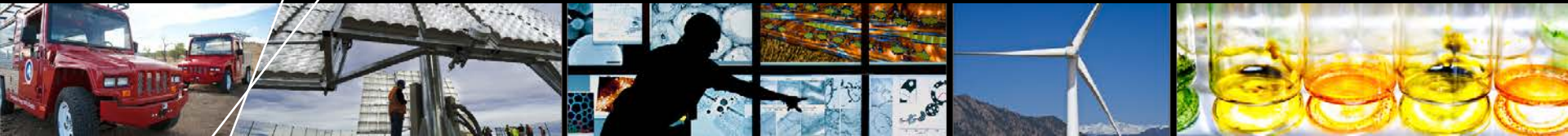




# NREL/Plexos Analysis of the Proposed EIM in the Western Interconnection



**Michael Milligan**

**Jack King**

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**Brendan Kirby**

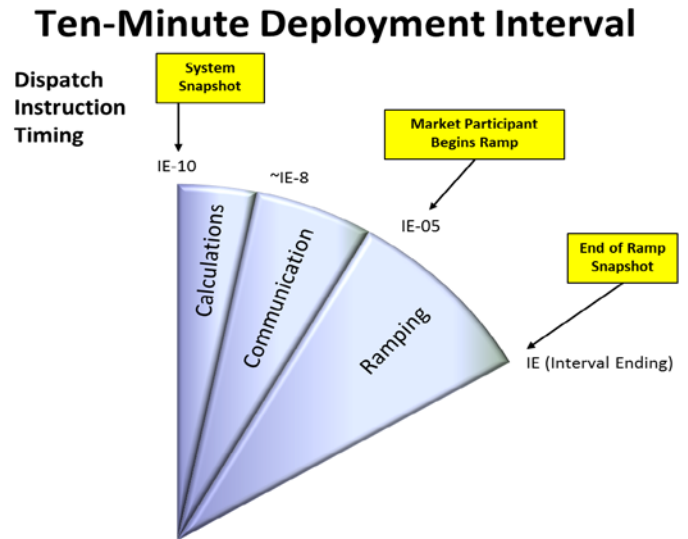
**Tao Guo (Energy Exemplar)**

**Transmission and Grid Integration Group, NREL**

**EIM PUC Meeting, September 13, 2012**

# Energy Imbalance Market (EIM)

- Security-constrained economic dispatch that redispatches generation every 5 minutes to maintain the balance between generation and load
- EIM flows have lowest non-firm transmission service priority and are curtailed first to respect transmission constraints
- Unit commitment is still performed by individual balancing areas to meet their load and reserve requirements
- Regulation service is still provided by individual balancing areas
- Participation is voluntary



# Project overview

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- **WIEB, on behalf of PUC EIM group, requested analysis to expand on WECC/E3 study with minimal changes in assumptions**
- **Funding provided by DOE Office of Electricity Delivery and Energy Reliability**
- **Objectives**
  - Evaluate potential benefits of EIM using 10-minute production simulations of the operation of the Western Interconnection
  - Identify individual balancing area benefits as well as societal (west-wide) benefits
  - Explore alternative EIM footprint scenarios and other sensitivity cases
- **Scope**
  - Potential operational benefits only (i.e., implementation costs excluded)
  - Operational benefits = Total production cost of base case - Total production cost of EIM case

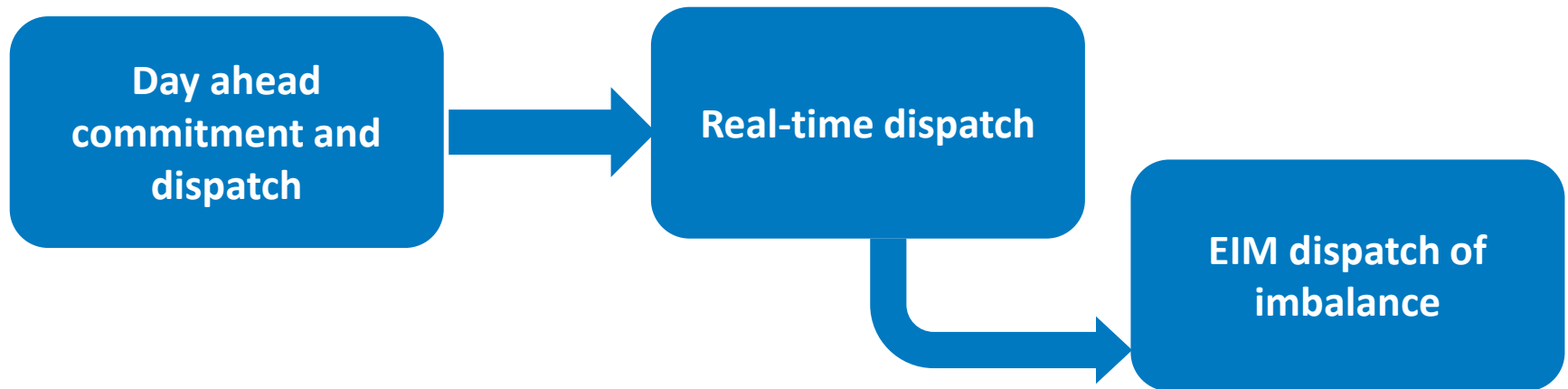
# System Model Starting Point

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- **System model from WECC Planning Case 0**
  - 2020 WI generation and transmission system model
  - 8% wind and 3% solar penetration (by annual energy)
- **Same assumptions as WECC/E3 study**
  - Fuel prices
  - Transmission area and reserve sharing area definitions
  - Hurdle rates used to approximate historical power flows
  - Contracts, in general, were not modeled
  - Information on which units provide reserve was not available
- **Differences**
  - Losses included in load

