California ISO

Western EIM Benefits Report

Fourth Quarter 2016

January 30, 2017

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Executive Summary

This report presents the benefits associated with participation in the western Energy Imbalance Market (EIM) for the fourth quarter of 2016. The benefits include cost savings and the use of surplus renewable energy to displace conventional generating resources.

The estimated gross benefits for October, November and December 2016 are $28.26 million, bringing the total benefits of EIM to $142.62 million since the California Independent System Operator (ISO) expanded its real-time market to balancing areas outside the ISO in November 2014.

Arizona Public Service Electric Company (APS) and Puget Sound Energy (PSE) joined EIM as new participating balancing authorities on October 1, 2016. The total gross EIM benefits increased as a result of the expanded EIM footprint even though demand is generally lower in the fall and winter. A similar trend was also observed in Q4 2015 when NV Energy (NVE) joined EIM.

The report also shows that EIM is helping to displace less-clean energy supplies with surplus renewable energy that otherwise may have been curtailed.[1] In Q4, the EIM used 23,390 MWh of surplus renewable energy to displace over 10,000 metric tons of CO2 emissions.

The benefit calculation methodology is described in a separate document.[2] This analysis demonstrates the real-time market's ability to select the most economic resources across the ISO, PacifiCorp, NVE, APS and PSE balancing authority areas (BAAs), which comprise the EIM footprint. The benefits quantified in this report fall into three categories and were described in earlier studies:[3]

- ***More efficient dispatch, both inter-and intra-regional, in the Fifteen-Minute Market (FMM) and Real-Time Dispatch (RTD). Q4 estimated savings = $28.27 million.***
- ***Reduced renewable energy curtailment. Q4 estimated reduction = 23,390 MWh displacing approximately 10,011 metric tons of CO2.***
- ***Reduced flexibility reserves needed in all balancing authority areas. Q4 reduction = 399 MW – 490 MW in the upward direction and 474 MW – 482 MW in the downward direction.***

[1] The GHG emission reduction reported is associated with the avoided curtailment only. The current market process and counterfactual methodology cannot differentiate the GHG emissions resulting from serving ISO load via the EIM versus dispatch that would have occurred external to the ISO without the EIM. For more details, see http://www.caiso.com/Documents/GreenhouseGasEmissionsTrackingReport-FrequentlyAskedQuestions.pdf
[2] EIM Quarterly Benefit Report Methodology, https://www.caiso.com/Documents/EIM_BenefitMethodology.pdf
[3] PacifiCorp-ISO, Energy Imbalance Markets Benefits, http://www.caiso.com/Documents/PacifiCorp-ISOEnergyImbalanceMarketBenefits.pdf

Background

The EIM began financially-binding operation on November 1, 2014 by optimizing resources across the ISO and PacifiCorp BAAs. NV Energy, operating in Nevada, began participating in December 2015. Arizona Public Service and Puget Sound Energy began operations October 1, 2016. The EIM footprint now includes portions of Arizona, California, Idaho, Nevada, Oregon, Utah, Washington, and Wyoming. The EIM facilitates renewable resource integration and increases reliability by sharing information between balancing authorities on electricity delivery conditions across the EIM region.

The ISO began publishing quarterly EIM benefit reports in January 2015. Prior reports can be accessed at http://www.caiso.com/informed/Pages/EIMOverview/Default.aspx.

EIM Benefits in Q4 2016

Table 1 shows the estimated EIM gross benefits by each BAA per month. The monthly savings presented in the table show $8.92 million for October, $8.79 million for November, and $10.55 million for December with a total estimated benefit of $28.27 million.

Region	October	November	December	Total
APS	2.81	1.68	1.49	5.98
ISO	1.62	3.09	3.95	8.66
NV Energy	1.00	1.47	0.60	3.07
PacifiCorp	3.24	1.89	3.86	8.99
PSE	0.25	0.66	0.65	1.56
Total	8.92	8.79	10.55	28.26

Table 1: Fourth quarter 2016 benefits

Inter-Regional Transfers

A significant contributor to EIM benefits are transfers across balancing areas, providing access to lower cost supply, while factoring in the cost of compliance with greenhouse gas (GHG) emissions regulations when energy is transferred into the ISO. As such, the transfer volumes are a good indicator of a portion of the benefits attributed to the EIM. Transfers can take place in both the Fifteen-Minute Market and Real-Time Dispatch (RTD).

