Regional Integration California Greenhouse Gas Compliance

and

EIM Greenhouse Gas Enhancement

Straw Proposal

November 17, 2016

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1 Introduction

As part of exploring the expansion of the ISO's balancing authority area into additional western states, the ISO will need to modify how the market determines which resources are serving load in the various states. Under a multi-state balancing authority area, energy flows within the balancing authority area will not use e-tags to identify their contract path or for interchange management. In order to determine energy flows based upon state boundaries within a new multi-state balancing authority area, the ISO must modify its greenhouse gas (GHG) tracking approach. Such an approach is needed so that the ISO market can reflect the costs associated with compliance with the California Air Resources Board (ARB) Cap-and-Trade Program or other states' GHG programs in energy prices for transactions subject to that program, but not in energy prices for transactions that are not subject to the program.

With introduction of the Energy Imbalance Market (EIM), the ISO developed a mechanism to reflect GHG compliance costs within locational marginal prices. Inside of the ISO balancing authority area, the energy price includes GHG compliance costs of generation. Outside of the ISO, if the load iss met with generation outside of the ISO, the energy price does not include GHG compliance costs. 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 of 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 rulemaking process to address concerns that the EIM GHG market design is not capturing the impact on 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 focusing on developing 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 restricts the GHG award allocation to incremental non-California resources' schedules above the optimal schedules determined in the first pass. The ISO can perform this two pass solution in all day-ahead and real-time market runs. As a result, the two pass market optimization and the need to differentiate California supply and non-California supply serving ISO load is scalable to a regional energy market operating in a multi-state balancing authority area.

2 Stakeholder process and timeline

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

Item	Date
Post Straw Proposal	November 17, 2016
Stakeholder Meeting	December 1, 2016
Stakeholder Comments Due	December 15, 2016
Post Draft Final Proposal	January 5, 2017
Stakeholder Conference Call	January 12, 2017
Stakeholder Comments Due	January 19, 2017
EIM Governing Body	TBD
Board of Governors	TBD

Table 1 - Schedule

3 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 GHG compliance by virtue of the fact that scheduling coordinators include the cost of this compliance in their energy bids. The system marginal energy cost component of locational marginal prices (LMP) is the same for all nodes. Load pays for GHG compliance costs at its load aggregation point price and generation receives compensation for its GHG compliance costs through its LMP. At intertie scheduling points, exports pay for GHG compliance costs through the LMP and imports receive compensation for the GHG compliance costs incurred through the applicable LMP.

The ISO market compensates resources for GHG compliance costs though their energy settlement. Generators within the ISO embed their GHG compliance costs within their energy bids used in the day-ahead and real-time markets. Importers into the ISO balancing authority area at ISO intertie scheduling points also embed their GHG compliance costs within their energy bids. The ISO also allows for the inclusion of GHG compliance costs in start-up and minimum load costs for generators. 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 default energy bids. These cost based bid curves are calculated by the ISO and when a transmission element is non-competitive, the mitigated bids are used by the market for determining LMPs. The ISO estimates the cost of GHG compliance and includes this cost in the default energy bid. For imports, the ISO does not use default energy bids since the ISO does not mitigate bids at intertie scheduling points.

4 GHG design for EIM

4.1 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.[1] 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.[2]

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 of 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 of the ISO, only the energy bid, both ISO resources and EIM participating resources, will be considered by the market optimization.

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[3] 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,

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1 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.

2 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

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

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.[4]

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.[5] This includes a variable cost option and a negotiated rate option[6]. However, rather 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

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4 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.

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

6 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 GHG bid cap, as calculated below, is not a reasonable measure of their GHG compliance cost.

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.

4.2 Concerns raised by CARB 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, a transfer from NV Energy balancing authority area to the ISO could occur while no transfers occurred from PacifiCorp West balancing authority area to the ISO occurred. 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.

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.[7] ARB, through its rulemaking process, is proposing changes to address these concerns. The ISO discussed the issue and at ARB's June 24 workshop[8] and at an ISO technical workshop[9] held on October 13.

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[7] 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.

[8] See presentation for June 24, 2016 Public Workshop on Mandatory GHG Reporting and Cap-and-Trade Program Electricity and Natural Gas Sectors

4.3 Options to address CARB'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 under consideration include:

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 are incrementally dispatched and maintain resource-specific cost and attribution. This requires a two pass market optimization to (1) determine the optimal dispatch outside of California and then (2) allow incremental dispatches of external resources into California.