# Approximations inherent to production simulation

- **Modeling approximates the dispatch of imbalances**
  - Day-ahead (DA) unit commitment is solved simultaneously with DA dispatch
  - The real-time dispatch differs from DA dispatch, resulting in the imbalance dispatched by the EIM



- **All areas treated alike in any given case (e.g., all areas on 1-hour dispatch, or all areas on 10-min dispatch), which causes bracketing of results**

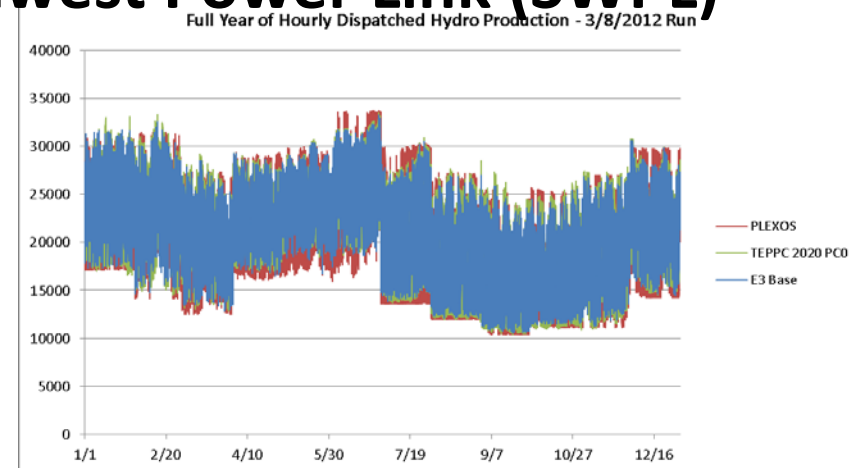
# Approximations inherent to production simulation

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- **Detailed representation of all contracts, joint ownership, transmission rights, coordination agreements not included due to lack of available information**
- **Hydro modeled by fixed profiles or approximation to hydro thermal coordination (HTC) rather than by detailed individual plant models, aligned with WECC TEPPC modeling results**
- **Lack of data on which units provide regulation, contingency reserve**

# System Model Improvements

- 10-minute simulation capability
- Hydro modeling is better match to TEPPC results, based on revised E3 and inputs from Columbia Grid
- Joint ownership of Hoover, Colstrip, Mid-Columbia units modeled
- Transmission rights on California-Oregon Transmission Project (COTP), Pacific Northwest DC tie, Intermountain DC tie, and Southwest Power Link (SWPL) modeled



# System Model Improvements

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- **Transmission “overbuild” caused by conversion from PROMOD to PLEXOS has been fixed**
- **Revised unit commitment for EIM cases that are compared to hourly BAU to differentiate imbalance from 10-min schedule**
- **Other modeling improvements were identified subsequent to calculating individual BA results but could not be implemented within the study scope**



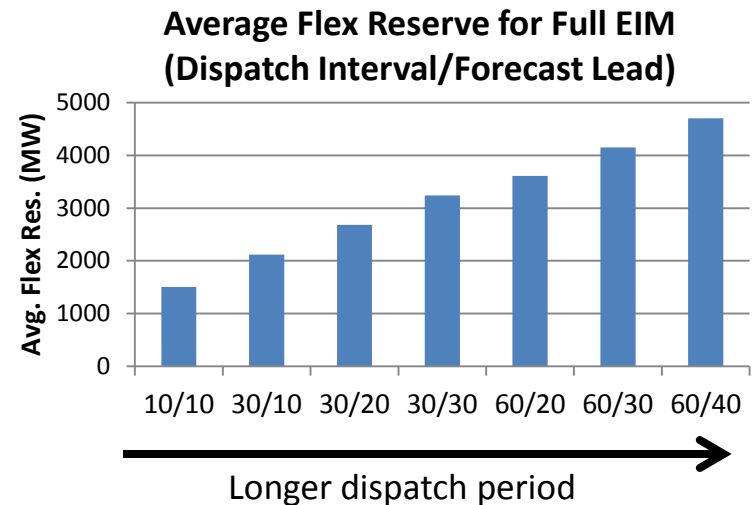
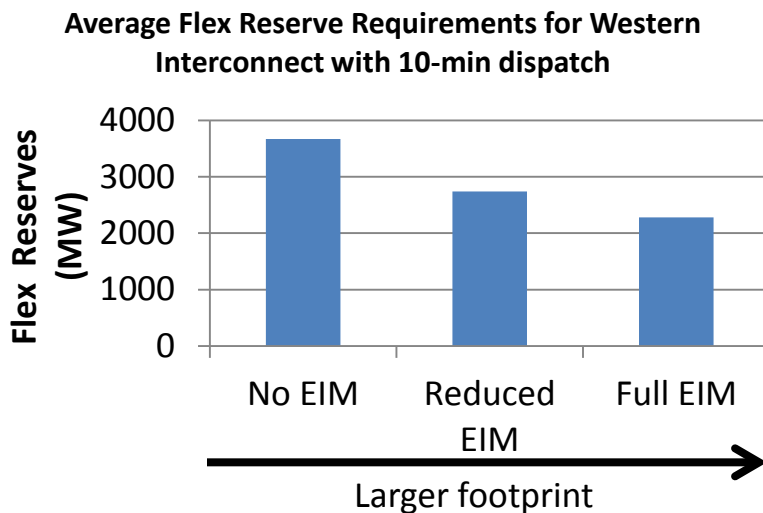
# Interpretation of results