Generally, transfer limits are based on transmission and interchange rights that participating balancing authority areas make available to the EIM, with the exception of the PacifiCorp West (PACW)-ISO transfer limit in RTD. The RTD transfer capacities between PACW and the ISO are determined based on the allocated dynamic transfer capability driven by system operating conditions. This report does not quantify a BAA's opportunity cost that the utility considered when using its transfer rights for the EIM.

Table 2 provides the 15-minute and 5-minute EIM transfer volumes with base schedule transfers excluded. The EIM entities submit inter-BAA transfers in their base schedules. The benefits quantified in this report are only attributable to the transfers that occurred through the EIM. The benefits do not

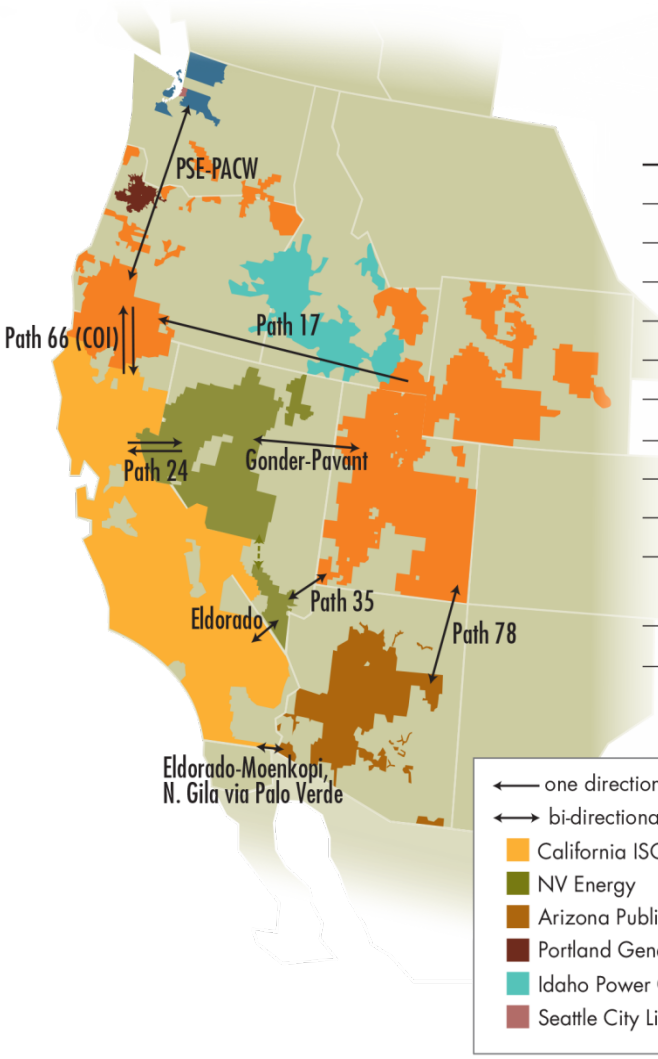
include any transfers attributed to transfers submitted in the base schedules that are schedule prior to the start of the EIM.

The transfer from BAA_x to BAA_y and the transfer from BAA_y to BAA_x are separately reported. For example, in an interval, if there is 100 MWh transfer on top of base transfer from ISO to NVE, it will be reported as 100 MWh from_BAA=ISO and to_BAA=NVE, and it will be reported as 0 MWh from_BAA=NVE and to_BAA=ISO in the opposite direction. The 15-minute transfer volume results from optimization in the 15-minute market with all bids and base schedules submitted into the EIM. The 5-minute transfer volume results from optimization with all bids and base schedules submitted into EIM, and unit commitments determined in the 15-minute market optimization. The maximum transfer capacities between EIM entities is shown in Graph 1.