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. 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 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 (non-California) loads in the first instance before assessing incremental dispatches from those external resources to serve ISO (California) load.

The computational and implementation requirements of conducting an additional market run in the real-time dispatch will not allow the ISO to implement this approach in fall 2017. Moreover, with this approach, potential simplifications may be necessary to reduce the solution time of the first pass. The first pass of the optimization determines the starting point from which to determine incremental dispatch of resources. These simplifications may impact the precision of the starting point used for the second pass.

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

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http://www.arb.ca.gov/cc/capandtrade/meetings/062416/arb_and_caiso_staff_presentations_updated.pdf

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

while exploring option 2. ARB discussed variants of option 2 and option 3 at a workshop[10] held on October 21.

Based on stakeholder comments, the ISO recommends that it focus 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.

The ISO discusses option 2 in more detail in this straw proposal.

4.4 Principles used to determine resolution

The ISO used the following principles in evaluating each of the options and believes they should be used going forward for any refinements:

- 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.
- 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

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

allows resource specific emission rates to be considered and that scheduling coordinators remain the point of regulation as first delivers.

- If possible, consider how 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.

The ISO believes that option 2 meets these principles and will continue to discuss how to simplify the market design to address the computational concerns with performing two market runs in the real-time dispatch. The ISO seeks stakeholder comments on these guiding principles and whether option 2 meets these principles. In addition, stakeholders are encouraged to suggest additional guiding principles to be considered and whether option 2 is consistent with the additional principle.

5 Enhancement to EIM GHG Design

5.1 Introduction

The ISO is examining an enhancement of 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 GHG allocation 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 capacity bid and the optimal dispatch, but the GHG allocation can extend to the resource's base schedule. In the proposed enhancement, the ISO's optimization will also limit the GHG to the incremental dispatch above an economic dispatch reference. This additional constraint addresses the concern that the optimization will attribute the GHG awards to low emitting resources while backfilling to serve external ISO load with emitting resources. The ISO will refer to this reference point as the "GHG allocation base," obtained as the optimal dispatch without imbalance energy transfer to California. 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 due to congestion management when the total footprint is optimized.

5.2 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 method.

5.2.1 Notation

The following notation is used to formulate the problem:

i	Node index.
k	Transmission constraint index.
$\forall$	For all…
CA	Set of nodes in California.
G_i	Optimal dispatch for generator at node i.
$\bar{G}_i$	GHG allocation base for generator at node i.
$\hat{G}_i$	Optimal GHG allocation for generator at node i.
G_{MINi}	Minimum capacity for generator at node i.
G_{MAXi}	Maximum capacity 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 or schedule on transmission constraint *k*.

F_{MAXk} Active power flow or schedule 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.

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*.

5.2.2 Optimization Problem

The ISO solves the problem in two passes:

1) The first pass calculates the GHG allocation base for each generator outside California as the optimal dispatch while net transfers to California is not allowed; net transfers from California is allowed, however.
2) The second pass calculates the optimal dispatch of all generators and the GHG allocation for each generator outside California while net transfer to California is allowed. The GHG allocation is limited by the GHG bid capacity and the incremental dispatch above the GHG allocation base.

The mathematical formulation of the first pass is as follows:

$$\min \sum_i C_i \, \bar{G}_i \qquad \text{(a)}$$

subject to:

$$\sum_i (\bar{G}_i - L_i) = 0 \qquad \text{(b)}$$

$$F_k \equiv \sum_i SF_{i,k} \, (\bar{G}_i - L_i) \leq F_{MAXk}, \forall k \qquad \text{(c)}$$

$$E_{CA} \equiv \sum_{i \notin CA} (\bar{G}_i - L_i) \leq 0 \qquad \text{(d)}$$

$$G_{MINi} \leq \bar{G}_i \leq G_{MAXi}, \forall i \qquad \text{(e)}$$

Where:

(a) is the objective function;

(b) is the system power balance constraint;

(c) are the transmission constraints;

(d) is the constraint that does not permit net export to CA; and

(e) are the upper/lower bounds on the generation dispatch.

The mathematical formulation of the second pass 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:

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

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

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

$$G_{MINi} \le G_i \le G_{MAXi}, \forall i \qquad \text{(e)}$$

$$0 \le \hat{G}_i \le G_{GHGi}, \forall i \notin CA \qquad \text{(f)}$$

$$\hat{G}_i \le \max(0, G_i - \bar{G}_i), \forall i \notin CA \qquad \text{(g)}$$

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) are the upper/lower bounds on the generation dispatch;

(f) are the GHG allocation limits to the GHG bid capacity; and

(g) are the GHG allocation limits to the incremental dispatch above the GHG allocation base.