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- **EIM operational benefit is sensitive to**
  - VG penetration and location
  - Mix of non-VG generation
  - Relative gas/coal prices
  - Intermediate steps made to coordinate operations that may be made independently of the EIM
  - Outcome of FERC Order 764 and adoption of 15-minute schedules (FERC requires they are offered, but not necessarily used)
  - Many other variables
- **Thus: even with perfect modeling, results are indicative, and should not be construed as a forecast**

# Flexibility Reserves

- Designed to address wind and solar variability
- 3 types: regulation, 10-min spinning, 30-min non-spinning
- *In addition to, not instead of*, existing types of reserves
- Calculated based on 3 years of wind and solar data variability
- Amount of flex reserves varies significantly with footprint size and dispatch interval



# Study Cases

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- **Two business-as-usual (BAU) cases to bracket future (i.e.,2020) operating procedures**
  - Hourly BAU: May *underestimate* other efficiency improvements
  - 10-minute BAU: May *overestimate* other efficiency improvements
- **Two EIM cases with different footprints**
  - Full EIM consists of WI excluding market operators CAISO and AESO
  - Reduced EIM further excludes BPA, CHPD, DOPD, GCPD, SCL, TPWR, WACM, and WALC
- **Two sensitivity cases**
  - Low gas price
  - Reduced reserves
- **Alignment cases for comparison to E3 study results**

# Revision to the Hourly BAU case

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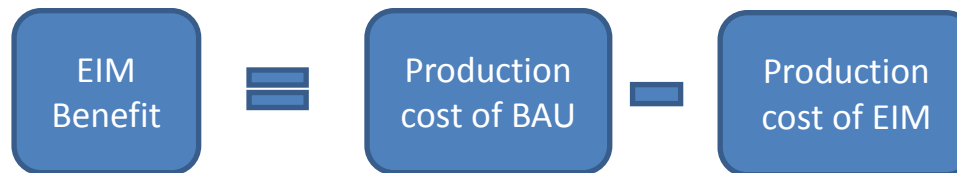
- **As a result of stakeholder questions and suggestions, the hourly BAU case assumes that hourly interchange is retained in the EIM case, and is set in the day ahead commitment**
- **The EIM dispatches in 10-minutes**
- **This significantly reduces the EIM benefit, decoupling the savings between the schedule change and the EIM**

# Study Approach

- **Perform production simulations**

- Emulates 1 year of operation, including day ahead unit commitment and real time dispatch (hourly for base cases, 10-min for EIM cases)
- Actual and forecasted power profiles for individual wind and solar sites drawn from NREL database, load profiles from WECC and PNNL
- Include flexibility reserve requirements as calculated for each case
- Model output includes overall system production costs (e.g. fuel cost, variable O&M, start up costs, etc), individual generator output, emissions, bus LMPs, etc.

- **Calculate societal (west-wide) benefits**



- **Allocate selected case results to individual balancing areas**

- More on this to follow

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# **RESULTS – SOCIETAL BENEFITS**

# Societal (west-wide) Benefits

- **Total production cost for the Western Interconnection consists of**

Variable production cost (fuel, O&M, startup)



Transmission losses  $\geq 115$  kV (post processed)



Cost of unserved load (valued at cost of CT = \$85/MWh)

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EIM Benefit



Production cost of BAU



Production cost of EIM

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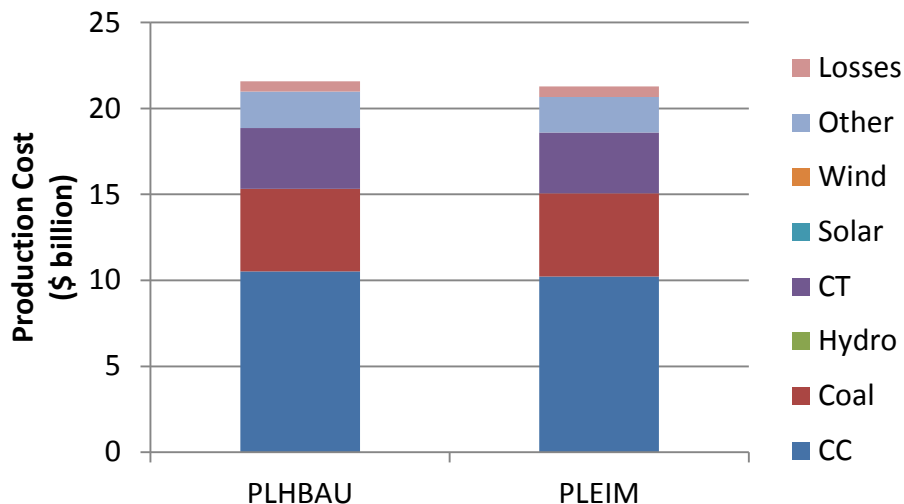
# **EIM SAVINGS FROM HOURLY BAU**



