EIM Quarterly Benefit Report Methodology

Effective with Q1, 2017 EIM benefits report

Revision History

Date	Version	Description	Author
02/01/2016	1.0		Lin Xu
04/30/2016	2.0	Allow the ISO's units to be committed in the counterfactual dispatch	Lin Xu
01/30/2017	3.0	Enhance resources' dispatching limits in the counterfactual. Adjust congestion rent allocation. Include flexible ramping transfer cost.	Lin Xu
05/01/2017	3.1	Change the ISO's reference transfer price to be the FMM price.	Lin Xu

Prior to the creation of this document, the methodology for the benefits calculation was posted in a technical bulletin and in the benefit report itself. This document consolidates these prior materials into a concise paper for easier understanding of how the EIM benefits are calculated.

The total EIM benefit is the cost saving of the EIM dispatch compared with a counterfactual (CF) without EIM dispatch. The counterfactual dispatch meets the same amount of real-time load imbalance in each BAA without EIM transfers between neighboring EIM BAAs. For an EIM BAA, the benefit can take the form of cost savings or profit or their combination. A BAA will be likely to have energy cost savings when the BAA is importing energy economically, or its base schedules are being optimized by the EIM. A BAA will be likely to have an energy profit when the BAA is exporting energy economically to other BAAs and being paid a price higher than the bid cost. A BAA other than the ISO may also have a GHG profit when the resource is allocated GHG MWs and is receiving GHG revenue based on marginal GHG cost that is likely higher than its own GHG bid cost.

For each 5-minute interval, the **EIM benefit for a BAA = counterfactual dispatch cost – (EIM dispatch cost + transfer cost + flex ramp transfer cost) + GHG revenue – GHG cost.** The 5-minute level EIM benefits are then aggregated each month with a multiplier 1/12 to convert ($/5 min) to a dollar amount.

EIM benefit calculation components

EIM dispatch cost

The total dispatch cost for a BAA for an interval is the sum of all the unit level EIM dispatch costs for that BAA for that interval.

For all BAAs other than CAISO, the dispatch cost only includes variable dispatch cost, i.e. the bids submitted by the corresponding Scheduling Coordinator.

For the ISO's long start units, we only consider variable dispatch cost. For the ISO's short start units, we use a generic cost formula, which includes variable dispatch cost, no load cost, and startup cost.. Specifically, the three-part cost for short start units includes:

- the variable dispatch cost of RTD, which is equal to the bid cost associated with the delta instruction above or below the base schedule for each interval,
- the no load cost associated with the incremental dispatch, which is equal to the no load cost divided by Pmax, then multiplied by the delta instruction from the base schedule,
- the startup cost associated with the incremental dispatch, which is equal to the startup cost divided by the minimum online hours, then multiplied by the delta instruction from base schedule divided by the Pmax.

The purpose of this generic cost formula is to evaluate cost differences between EIM dispatches and counterfactual dispatches without performing sophisticated unit commitment simulations. Prior to Q1 2016, only variable dispatch cost was considered in the EIM benefit calculation. With NV Energy joining EIM and improving the transfer capabilities from and to the ISO, we observed a significantly increased transfer volume in EIM. The higher transfer volume cannot be sufficiently replaced by resources online in EIM without committing or de-comitting resources, and hence why the ISO adopted a three-part cost formula as of Q1 2016 to allow for unit commitment decisions to better evaluate the production difference between EIM and the counterfactual dispatch of the ISO. The unit commitment decisions were made only for short start units that were not combined cycle units. The combined cycle units have complicated models in EIM, so their counterfactual commitment status is fixed at the EIM commitment status to avoid oversimplification.

We approximate the ISO's commitment costs by converting the startup cost and no load cost into variable dispatch cost, assuming a committed short start resource will be fully loaded for minimum online hours. For each supply segment, the corresponding three-part variable cost is equal to

bid_price + no_load_cost/Pmax + startup_cost/min_up_hour/Pmax

Note the formula above converts startup cost (in unit $) and no load cost (in unit $/h) into variable dispatch cost (in unit $/MWh). By doing this, the commitment for the ISO's short start units can be determined based on the economic metric order of the three-part variable cost.