When the net transfer (export) to California (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 transfer (export) to California is positive, the GHG allocation constraint is binding with a zero or negative shadow price (η).

In this mathematical formulation, the ISO assumes all supply resources outside of California including imports at boundary of a multi-state balancing authority area, submit GHG bids.

The LMPs are determined as follows:

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

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

5.3 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 applies to all markets. As part of the regional integration effort, the GHG allocation would be on the net transfer to California that clears the integrated forward market (IFM). In the 15-minute market (FMM), the GHG allocation reflects the net transfer deviation (from the IFM) to California that clears the in the FMM. In the real-time dispatch (RTD), the GHG allocation reflects the net transfer deviation (from the FMM) to California that clears the RTD. In all markets, the GHG allocation is re-optimized and limited by the GHG bid capacity and the incremental schedule from the GHG allocation base 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, similar to the energy settlement. The market participants' compliance and reporting responsibility is only for the total 5-minute GHG allocation from RTD.

5.4 Implementation Considerations

The introduction of an additional market run introduces computational concerns for RTD since this market is run every 5-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. This can reduce the GHG accounting accuracy since the GHG attribution is incremental to a less precise baseline. 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 previous FMM run. Resources committed in the current FMM run will have a GHG

allocation base of zero; however, their GHG allocation base will be updated for the next FMM and subsequent RTD runs.

- 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 will be relaxed which can result in a GHG allocation base that is not ramp feasible between intervals.

- To avoid a full solution for the advisory intervals in FMM and RTD, the advisory GHG allocation base will be calculated without network constraints that would otherwise require a power flow solution for each of the advisory intervals. With fixed unit commitment from (1), no ramp rate constraints from (2), and without network constraints, the GHG allocation base in the advisory intervals can be calculated from a simple merit order stack. Nevertheless, the GHG allocation base for the financially binding interval, which is relevant for settlements, will be calculated subject to applicable network constraints.

- Further performance gains can be achieved by staggering the FMM and RTD runs so that when the second pass is completed, the first pass for the next market is started immediately while the results from the second pass are reviewed and then published. This can result in different initial conditions between the first pass and the second pass market optimizations.

5.5 Examples

At the October 13, 2016 technical workshop, the ISO included market optimization examples for the two pass solution. The examples are on slides 17 to 26 in the presentation available at http://www.caiso.com/Pages/documentsbygroup.aspx?GroupID=6C44FA42-DFB1-4835-9202-3595BAA3A293.

In addition, the ISO has posted a spreadsheet as an illustrative model for the two pass solution discussed in the straw proposal. The spreadsheet compares various scenarios of the current GHG design compared to the two pass design. In the spreadsheet, the first pass is input by the user because the GHG allocation base can be calculated without the use of a solver in the simplified examples.

6 Extending enhanced EIM design to support regionalization

6.1 Change from balancing authority area paradigm to a supply to serve load under a given GHG regime paradigm

In the ISO's current day-ahead and real-time markets, the market, both day-ahead and real-time including the EIM rules, treats supply serving any load located within the ISO balancing

authority area[11] as subject to the California Cap-and-Trade Program. The paradigm that the ISO balancing authority area is analogous to California's geographical boundary was maintained when the initial EIM GHG market design was developed.[12] In the issue paper we highlighted that this paradigm must change when the ISO becomes a multi-state balancing authority area, obviously, because there will be other states besides California in the balancing authority area. In addition, this paradigm shift is also needed to implement option 2 in the EIM.

We are using the term GHG regime to represent a given carbon reduction program which results in the cost of carbon being included in the market optimization. The California cap-and trade program is an example of a GHG regime. This regime places a compliance obligation on generation located within California and on external supply which is serves California load. The cost of carbon is reflected in the market dispatch because the cost of complying with the GHG program is included in the energy bids or separate GHG bid adder. Another potential GHG regime would be a carbon tax that is placed on generators in a given state. This would result in the need to model another GHG regime in the market optimization. In should be noted, that multiple states could belong to the same GHG regime. These states would agree upon the cost of carbon and which resources are under the program, such as internal and/or external resources serving load in those states.

As discussed above in section 5, the market optimization will, in the first pass for each market interval, enforce a constraint that load within a given GHG regime cannot be served by generation not associated with that GHG regime. However, it cannot be assumed that generation that serves the load will be located within the same state as the GHG regime. The supply could be located in another state in the multi-state balancing authority area or it could be an import from outside the multi-state balancing authority area. It would be inappropriate not to consider the output from these resources when determining how much generation is being served by a resource in a different GHG regime in the first pass optimization.