# EIM Savings from Hourly Dispatch BAU

- Total savings approximately \$300 million
- Reductions in gas fired resources
- Increase in coal resources utilization

Total Annual Production Cost Comparison for Full EIM over Hourly Dispatched BAU by Resource Type

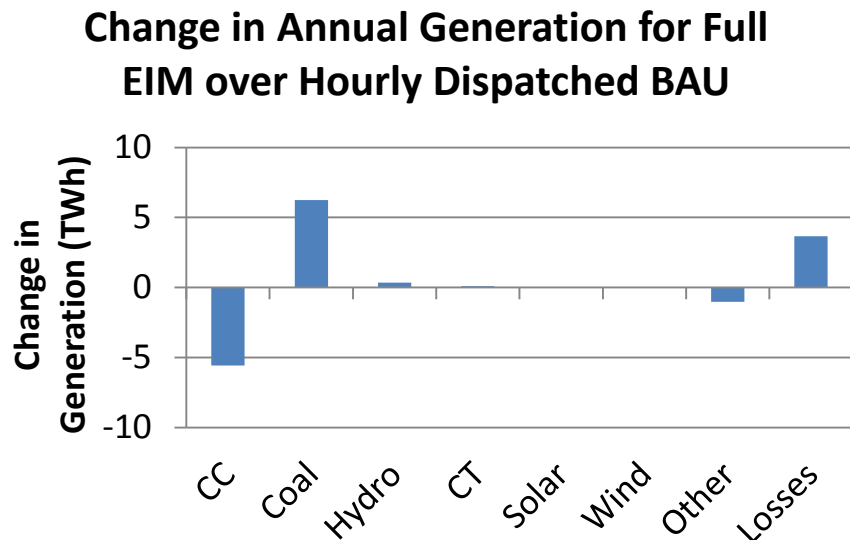


	PLHBAU (\$billions)	PLEIM (\$billions)	Difference (\$billion)
CC	10.52	10.22	-0.303
Coal	4.80	4.84	0.044
CT	3.54	3.54	-0.001
Other	2.12	2.07	-0.054
Losses	0.60	0.62	0.020
Total	21.58	21.29	-0.294

Negative values indicate EIM savings

# EIM Savings from Hourly Dispatch BAU

- Combined cycle energy is reduced & replaced by coal
- Slight decrease in other generation
- Losses increase by about 11% with the EIM
  - More energy is flowing greater distances



	PLHBAU (TWh)	PLEIM (TWh)	Difference (TWh)
CC	187	181	-6
Coal	286	292	6
Hydro	253	254	0
CT	43	43	0
Solar	32	32	0
Wind	80	80	0
Other	143	142	-1
Losses	33	37	4
Total	1056	1060	4

Negative values indicate EIM savings

# EIM Emissions Changes from Hourly BAU

	CO2 (ktons)	NOx (ktons)	SO2 (ktons)
Hourly BAU	473,913	697	461
EIM	477,457	708	468
Increase	3,544	11	6
%	0.7%	1.5%	1.4%

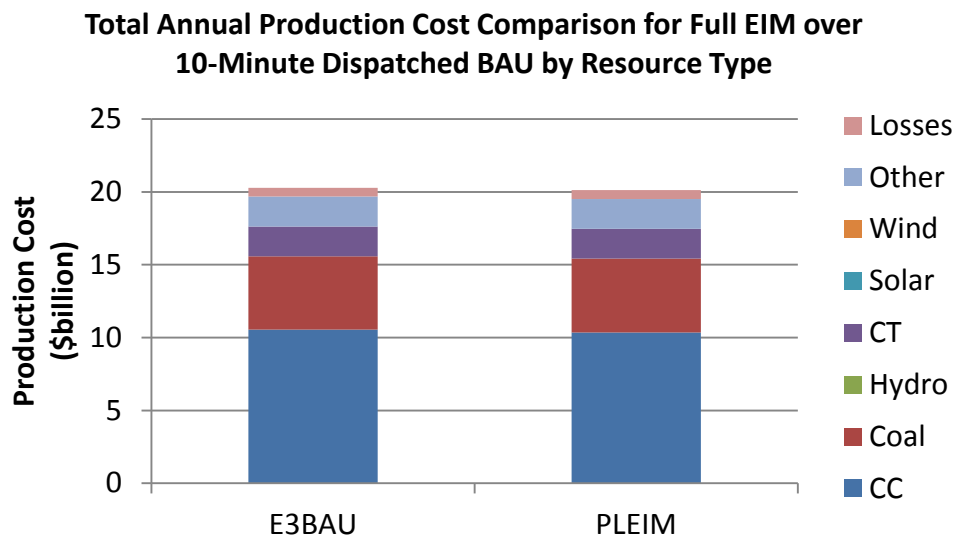
- **0.7% increase in carbon due to additional coal usage**
- **Additional coal is used because the EIM pools variability, allowing base-load generation to replace some mid-merit generation**
- ***Model is relentless about finding least-cost solution and does not attempt to minimize emissions***