Transfer cost

As a convention, select the importing direction as the default direction for a transfer, so the importing transfer is positive and the exporting transfer is negative. The transfer cost is equal to the transfer MW times the transfer price. For transfers involving the ISO in either the importing direction or the exporting direction, the transfer price is the other BAA's LMP plus the shadow price of the transfer. In doing this, the congestion rent on the transfer will be fully attributed to the other BAA. For transfers involving two BAAs that are not the ISO, the transfer price will split the congestion shadow price on the transfer in half. For an importing BAA, the transfer price is the LMP of the BAA minus half of the absolute value of the transfer shadow price. For an exporting BAA, the transfer price is the LMP of the BAA plus half of the absolute value of the transfer shadow price. The transfer could occur in both the 15-minute market and the 5-minute market. In this case, the transfer cost is 15-minute transfer * 15-minute transfer price + (5-minute transfer – 15-minute transfer) * 5-minute transfer price for each 5-minute interval.

Flex ramp transfer cost

In 2016, the ISO implemented the flexible ramping products to replace flexible ramping constraints. The flexible ramping products are available capacities to handle future load and generation uncertainties, and include both the upward ramping capacity and downward ramping capacity. They may be put aside in RTD to enhance dispatch flexibility. One BAA's flexible ramping capacities in RTD may be helping other BAAs. In this case, the BAA that exports flexible ramping products should receive payment from other BAAs to compensate the dispatch cost of keeping flexible ramping capacities, and the BAA that imports flexible ramping products should pay other BAAs to reflect its dispatch cost to handle future uncertainties. This is similar to how energy transfer is treated in the EIM benefit calculation. Energy transfer is explicitly modeled in EIM, while flexible ramping transfer is not. We need to calculate a BAA's flexible ramping transfer. First, we allocate the system flex ramp award to each BAA in proportion to its individual BAA requirement. Then we calculate the flex ramp transfer as the BAA's RTD flexible ramping award minus its allocated share. The flex ramp transfer cost is equal to the flex ramp transfer multiplied by the EIM whole footprint flex ramp shadow price.

Counterfactual dispatch cost

The counterfactual dispatch for an EIM BAA mimics the market operations without importing or exporting through the EIM transfers. The counterfactual dispatch moves units inside the BAA to meet the same real-time load imbalance as the EIM dispatch without considering transmission constraints. However, for PacifiCorp, the transfer limit between PACE and PACW is enforced in the counter factual dispatch. Relaxing transmission constraints tends to underestimate the counterfactual dispatch cost and the EIM benefit. However, because few transmission constraints were observed binding in EIM, it is unlikely the EIM benefit will be significantly underestimated.

The counterfactual dispatch makes unit commitment decisions only for the ISO's short start units. The unit commitment decisions are based on the generic three-part variable cost formula, which has converted startup cost and no load cost into variable dispatch cost. So unit commitment can be determined by the economic metric order of the three-part cost.

Prior to the 2016 Q4 report, we used the resources' RTD dispatching limits from the EIM in the counterfactual. The EIM dispatching limits are 10-minute ramp limited in RTD, and they may be overly constraining for the counterfactual theoretically. The counterfactual will replace the transfers with internal dispatches, but it does not need to do it within 10-minute timeframe. When EIM transfer volumes are moderate relative to the EIM dispatching range, this limitation may not be a real problem, because the EIM dispatch range is mostly sufficient to replace the transfers. With the EIM footprint increases, the transfer volume between BAAs also increases. We observed some EIM transfers exceeded 1,000 MW frequently. The EIM dispatching range started to show its limitation. From 2016 Q4, we enhanced the counterfactual dispatching range method. This enhancement will allow resources to be dispatched at their base schedules in the counterfactual case instead of being restricted to their EIM dispatch limits which could be overly constraining with large transfers.

The counterfactual dispatch limits will be calculated as follows:

CF_lower_limit = min{ base_schedule, FMM_lower_limit, RTD_lower_limit },

CF_upper_limit = max{ base_schedule, FMM_upper_limit, RTD_upper_limit }.

Table 1 provides some examples of how the counterfactual dispatch limits are calculated.

Base schedule	FMM lower limit	FMM upper limit	RTD lower limit	RTD upper limit	Counterfactual lower limit	Counterfactual upper limit
200	110	290	170	230	110	290
200	210	300	270	300	200	300
200	10	100	10	40	10	200

Table 1. Counterfactual dispatch limits examples

In cases where a counterfactual dispatch could not be produced for a BAA using available bids, the highest bid dispatched will be extended as the marginal cost for procuring more supply. An EIM BAA may restrict the pool of dispatchable units in the counterfactual dispatch if that the BAA's practice prior to joining EIM was to balance real-time load from a limited pool.

ISO counterfactual dispatch

The ISO would need to meet load without EIM transfers in the counterfactual dispatch. The counterfactual dispatch is constructed in the following way.