Year	Month	from_BAA	to_BAA	15m EIM transfer (15m - base)	5m EIM transfer (5m - base)
2016	October	AZPS	CISO	172,568	229,386
		AZPS	NEVP	491	378
		AZPS	PACE	16,844	13,949
		CISO	AZPS	21,220	12,790
		CISO	NEVP	73,296	53,379
		CISO	PACW	41,672	38,939
		NEVP	AZPS	112	101
		NEVP	CISO	46,195	89,750
		NEVP	PACE	51,875	47,773
		PACE	AZPS	113,970	137,442
		PACE	NEVP	48,731	50,562
		PACE	PACW	8,905	15,052
		PACW	CISO	27,620	39,203
		PACW	PSEI	37,324	29,565
		PSEI	PACW	25,156	33,599

Year	Month	from_BAA	to_BAA	15m EIM transfer (15m - base)	5m EIM transfer (5m - base)
2016	November	AZPS	CISO	159,791	159,930
		AZPS	NEVP	510	498
		AZPS	PACE	22,675	15,371
		CISO	AZPS	30,518	19,611
		CISO	NEVP	44,124	57,652
		CISO	PACW	24,827	25,010
		NEVP	AZPS	114	112
		NEVP	CISO	93,231	106,982
		NEVP	PACE	80,547	82,904
		PACE	AZPS	141,519	135,525
		PACE	NEVP	27,037	32,731
		PACE	PACW	9,597	20,985
		PACW	CISO	59,371	64,138
		PACW	PSEI	14,312	16,268
		PSEI	PACW	50,070	49,439
2016	December	AZPS	CISO	241,862	213,911
		AZPS	NEVP	80	80
		AZPS	PACE	11,351	6,593
		CISO	AZPS	16,213	9,701
		CISO	NEVP	67,133	77,243
		CISO	PACW	18,260	22,301
		NEVP	AZPS	80	82
		NEVP	CISO	48,730	66,086
		NEVP	PACE	81,818	80,467
		PACE	AZPS	207,945	191,406
		PACE	NEVP	23,055	34,078
		PACE	PACW	12,192	32,277
		PACW	CISO	86,019	93,992
		PACW	PSEI	35,982	43,665
		PSEI	PACW	36,658	34,679

Table 2: Energy transfers (MWh) in the FMM and RTD for the fourth quarter 2016



Path	Estimated Max Capacity (MW)*
Path 24 *(west to east)*	100
Path 24 *(east to west)*	35-90
Eldorado	1,500
Path 35 *(west to east)*	580
Path 35 *(east to west)*	538
Gonder-Pavant	130
Path 66 *(ISO to PACW)*	331
Path 66 *(PACW to ISO)*	432
Path 17	200
PSE to PACW	300
Eldorado, Moenkopi, N. Gila, Palo Verde	2,500
Path 78	600

Graph 1: Estimated maximum transfer capacity

Reduced Renewable Curtailment and GHG Reductions

The EIM benefit calculation includes the economic benefits that can be attributed to avoided renewable curtailment within the ISO. If not for energy transfers facilitated by the EIM, some renewable generation located within the ISO would have been curtailed via either economic or exceptional dispatch. The total avoided renewable curtailment volume in MWh for Q4 2016 was calculated to be 6,204 MWh (October) + 8,500 MWh (November) + 8,686 MWh (December) = 23,390 MWh total.

The environmental benefits of avoided renewable curtailment are significant. Under the assumption that avoided renewable curtailments displace production from other resources at a default emission rate of 0.428 metric tons CO2/MWh, avoided curtailments displaced an estimated 10,011 metric tons of CO2 for Q4 2016. Avoided renewable curtailments also may have reduced the volume of renewable credits that would have been retracted. However, this report does not quantify the additional value in dollars associated with this benefit. Total estimated reductions in the curtailment of renewable energy along with the associated reductions in CO2 are shown in Table 3.

Year	Quarter	MWh	Eq. Tons CO2
2015	1	8,860	3,792
	2	3,629	1,553
	3	828	354
	4	17,765	7,521
2016	1	112,948	48,342
	2	158,806	67,969
	3	33,094	14,164
	4	23,390	10,011
	Total	359,320	153,706

Table 3: Total reduction in curtailment of renewable energy along with the associated reductions in CO2

Flexible ramping procurement diversity savings

The EIM facilitates procurement of flexible ramping capacity in the FMM to address variability that may occur in the RTD. Because variability across different BAAs may happen in opposite directions, the flexible ramping requirement for the entire EIM footprint can be less than the sum of individual BAA's requirement. This difference is known as flexible ramping procurement diversity savings. Starting in November 2016, the ISO replaced the flexible ramping constraint with flexible ramping products. The old constraint had only the upward direction, while the new products have both upward and downward direction. The minimum and maximum requirements for each BAA are listed in Table 4.