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# **EIM SAVINGS FROM 10-MINUTE BAU**

# EIM Savings from 10-minute Dispatch BAU

- **Total savings are \$146 million**
- **Major savings in reduction of combined cycle usage**
  - Less CT use in the 10-minute vs. hourly BAU due to lower reserve requirements

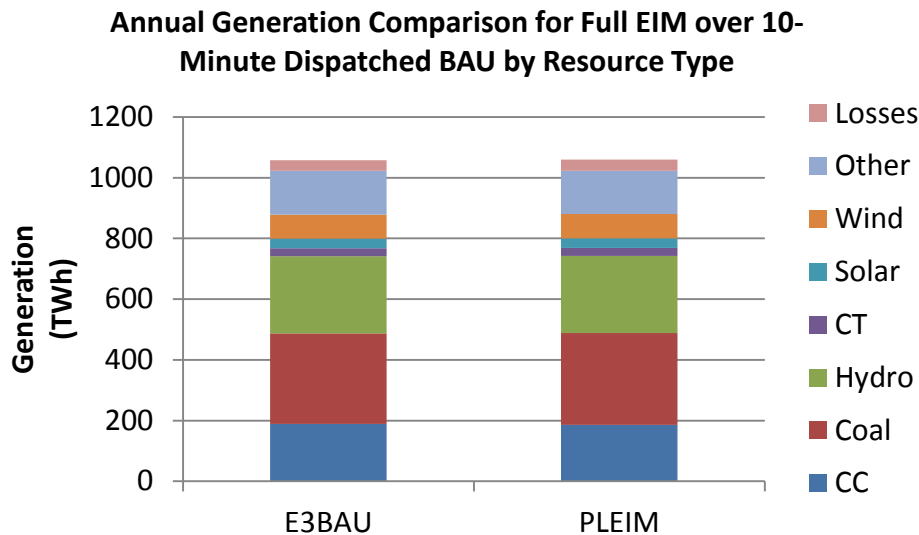


	E3BAU (\$billions)	PLEIM (\$billions)	Difference (\$billions)
CC	10.55	10.36	-0.190
Coal	5.02	5.07	0.047
CT	2.05	2.05	0.004
Other	2.06	2.03	-0.034
Losses	0.59	0.62	0.027
<b>Total</b>	<b>20.27</b>	<b>20.12</b>	<b>-0.146</b>

Negative Values indicate EIM savings

# EIM Savings from 10-minute Dispatch BAU

- **Reductions in combined cycle and “other” (i.e., non-coal steam & biomass) generation**
  - Coal makes up for this reduction
  - This is a function of the relative fuel prices
- **Losses increase due to more energy flowing longer distances in the EIM**



	E3BAU (TWh)	PLEIM (TWh)	Difference (TWh)
CC	189	186	-3.5
Coal	298	303	4.8
Hydro	254	254	-0.1
CT	26	26	0.0
Solar	32	32	0.0
Wind	80	80	0.0
Other	144	143	-1.1
Losses	35	37	2.4
<b>Total</b>	<b>1057</b>	<b>1060</b>	<b>2.5</b>

Negative Values indicate EIM savings

# EIM Emissions Changes from 10-min BAU

- **0.6% increase in CO<sub>2</sub> due to additional coal usage**
- **Other emissions also increase slightly**

	CO2 (ktons)	NOx (ktons)	SO2 (ktons)
10 Minute BAU	478,749	713	483
EIM	481,585	722	487
Increase	2,836	9	5
% Increase	0.6%	1.2%	1.0%

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# **RESULTS – INDIVIDUAL BALANCING AREA ALLOCATION**



# Allocation of EIM Benefits to Individual BAs

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- **Based on the WECC/E3 “Benefits Allocation Roadmap”**
- **Method accounts for**
  - Changes in production cost
  - Changes in import/export cost
- **Requires post-processing of the PLEXOS model output**
- **Result = “adjusted production cost” (APC)**
- **Negative values represent EIM savings**

# Participant Benefit Comparison of APC: EIM Savings from 10-min and Hourly BAU Cases

Comparisons of EIM with 2 Base Case		
	EIM-10 Min BAU	EIM-1Hour BAU
	Adjusted Production Cost Increase	Adjusted Production Cost Increase
APS	(17,331,585)	(336,589)
AVA	(29,281,815)	(45,587,793)
BCTC	(4,044,119)	27,266,346
BPA	174,371,510	313,296,691
CHPD	3,347,904	6,047,163
DOPD	2,398,329	3,968,370
EPE	(5,983,061)	(7,700,546)
GCPD	1,322,219	1,980,291
IID	1,325,259	6,712,501
IPC	(3,622,283)	1,773,300
LADWP	(53,202,171)	(89,732,492)
NEVP	(24,050,621)	(6,799,425)
NWE	(26,812,270)	(23,921,638)
PACE	(94,136,285)	(78,754,619)
PACW	(35,365,287)	(64,684,313)