1. Calculate the ISO's net EIM transfer;
2. Economically dispatch resources from the ISO to replace the transfer
   - A. If the ISO is importing from the EIM,
     - a. Find the ISO's undispatched supply with the variable cost (bid and three-part converted) greater than or equal to the reference FMM transfer price;

    b. Sort and stack the supply by the variable cost from low cost to high cost; and
    c. Clear the supply stack from low cost to high cost up to the transfer megawatts
B. If the ISO is exporting to the EIM,
    a. Find the ISO's dispatched supply with the variable cost (bid and three-part converted) less than or equal to the reference FMM transfer price;
    b. Sort and stack them by the variable cost from high cost to low cost; and
    c. Clear the supply stack from high cost to low cost up to the transfer megawatts

The reference FMM transfer price for the ISO is the maximum price of the incoming transfer points if the ISO is a net transfer importer, and the minimum price of the outgoing transfer points if the ISO is a net transfer exporter. Undispatched supply at lower bid cost than the reference price is dispatched out of merit when the ISO is importing transfer at the reference price. Dispatched supply at higher bid cost than the reference price is also dispatched out of merit when the ISO is exporting transfer at the reference price. The ISO has complex networks and constraints that are modeled in the EIM but not in the counterfactual. For example, supplies can be locally transmission constrained and undispatached in the EIM, which have available supply at lower bid cost than the LMP of the rest of the ISO. They should remain undispatched in the counterfactual even they have lower supply cost, because they are constrained by transmission. In the ISO's counterfactual dispatch, we only consider supplies above the reference transfer price to replace incoming transfer into the ISO, and thus preventing the transmission constrained lower cost supply being dispatched. Vice versa for the supplies below the reference transfer price to replace outgoing transfer. Prior to 2016 Q4, the counter factual dispatch (applies for whole EIM, not just the ISO) was based on 5-minute dispatch capability, and the reference price is the RTD price. To be consistent with the change in 2016 Q4 to extend resources' dispatch limits to FMM and base schedules, the ISO's reference transfer price is changed to be the FMM price.

NV Energy, Arizona Public Service, and Puget Sound Energy counterfactual dispatch

NV Energy, Arizona Public Services, and Puget Sound Energy all have their counter factual dispatch constructed in the following way. We will use NVE as an example.

1. Calculate the real-time net load imbalance for NVE;
2. Economically dispatch resources from NVE on top of the base schedules to meet NVE's net load imbalance
    A. If the net load imbalance is positive,
        a. Find NV Energy's bid-in supply above base schedules;
        b. Sort and stack them by the variable cost from low cost to high cost; and
        c. Clear the supply stack from low cost to high cost up to the net load imbalance.
    B. If the net load imbalance is negative,
        a. Find NV Energy's bid-in supply below base schedules;
        b. Sort and stack them by the variable cost from high cost to low cost; and
        c. Clear the supply stack from high cost to low cost up to the net load imbalance.

PacifiCorp counterfactual dispatch

PacifiCorp East BAA and PacifiCorp West BAA would need to meet demand without intra-hour transfers between PacifiCorp and the ISO, but transfers could occur between PACE and PACW in the counterfactual dispatch. The PacifiCorp counter factual dispatch will be constructed in the following way:

1. Calculate the real-time net load imbalance for each BAA;
2. Economically dispatch resources from the limited pool on top of the base schedules to meet net PacifiCorp load imbalance without violating the transfer limitations between PACE and PACW.
   A. If the net load imbalance is positive,
      a. Find PacifiCorp's bid-in supply above base schedules;
      b. Sort and stack them by the variable cost from low cost to high cost; and
      c. Clear the supply stack from low cost to high cost up to the net load imbalance subject to the transfer limit between PACE and PACW
   B. If the net load imbalance is negative,
      a. Find PacifiCorp's bid-in supply below base schedules;
      b. Sort and stack them by the variable cost from high cost to low cost; and
      c. Clear the supply stack from high cost to low cost up to the net load imbalance subject to the transfer limit between PACE and PACW

GHG revenue

Greenhouse gas (GHG) revenue for a resource is equal to its GHG allocation MW times the GHG price.

GHG cost

GHG cost for a resource is equal to its GHG allocation MW times its GHG bid.

Example

This example illustrates how the EIM benefit is calculated.