Year	Month	BAA	Direction	Minimum requirement	Maximum requirement
2016	October	AZPS	up	20	150
		CISO	up	75	500
		NVEP	up	20	100
		PACE	up	21	150
		PACW	up	15	100
		PSEI	up	20	150
		ALL EIM	up	100	530
2016	November	AZPS	up	0	254
		CISO	up	72	1,000
		NVEP	up	0	202
		PACE	up	71	300
		PACW	up	4	150
		PSEI	up	10	135
		ALL EIM	up	0	1,753
		AZPS	down	0	350
		CISO	down	5	1,000
		NVEP	down	0	250
		PACE	down	30	300
		PACW	down	18	175
		PSEI	down	2	135
		ALL EIM	down	0	1,200
2016	December	AZPS	up	38	400
		CISO	up	0	1,000
		NVEP	up	6	179
		PACE	up	58	300
		PACW	up	18	150
		PSEI	up	5	135
		ALL EIM	up	0	1,800
		AZPS	down	31	350
		CISO	down	2	1,000
		NVEP	down	9	250
		PACE	down	61	300
		PACW	down	24	175
		PSEI	down	13	135
		ALL EIM	down	0	1,200

Table 4: Flexible ramping requirements

The flexible ramping procurement diversity savings for all the intervals averaged over a month are shown in Table 5. The percentage savings is the average MW savings divided by the sum of the four individual BAA requirements.

	October		November		December	
Direction	Up	Down	Up	Down	Up	Down
Average MW saving	490	N/A	415	474	399	482
Sum of BAA requirements	986	N/A	1,238	1,162	1,236	1,166
Percentage savings	50%	N/A	33%	41%	32%	41%

Table 5: Flexible ramping procurement diversity saving for fourth quarter 2016

Previously with the old flexible ramping constraint design, procured flexible ramping capacity could be fully accessed in RTD. If the flexible ramping procurement in the FMM was beneficial, it would reduce the RTD dispatch cost. With the EIM benefits being quantified on a 5-minute level, the benefit of flexible ramping was fully captured in the RTD dispatch. The EIM benefits calculated at a 5-minute level included the savings from procuring and deploying flexible ramping. However, this analysis did not breakout the dollar savings separately because the savings were tightly integrated with the RTD dispatch.

Under the new flexible ramping product design, flexible ramping capacity may be kept in RTD to deal with uncertainties in the future interval. The RTD flexible ramping capacity is prorated to each BAA. Flexible ramping surplus MW is defined as the awarded flexible ramping capacity in RTD minus its share, and the flexible ramping surplus cost as the flexible ramping surplus MW multiplied by the flexible ramping EIM wide marginal price. A positive flexible ramping surplus MW is the capacity that a BAA provided to help other BAAs, and a negative flexible ramping surplus MW is the capacity that a BAA received from other BAAs. The EIM dispatch cost for a BAA with positive flexible ramping surplus MW is increased because some capacities are used to help other BAAs. The flexible ramping surplus cost is subtracted from the BAA's EIM dispatch cost to reflect the true dispatch cost of a BAA. Please read the Appendix for more details.

Conclusion

Participation in the western EIM continues to show that utilities can realize cost benefits and reduced carbon emissions. With $142.62 million in gross benefits to date, the realized savings are in line with analysis conducted before the market expansion launched in November 2014. The EIM resource sharing also continues to have a positive effect on reducing greenhouse gas emissions by using excess renewable generation that otherwise would be turned off. Using surplus energy to meet demand across the EIM footprint can replace less clean energy sources. The GHG quantified benefits due to avoided curtailments[4] of 153,706 metric tons for 2015 through 2016 is roughly equivalent to avoiding the emissions from 32,316 passenger cars driven for one year.

[4] Ibid. See footnote 1 on page 3.