# Participant Benefit Comparison of APC: EIM Savings from 10-min and Hourly BAU Cases

Comparisons of EIM with 2 Base Case		
	EIM-10 Min BAU	EIM-1Hour BAU
PGN	(51,927,535)	(75,600,701)
PNM	(12,220,910)	(7,792,817)
PSCO	(83,894,222)	(110,717,692)
PSE	(72,624,072)	(103,165,905)
SCL	(11,898,449)	(24,032,821)
SMUD	(22,133,509)	(41,089,978)
SPP	(14,963,693)	(23,422,745)
SRP	(42,835,383)	(55,455,397)
TEP	(18,074,939)	(14,603,714)
TID	(5,442,557)	(11,342,901)
TPWR	(3,978,440)	(8,258,778)
WACM	(5,438,188)	(804,676)
WALC	93,814	21,964,557
WAUM	(10,573,144)	(7,373,887)
EIM Participant Total	(466,975,503)	(418,170,207)

# Non-Participant Benefit Comparison of APC: EIM Savings from 10-min and Hourly BAU Cases

Comparisons of EIM with 2 Base Case		
	EIM-10 Min BAU	EIM-1Hour BAU
AESO	(16,204,297)	22,892,268
CFE	3,797,509	(291,931)
PGE	(78,111,681)	(100,670,891)
SCE	(56,257,891)	(104,574,242)
SDGE	(21,089,078)	(23,541,831)
Non Participants Total	(167,865,438)	(206,186,628)
EIM Participant Total (From Prev. Slide)	(466,975,503)	(418,170,207)
Total	(634,840,941)	(624,356,835)

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# **SENSITIVITY RESULTS – SOCIETAL BENEFITS**

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# **REDUCED FOOTPRINT EIM SAVINGS FROM HOURLY BAU**

# Reduced Footprint EIM Results

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- **Results will be available in a few days**

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# **REDUCED FOOTPRINT EIM SAVINGS FROM 10-MIN BAU**



# Reduced Footprint EIM Savings from 10-Minute Dispatch BAU

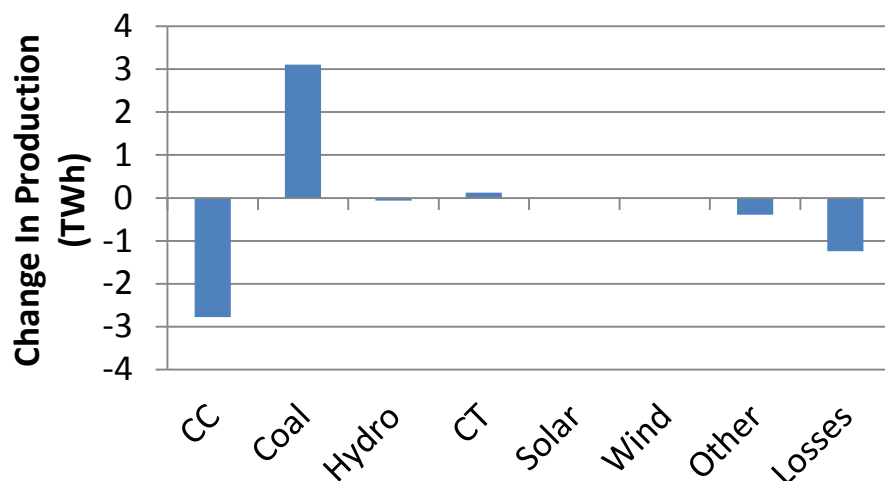
- **WAPA, BPA, and several embedded BAs do not participate in EIM**
- **Savings are \$95 million**
  - \$52M less than the full footprint EIM savings of \$146M

	E3BAU (\$billions)	PLEIM -PMA (\$billions)	Difference (\$billions)
CC	10.55	10.40	-0.146
Coal	5.02	5.07	0.050
CT	2.05	2.06	0.008
Other	2.06	2.05	-0.014
Losses	0.59	0.60	0.007
Total	20.27	20.17	-0.095

Negative values indicate EIM savings

EIM w/o PMA excludes BPA, CHPD, BCTC, DOPD, GCPD, SCL, TPWR, WACM, WALC

Change in Annual Generation for Reduced EIM over 10-Minute Dispatched BAU



# Reduced Footprint EIM Effect on Emissions

- **Reduced participation EIM with the 10-Minute BAU shows a 0.4% increase in CO<sub>2</sub>**
- **Other emissions also increase slightly**

	CO2 (ktons)	NOx (ktons)	SO2 (ktons)
10 Minute BAU	478,749	713	483
EIM	480,740	720	488
Increase	1,991	6	6
%	0.4%	0.9%	1.2%