The transfers out of the EIM optimization are listed in Table 2. Base scheduled transfers have been excluded in the FMM transfers and RTD transfers.

from BAA	to BAA	FMM transfer	FMM transfer price	RTD incremental transfer	RTD transfer price	transfer cost
PACE	NEVP	140	$26	10	$25	$3,890
NEVP	CISO	160	$26	20	$30	$4,760
PACE	PACW	190	$26	10	$25	$5,190
PACW	CISO	110	$26	-10	$30	$2,560

Table 2. An example of BAA to BAA transfers and prices

Assume the EIM energy imbalance and prices are as follows. Every BAA is balanced with Gen + Transfer – Load = 0. Assume the EIM optimization results in $1 GHG price, which means the ISO's LMP is $1 higher than the neighboring BAA (NEVP and PACW), because there is no congestion going into the ISO in the example. In the table below, positive transfer MW means the BAA is importing and negative transfer MW means it is exporting. Also, transfers in the table are sum of the transfers occur in both the FMM and the RTD with base scheduled transfer being excluded.

BAA	Gen	Load	Net transfer in MW	LMP	GHG price
CISO	0	280	280	$31	$1
NEVP	50	20	-30	$30	
PACE	150	-200	-350	$20	
PACW	100	200	100	$30	

Table 3. EIM energy imbalance and prices by BAA for one 5-minute interval

Transfer cost

The transfers occur in both FMM and RTD, and their volume and prices are listed in Table 3. They are calculated from applying the convention that importing is positive and exporting is negative the BAA to BAA transfers, and summing them over all the neighboring BAAs.

BAA	transfer cost
CISO	$7,320 = $4,760+$2,560
NEVP	($870) = $3,890-$4,760
PACE	($9,080) = -$3,890-$5,190
PACW	$2,630 = $5,190-$2,560

Table 3. EIM transfer cost by BAA

For flex ramp, we calculate its transfer and transfer cost in Table 4.

BAA	Direction	Req.	Award	Allocation	Flex ramp transfer in	Flex ramp price	Flex ramp transfer cost
CISO	upward	150	100	75	-25	$1	-$25

NEVP	upward	10	0	5	5	$1	$5
PACE	upward	20	0	10	10	$1	$10
PACW	upward	20	0	10	10	$1	$10
CISO	downward	0	0	0	0	$2	$0
NEVP	downward	10	10	2	-8	$2	-$16
PACE	downward	20	0	4	4	$2	$8
PACW	downward	20	0	4	4	$2	$8

Table 4. Flex ramp transfer example

EIM dispatch cost

Now calculate the total bid cost associated with the EIM dispatches (delta from base schedules). The EIM dispatch costs are listed in Table 5.

BAA	Gen_EIM	EIM dispatch cost
CISO	0	$0
NEVP	50	$1,450
PACE	150	$2,700
PACW	100	$2,800

Table 5. EIM dispatch cost by BAA

Counterfactual dispatch cost

Then construct the counterfactual dispatches as described in the previous section, and sum up the counter factual dispatch cost for each BAA as shown in Table 6.

BAA	Gen_CF	Counterfactual dispatch cost
CISO	280	$9,240
NEVP	20	$640
PACE	-200	($3,800)

PACW	200	$6,200

Table 6. Counterfactual dispatch cost by BAA

GHG cost and revenue

The GHG costs associated with the 280 MW of importing transfer into CISO, and the revenues received by the GHG allocated MWs in both FMM and RTD are listed in Table 7.

BAA	GHG FMM MW	GHG RTD MW	GHG cost	GHG revenue
CISO	270	280	$0	-$280
NEVP	0	0	$0	$0
PACE	200	200	$20	$200
PACW	70	80	$75	$80

Table 7. GHG cost and revenue by BAA

EIM benefit

With all the cost and revenue for each BAA available, we can use the formula EIM benefit for a BAA = counterfactual dispatch cost – (EIM dispatch cost + transfer cost + flex ramp transfer cost) + GHG revenue – GHG cost to calculate EIM benefit for each BAA. The results are shown in Table 8.

BAA	CF dispatch cost	EIM dispatch cost	Transfer cost	Flex transfer cost	GHG cost	GHG revenue	EIM benefit
CISO	$9,240	$0	$7,320	($25)	$0	($280)	**$1,615**
NEVP	$640	$1,450	($870)	($11)	$0	$0	**$49**
PACE	($3,800)	$2,700	($9,080)	$18	$20	$200	**$2,778**
PACW	$6,200	$2,800	$2,630	$18	$75	$80	**$793**

Table 8. EIM benefit for one 5-minute interval

This calculation is performed for each 5-minute interval with unit $/hr. We convert the $/hr benefit into the dollar benefit by multiplying 1/12. Then the 5-minute interval benefits in dollar amount can be aggregated into the monthly benefit by summing all the 5-minute intervals in the month.