing authority area and integrated market, including the day-ahead market.

11 https://www.arb.ca.gov/cc/capandtrade/meetings/20161021/oct-21-workshop-slides.pdf

12 See ARB comment on the ISO's straw proposal at http://www.caiso.com/Documents/CARBComments-RegionalIntegration-EIMGreenhouseGasCompliance-StrawProposaldocx.pdf

- Resources located outside of California must be able to opt out of supporting EIM or regional transfers to serve California load that would be subject to ARB GHG regulations.
- Output from resources located outside of California serving load outside of California cannot be part of a transfer into California and are thus not subject to ARB GHG regulations.
- If possible, regional and EIM transfers serving California load should be subject to similar regulatory requirements as other electricity supply serving California load. This allows resource specific emission rates to be considered and that scheduling coordinators remain the point of regulation as first delivers.
- If possible, consider how the solution may align with greenhouse gas regulatory programs in other states/provinces, the extension of the Western Climate Initiative to states or provinces participating in the EIM or regional energy market, or state implementation plans under the Clean Power Plan.

6 Enhancement to EIM GHG Design

6.1 Introduction

The ISO is proposing an enhancement to the current GHG emission cost model in the EIM. This enhancement will attempt to minimize the emission cost of "secondary dispatch" of supply resources outside California that serve load outside California when the EIM dispatches other resources outside California for imbalance energy that serves California load.

In the current GHG market design, EIM participating resources submit a base schedule, an energy bid, which is a staircase capacity-price curve above and below the base schedule, and a GHG bid adder composed of a single GHG capacity bid and a single GHG price bid. The GHG capacity bid limits the resource's GHG allocation for EIM transfer into the ISO.

ARB considers these imbalance energy transfers to be electricity imports under its GHG regulations, and EIM participating resource scheduling coordinators for those transfers are subject to compliance with ARB's regulations. The GHG price bid reflects the GHG compliance obligation cost based on the resource's GHG emissions. These bids are considered in market optimization resulting in an optimal dispatch and a GHGallocation for EIM participating resources; the energy bid is considered as the cost of the imbalance energy serving load outside California, whereas the energy bid plus the GHG price bid is considered as the cost of the imbalance energy serving load in California through the imbalance energy transfer to California. The GHG award or allocation is the portion of the imbalance energy transfer to California that is attributed to the EIM participating resource, which is deemed to serve load in California.

The shadow price of the GHG allocation constraint, which allocates the imbalance energy transfer to California among EIM participating resources according to their GHG bid is the marginal GHG compliance obligation cost. The ISO includes this cost in the LMPs outside

California as a separate fourth component. If there is an imbalance energy transfer from California to the rest of the EIM area, the constraint is not binding and the shadow price is zero. Otherwise, if there is an imbalance energy transfer to California, the constraint is binding and that shadow price is negative, resulting in higher LMPs within California due to the additional GHG compliance obligation cost for imported energy that serves California load.

In the current EIM market design, the ISO's optimization limits the GHG allocation to an EIM participating resource by the resource's GHG bid quantity and the optimal dispatch, but the GHG allocation can extend to the resource's base schedule. In the proposed enhancement, the ISO will limit the GHG bid quantity of EIM participating resources to the resource's upper economic limit minus an economic dispatch reference. This will restrict the potential GHG attribution to resources that have upward dispatch capability after detmining the optimal schedule to serve non-ISO load.The ISO will refer to this reference point as the "GHG allocation base," obtained as the optimal dispatch without imbalance energy transfer to the ISO. Currently, the ISO does not optimize EIM base schedules. Therefore, incremental and decremental energy bids above and below base schedules may present trade opportunities that must be cleared in the market to yield an optimal dispatch reference – the GHG allocation base. The GHG allocation base minimizes the backfill effect outside California except for any offsetting incremental and decremental dispatch when the total footprint is optimized.

6.2 Mathematical Formulation

To illustrate the method, the ISO provides an example in this section. For simplicity, the example ignores day-ahead and base schedules, ancillary services, transmission losses, startup and minimum load costs, and inter-temporal constraints, focusing on a single time period. The ISO's example also ignores energy transfers between balancing authority areas in the EIM area and their associated constraints because they are not relevant to the GHG allocation base method. Without loss of generality, imports/exports to/from the EIM Area from non-EIM BAAs are modeled as generators/loads.

6.2.1 Notation

The following notation is used to formulate the problem:

i	Node index.
k	Transmission constraint index.
$\forall$	For all…
$^{(1)}$	Superscript denoting pass 1 optimal solution.
CA	Set of nodes in California.
S	Set of available online generators that are designated as California Supply.
G_i	Optimal dispatch for generator at node *i*.
$\bar{G}_i$	GHG allocation reference for generator at node *i*.