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# **GAS PRICE SENSITIVITY FROM HOURLY BAU**

# Gas Price Sensitivity

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- **Results should be available within a few days**

# Summary

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- **Full EIM participation results in about \$150-300 million in societal benefit**
- **Most participants benefit**
  - More efficient dispatch
  - Reduced LMPs in many cases
- **Non-participant benefits driven by**
  - need for uniform modeling
  - Access to less expensive generation via the EIM
- **Next steps →**

# Next Steps

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- **Current phase of EIM analysis**
  - Additional results (e.g., gas sensitivity) next week
  - Final report in October
- **Potential follow on work (if stakeholders would find it useful)**
  - Modeling refinements and additional data
  - Re-examination of assumptions and potential departure from WECC PC0 (WECC PC1 or new 2022 case?)
  - Potential alternative scenarios/penetrations
  - Deeper industry involvement and review; coordination with NWPP MC efforts

# Backup Slides

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# BAA Acronyms

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**Avista (AVA)**

**Bonneville Power Administration (BPA)**

**PUD No 1 of Chelan County (CHPD)**

**PUD No 1 of Douglas County (DOPD)**

**PUD No 1 of Grant County (GCPD)**

**Seattle City Light (SCL)**

**Tacoma Power (TPWR)**

**Puget Sound Energy (PSE)**

**Idaho Power Corp (IPC)**

**Northwest Energy (NWE)**

**Pacificorp East (PACE)**

**Pacificorp West (PASW)**

**Portland General Electric (PGE)**

**Arizona Public Service (AZPS)**

**El Paso Electric (EPS)**

**Imperial Irrigation District (IID)**

**Public Service Company of New Mexico (PNM)**

**Public Service Company of Colorado (PSCO)**

**Sacramento Municipal Utility District (SMUD)**

**NV Energy (Sierra Pacific Power (SPP), Nevada Power (NEVP))**

**Salt River Project (SRP)**

**Tucson Electric Power (TEP)**

**Turlock Irrigation District (TID)**

**WAPA - Colorado Missouri Region**

**WAPA - Lower Colorado Region**

**WAPA - Upper Great Plains West**

**California Independent System Operator (CAISO)**

**Pacific Gas & Electric (PG&E)**

**Southern California Edison (SCE)**

**San Diego Gas & Electric (SDGE)**

**Los Angeles Department of Water and Power (LADWP)**

**British Columbia Transmission Corporation (BCTC)**

**Alberta Electric System Operator (AESO)**



	BAA	Load			Wind			Solar			Total VG			VG Penetration	
		Min	Avg	Max	Avg	Max	CF	Avg	Max	CF	Avg	Max	CF	Avg	Max
		(MW)	(MW)	(MW)	(MW)	(MW)	(MW)	(%)	(MW)	(MW)	(%)	(MW)	(MW)	(%)	(%)
Load data, wind and solar energy penetration by BA.	APS	2550	4100	8410	58	173	34%	371	1293	29%	429	1464	29%	10%	46%
	AVA	1041	1715	2882	105	323	32%	0	0	0%	105	323	32%	6%	28%
	BCTC	5091	7194	11393	0	0	0%	0	0	0%	0	0	0%	0%	0%
	BPA	4748	6577	10377	1909	6693	29%	0	0	0%	1909	6693	29%	29%	126%
	CHPD	323	464	719	0	0	0%	0	0	0%	0	0	0%	0%	0%
	DOPD	100	244	466	0	0	0%	0	0	0%	0	0	0%	0%	0%
	EPE	794	1215	2135	0	0	0%	9	44	22%	9	44	22%	1%	4%
	GCPD	352	592	877	0	0	0%	0	0	0%	0	0	0%	0%	0%
	IID	231	537	1243	219	857	26%	0	0	0%	219	857	26%	47%	300%
	IPC	1280	2233	4043	101	330	31%	0	0	0%	101	330	31%	5%	20%
	LDWP	2171	3712	6778	210	585	36%	74	321	23%	285	848	34%	8%	25%
	NEVP	1893	3224	6603	0	0	0%	281	835	34%	281	835	34%	8%	36%
	NWMT	864	1307	1875	298	833	36%	0	0	0%	298	833	36%	23%	82%
	PACE	4685	6387	10548	814	1973	41%	0	0	0%	814	1973	41%	13%	38%
	PACW	1311	2361	3904	174	630	28%	2	9	18%	176	635	28%	8%	42%
	PGN	1488	2681	4294	230	805	29%	2	11	18%	232	813	29%	9%	47%
	PNM	1346	1846	2886	269	749	36%	76	257	30%	345	1001	35%	19%	62%
	PSC	3859	5651	9339	886	2880	31%	242	1000	24%	1128	3782	30%	20%	74%
	PSE	1829	3010	5365	345	1067	32%	0	0	0%	345	1067	32%	12%	54%
	SCL	766	1243	1924	0	0	0%	0	0	0%	0	0	0%	0%	0%
	SMUD	1305	2111	4802	19	104	18%	0	0	0%	19	104	18%	1%	6%
	SPP	1060	1453	2155	40	150	26%	0	0	0%	40	150	26%	3%	13%
	SRP	2610	4599	8800	38	127	30%	62	165	38%	100	290	35%	2%	8%
	TEP	1123	1877	3677	12	50	25%	106	494	22%	119	543	22%	6%	38%
	TIDC	215	358	793	0	0	0%	0	0	0%	0	0	0%	0%	0%
	TPWR	352	618	1035	0	0	0%	0	0	0%	0	0	0%	0%	0%
	WACM	2586	3388	4678	131	420	31%	6	30	20%	137	444	31%	4%	15%
	WALC	409	860	1591	0	0	0%	17	87	20%	17	87	20%	2%	14%
WAUW	22	72	128	0	0	0%	0	0	0%	0	0	0%	0%	0%	