For example, assume a load serving entity in California has contracted with a wind resource in Oregon. The scheduling coordinator for the resource submits an energy bid of $0/MWh and a GHG bid adder of $0/MWh. If this resource's output was considered a non-California GHG regime supply resource, in the first pass the resource could be dispatched which reduces the need to dispatch an external gas resource. The GHG allocation base would reflect that it is economic to serve external load with the wind resource versus the gas resource. However, since the second pass optimization restricts attribution for supporting the transfer into California

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[11] It should be noted that currently the ISO does include Valley Electric Association load that is located in Nevada, within its balancing authority area. The decision to maintain the existing balancing authority area structure was chosen to minimize the implementation complexity when the California Cap-and-Trade Program was established.

[12] During the EIM stakeholder process, the potential was recognized for a balancing authority area that is located solely within California may seek to join the EIM. In this scenario, the resources in this balancing authority would bid in the same manner as resources in the ISO. The resource would submit a single energy bid and not have separate bid costs submitted for energy and GHG costs. The locational marginal prices in this balancing authority area, as in the ISO, would not include a separate GHG component.

to the GHG allocation base determined in the first pass optimization, only the gas resource can be attributed to support California load. This results in California load paying a higher energy price because the costs of GHG compliance of the non-California gas resource is reflected in the California LMP. However, the only reason the gas resource is available for incremental dispatch in the second pass optimization is because the contracted wind resource backfilled the gas resource to meet load outside of California in the first pass market optimization.

In the master file, a market participant will select the GHG regime external resources and imports are subject to depending the resource is contracted with a load serving entity (LSE) in another state. Resources located within the geographical boundary of a state are by default in that state's GHG regime. To illustrate, assume that the ISO is a multi-state balancing authority area and only California has a GHG regime. Master file will have a "CA GHG" flag. A resource enters Y if the resource is located in California or has a contract California load.

- Generator located inside California: Flag = Y
- Generator located outside California and a California LSE contract: Flag = Y
- Generator located outside California without a California LSE contract: Flag = N
- Import (system resource) to multi-state BAA and a California LSE contract: Flag = Y
- Import (system resource) to multi-state BAA without a California LSE contract: Flag = N

All resources outside of California and imports will always submit a separate GHG bid adder, even if under contract with a California LSE. This is because if this supply outside of California is used to meet non-California load, the supply does not incur a GHG compliance obligation. This occurs today in the ISO when a resource adequacy import does not clear in the day-ahead market. The scheduling coordinator has met their resource adequacy must offer obligation, but it does not restrict the market participant from entering into a bilateral contract with a party outside of the ISO. In this case, while the California LSE has contracted with the generation needed to support an import, the market participant can sell the output to other parties and not incur a GHG compliance obligation. By allowing the separate GHG bid, the transaction that was previously performed bilaterally can now be cleared through the ISO market.

6.1.1 Multiple resource ids to support multiple GHG regimes

For generators located outside of California, there may periods where the resource is under contract with a California LSE and other times it is not. The scheduling coordinator can reflect this by creating two "resource ids" for use in the ISO market. The scheduling coordinator would then use the appropriate resource id corresponding to the respective time periods for which the resource's output is, and is not, contracted to supply a California LSE's load.

6.1.2 GHG regime of intertie transactions

Intertie scheduling points in a multi-state balancing authority are not considered part of any GHG regime and will always be included in the non-GHG regime. In order for imports to be included in California supply, the import must be registered as a system resource. This allows

the ISO to create a resource identification that is used by the scheduling coordinator to submit import bids. Since a resource is created, the scheduling coordinator can select the CA GHG flag when the system resource is set up in master file. However, not all imports are required to be a system resource. For scheduling coordinators submitting these import bids, the ISO creates a transaction id when the bid is submitted. These imports are not included in the master file, thus there is no ability to select a flag to be California supply. As a result, imports using transaction ids will be considered supply for the non-GHG regime region. These imports can submit a GHG bid adder and can be attributed to supporting California load in the second pass optimization.

6.1.3 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.

6.2 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.

6.3 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 Next Steps

The ISO plans to discuss this straw proposal with stakeholders during a stakeholder meeting to be held on December 1st. The ISO requests comments from stakeholders on the straw proposal. Stakeholders should submit written comments by December 15th to InitiativeComments@caiso.com.

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