$\hat{G}_i$	Optimal GHG allocation for generator at node *i*.
UEL_i	Upper economic limit for generator at node *i*.
LEL_i	Lower economic limit for generator at node *i*.
L_i	Distributed load forecast at node *i*.
C_i	Incremental energy bid for generator at node *i*.
G_{GHGi}	GHG bid capacity for generator at node *i*.
C_{GHGi}	GHG bid price for generator at node *i*.
$SF_{i,k}$	Shift factor of power injection at node *i* on transmission constraint *k*.
F_k	Active power flow on transmission constraint *k*.
F_{MAXk}	Active power flow limit on transmission constraint *k*.
E_{CA}	Net imbalance energy export to CA from the rest of the EIM Area, including imports to the EIM Area from non-EIM BAAs.
T_{15}	Net 15min static EIM transfer to CISO calculated by RTUC; it is the net of all static ETSRs to CISO (positive for export and negative for import).
LMP_i	Locational Marginal Price at node *i*.
λ	Shadow price of the system power balance constraint.
μ_k	Shadow price of the transmission constraint *k*.
η	Shadow price of GHG allocation constraint.
R_{GHG}	GHG regulation revenue.
R_{GHGi}	GHG regulation revenue distribution to generator at node *i*.

6.2.2 Optimization Problem with California Supply

“California Supply” refers to resources outside the ISO that have a contract with a load serving entity in the ISO for serving ISO load. On an hourly basis, scheduling coordinators will select a flag during their bid submission to identify that the resource is contracted to serve ISO load. GHG allocation to these resources should be allowed in the first pass, but it will be limited by their GHG bid quanity. The GHG allocation base for California Supply will be the optimal schedule from the first pass, minus the GHG allocation from the first pass. The GHG bid quanity will then be set at the upper economic limit less the GHG allocation base. The requirements to support California Supply are as follows:

- STUC/RTUC shall limit the GHG allocation to zero in the first pass for all EIM Participating Resources except the ones that are designated as California Supply, for which the GHG allocation shall be limited to the GHG bid capacity.
- RTD shall consider the GHG bid from all EIM Participating Resources in the first pass, but shall enforce a net EIM Transfer limit for CISO to be greater than the higher of the net 15 minute static EIM Transfer schedule from RTUC, or the sum of the GHG bid capacities from California Supply Resources that are available and online.

- STUC/RTUC/RTD shall consider the GHG bid from all EIM Participating Resources in the second pass. The GHG allocation reference for limiting the GHG allocation in the second pass shall be the optimal schedule from the first pass minus the GHG allocation from the first pass.

<u>Example</u>

A 100MW EIM Participating Resource designated as California Supply and has an energy bid curve up to its Pmax and a GHG bid quanity equal to 100MW. The resource is dispatched in the first pass at 70MW with a 10MW GHG allocation. The portion of the optimal dispatch that did not receive a GHG allocation (60MW) is deemed to be serving non-ISO load and is the GHG allocation reference for limiting the GHG allocation in the second pass. Therefore, in the second pass, the GHG bid quantity is limited to 40MW (100MW – 60MW). The single optimization problem for both first and second pass with support for California Supply is as follows:

$$\min\left(\sum_{i} C_i\, G_i + \sum_{i \notin CA} C_{GHGi}\, \hat{G}_i\right) \qquad \text{(a)}$$

subject to:

$$\sum_{i} (G_i - L_i) = 0 \qquad \text{(b)}$$

$$F_k \equiv \sum_{i} SF_{i,k}\,(G_i - L_i) \leq F_{MAXk}, \forall k \qquad \text{(c)}$$

$$E_{CA} \equiv \sum_{i \notin CA} (G_i - L_i) \leq \sum_{i \notin CA} \hat{G}_i \qquad \text{(d)}$$

$$E_{CA} \equiv \sum_{i \notin CA} (G_i - L_i) \leq \max\left(-T_{15}, \sum_{\substack{i \notin CA \\ i \in S}} G_{GHGi}\right) \qquad \text{(e)}$$

$$\sum_{\substack{i \notin CA \\ i \notin S}} \hat{G}_i \leq -T_{15} \qquad \text{(f)}$$

$$LEL_i \leq G_i \leq UEL_i, \forall i \qquad \text{(g)}$$

$$0 \leq \hat{G}_i \leq \min\left(G_i, G_{GHGi}, UEL_i - \bar{G}_i\right), \forall i \notin CA \qquad \text{(h)}$$

Where:

(a) is the objective function expanded with the GHG regulation cost;

(b) is the system power balance constraint;

(c) are the transmission constraints;

(d) is the GHG allocation constraint that allocates the net export to CA to generators outside CA;

(e) is only applicable in RTD first pass to constrain the GHG allocation to the fifteen-minute net static exports to CA, or the total GHG capacity from online available EIM Resources that are designated as CA Supply, whichever greater; this constraint is not present in RTUC or the second pass;

(f) is only applicable in RTD first pass to limit the competitive GHG allocation to non-CA Supply resources to the 15min net static exports to CA; this constraint is not present in RTUC or the second pass;

(g) are the upper/lower bounds on the generation dispatch; and

(h) are the GHG allocation limits where the GHG allocation reference is as follows:

	RTUC/STUC		RTD	
	Pass 1	Pass 2	Pass 1	Pass 2
CA Supply	$\bar{G}_i = 0$	$\bar{G}_i = G_i^{(1)} - \hat{G}_i^{(1)}$	$\bar{G}_i = 0$	$\bar{G}_i = G_i^{(1)} - \hat{G}_i^{(1)}$
Non-CA Supply	$\bar{G}_i = UEL_i$	$\bar{G}_i = G_i^{(1)} - \hat{G}_i^{(1)}$	$\bar{G}_i = 0$	$\bar{G}_i = G_i^{(1)} - \hat{G}_i^{(1)}$

When the net export to CA (E_{CA}) is zero or negative (import), the GHG allocation constraint is not binding and all GHG allocations ($\hat{G}_i$) are zero. When the net export to ISO is positive, the GHG allocation constraint is binding with a zero or negative shadow price (η).

In this mathematical formulation, it is assumed that all supply resources outside ISO submit GHG bids. EIM Non-Participating Resources do not submit any bids and thus receive no GHG allocation.

The LMPs are determined as follows:

$$LMP_i = \lambda - \sum_i SF_{i,k}\, \mu_k\, , \forall i \in CA$$

$$LMP_i = \lambda - \sum_i SF_{i,k}\, \mu_k + \eta, \forall i \notin CA$$

6.3 Settlement

The market optimization ensures that the external resources that are attributed as supporting a transfer into California have their GHG compliance costs compensated. This is achieved by collecting GHG allocation award revenue through the prices paid by load and supply internal to California. This revenue is then distributed to the external resources that support the transfer into California.

The GHG allocation award revenue is calculated as follows:

$$R_{GHG} = -\eta\, E_{CA} = -\eta \sum_{i \notin CA} \hat{G}_i$$

This revenue is distributed to the generators outside California with GHG awards (allocations) as follows:

$$R_{GHGi} = -\eta \, \hat{G}_i$$

The ISO's market results would identify these generators as providing EIM transfers to California. EIM participating resource scheduling coordinators would be subject to California GHG compliance obligation and reporting responsibility for their resources' GHG award allocation.

The mathematical formulation is general and it applies to all markets. In the Day Ahead Market (DAM), as part of the regional integration effort, the GHG allocation would be on the net export to CA that clears the Integrated Forward Market (IFM), where virtual supply and demand are treated similarly to generation and load, respectively. In the Fifteen Minute Market (FMM), the GHG allocation is on the net export deviation (from the IFM) to CA that clears the FMM. Before the regional integration there is no DAM GHG allocation and the FMM GHG allocation is on the entire net export to CA that clears the FMM. In the Real-Time Dispatch (RTD), the GHG allocation is on the net export deviation (from the FMM) to CA that clears the RTD. In all markets, the GHG allocation is re-optimized and limited by the relevant GHG allocation limit in that market. If the GHG allocation is lower than the one in the previous market, the market participant will buy back the difference at the GHG allocation constraint shadow price, similarly to the energy settlement. The market participants' compliance and reporting responsibility is only for the 5-minute GHG allocation from RTD.

6.4 Implementation Considerations

The introduction of an additional market run introduces computational concerns for RTD since this market is run every five-minutes and provides operationally binding instructions to resources. The performance impact (additional time to reach the market solution) of a first full optimization pass to calculate the GHG allocation base is prohibitive for the FMM and RTD applications. Several approximations will be necessary to make this method workable. These approximations reduce the precision of the GHG allocation base. The following is a list of potential approximations for the first pass:

- To avoid a full unit commitment in the first pass, the unit commitment status of resources and the configuration state of multi-stage generators (MSGs) will be obtained from the MPM run.
- The Market Power Mitigation (MPM) in RTUC will only have a single pass where the GHG allocation reference will be zero.
- Since the FMM is initialized from the last RTD run, and the RTD is initialized from the state estimator solution, there may be insufficient ramp capability to calculate a feasible solution in the first pass when the net transfer to California is constrained to be non-positive. Consequently, ramp constraints should be modeled as soft constraints in the first pass in case they need to be relaxed.
- Since the pricing solution is not relevant for the first pass, only a scheduling run without a pricing run would be performed.

As discussed above, in order to ensure that the solution time of the two pass solution can be achieved within the existing market timelines, simplifications to the first pass are needed. The ISO plans to publish a report evaluating the accuracy GHG attribution in reflecting the atmospheric impact of the EIM dispatch. After assessing the accuracy of the EIM GHG enhancement, the ISO will then seek EIM Governing Body and ISO Board of Governors' approval of the design changes.

6.5 Support for Multiple GHG Programs in the West

In modifying the existing EIM approach for tracking GHG compliance obligations[13] to support a multi-state balancing authority area, the design must be mindful of the potential need to support multiple GHG trading programs in the West.

Currently in the West, only California has a GHG regime, i.e. the California Cap-and-Trade Program. All other states would be in the non-GHG regime region. If a state joined the California Cap-and-Trade Program, then the load and generation within that state would be part of the California GHG regime region. That means in the first pass optimization, a constraint will be enforced that load in California, plus the other state, must be less than the generation contracted with load in California plus the other state.

If a new GHG regime was created by one or more states, how this program is reflected in the market optimization depends on whether the GHG regime places a GHG compliance obligation on supply from outside its state (i.e. on imports or transfers for other states within the multi-state balancing authority area). If the new GHG regime does place a GHG compliance obligation on external supply, then in the first pass market optimization, a constraint will be enforced that this GHG regime cannot have load greater than its contracted supply, i.e. cannot have transfers into its GHG regime from external supply. Also, external resources will now have to submit an additional and separate GHG bid adder to cover the costs of compliance obligations in both the new GHG regime and the California GHG regime. The ability for an external resource under a non-GHG regime to opt out of either the new GHG regime or the California GHG regime is unchanged. This new GHG regime will result in an additional component of the LMP outside of the new GHG regime region. If the new GHG regime only places a compliance obligation on generation located within its state or has a carbon tax, these costs would be reflected in the resources' energy bids similar to what is done by resources in California today.

7 Extending Enhanced EIM Design to Support Regionalization

The enhanced GHG design for EIM discussed above can be extended to the day-ahead market to support a regional balancing authority area. Discussed below are additional design enhancements that would be necessary in the event the ISO becomes a regional balancing authority area.

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13 In this paper, the phrase GHG compliance obligation is used as shorthand for California Cap-and-Trade Program compliance obligations.

7.1 Imports/exports under a Multi-state Balancing Authority Area

Under the current paradigm, an import to the ISO balancing authority area is considered to serve load within California, an export from the ISO is sourced from generation within California, and a wheel may serve load outside of California with generation outside of the ISO balancing authority area. Thus the market model assumes that all market nodes used to represent intertie scheduling points for imports and exports with the ISO involve either imports serving load in California or exports sourced from generation within California. Under a multi-state balancing authority area, the intertie scheduling points will not be modeled as part of a state and as a result will be considered part of the non-GHG regime region. For example, assume there were two ISO market participants, one importing 100MW and another exporting 40MW. The current paradigm would result in a 100MW compliance obligation. Under the multi-state balancing authority area, the total compliance obligation would be 60MW because only 60MW would be attributed as serving California load.

Thus, imports to the multi-state balancing authority area will only receive a GHG allocation if the market optimization attributes a transfer into California from these imports. Therefore, the total California GHG compliance obligation for a given interval will be the higher of California load or generation located within the boundary of California.

7.1.1 GHG Regime of Convergence Bidding

The convergence bidding functionality allows scheduling coordinators to submit virtual supply and virtual demand bids at any node, trading hub or load aggregation point. Virtual supply/demand will be considered in the GHG regime of the state the node is located in geographically. Virtual supply will not submit a separate GHG bid adder to be considered for attribution to support a transfer to another GHG regime region. In addition, a trading hub or load aggregation point must be comprised of nodes which are located in a single GHG regime region.

8 Next Steps

The ISO plans to discuss this straw proposal with stakeholders during a stakeholder meeting to be held on June 22nd. The ISO requests comments from stakeholders on the straw proposal. Stakeholders should submit written comments by July 6th to InitiativeComments@caiso.com.