# Fuel Prices

- **Gas prices (nominal = \$7.28, low = \$4.50)**
- **Coal prices**

Fuel	Value	Units
Coal - AESO	1.49	\$/MMBTU
Coal - APS	1.88	\$/MMBTU
Coal - BPA	2.12	\$/MMBTU
Coal - FAR EAST	1.49	\$/MMBTU
Coal - LDWP	1.21	\$/MMBTU
Coal - NEVP	1.73	\$/MMBTU
Coal - NWMT	1.04	\$/MMBTU
Coal - PACE_UT	1.21	\$/MMBTU
Coal - PACE_WY	0.98	\$/MMBTU
Coal - PG&E_BAY	1.73	\$/MMBTU
Coal - PG&E_VLY	1.73	\$/MMBTU
Coal - PGN	2.12	\$/MMBTU
Coal - PNM	1.38	\$/MMBTU
Coal - PSC	1.42	\$/MMBTU
Coal - SCE	1.73	\$/MMBTU
Coal - SPP	1.73	\$/MMBTU
Coal - SRP	1.88	\$/MMBTU
Coal - TEP	1.88	\$/MMBTU
Coal - WACM	1.42	\$/MMBTU
Coal - WALC	1.88	\$/MMBTU

# Hurdle Rates

From BA	To BA	Forward	Backward	From BA	To BA	Forward	Backward
Alberta	British Columbia	4.72	3.63	New Mexico	EPE	5.43	5.63
Alberta	NWE	4.72	3.63	New Mexico	WALC	5.43	3.64
AVA	British Columbia	4.07	3.63	NNV	California	6.04	3.88
AVA	BPA	4.07	3.26	NNV	LADWP	40	9.68
AVA	PACW	4.07	5.06	NNV	NVP	6.04	3.03
AVA	PGN	4.07	1.62	NWE	AVA	14.72	4.07
AZPS	California	9.62	3.88	NWE	BPA	14.72	3.26
AZPS	IID	2.12	4.13	NWE	PACE	14.72	5.06
AZPS	LADWP	9.62	9.68	NWE	WACM	12.22	7.27
AZPS	New Mexico	2.12	5.43	PACE	AZPS	12.56	3.62
AZPS	SRP	2.12	2.98	PACE	California	40	9.68
AZPS	TEP	2.12	4.88	PACE	IPC	5.06	3.86
AZPS	WALC	2.12	3.64	PACE	LADWP	40	9.68

# Hurdle Rates

From BA	To BA	Forward	Backward	From BA	To BA	Forward	Backward
BPA	BANC	8.94	5.99	PACE	NVP	12.56	2.03
BPA	British Columbia	3.26	3.63	PACE	NNV	5.06	6.04
BPA	California	11.44	7.29	PACE	WACM	10.06	7.27
BPA	LADWP	8.94	9.68	PACE	WALC	12.56	2.64
BPA	NNV	6.44	6.04	PACW	California	10.06	3.88
BPA	PACW	3.26	5.06	PACW	PGN	5.06	1.62
BPA	PGN	3.26	1.62	PSCO	New Mexico	9.22	5.43
BPA	PSE	3.26	0.96	PSCO	WALC	11.72	3.64
California	BANC	3.88	5.99	SRP	California	7.98	3.88
EPE	California	20.13	10.88	SRP	TEP	2.98	4.88
IID	California	4.13	3.88	SRP	WALC	2.98	3.64
IPC	AVA	11.36	4.07	TEP	EPE	4.88	5.63
IPC	BPA	11.36	3.26	TEP	New Mexico	2.38	5.43
IPC	NNV	11.36	6.04	WACM	New Mexico	14.77	5.43
IPC	PACW	11.36	5.06	WACM	PSCO	14.77	4.22
IPC	PGN	11.36	1.62	WACM	WALC	14.77	3.64
LADWP	California	9.68	3.88	WALC	California	8.64	3.88
NVP	California	8.03	3.88	WALC	IID	3.64	4.13
NVP	LADWP	8.03	9.68	WALC	LADWP	8.64	9.68
NVP	WALC	3.03	3.64	WALC	TEP	3.64	4.88

# Balancing Authority Areas

Alberta Electric System Operator (AESO)	Idaho Power Corp (IPC)
Avista (AVA)	(FAR EAST)
Arizona Public Service (AZPS)	Magic Valley (MAGIC)
Balancing Area of Northern California (BANC)	Treasure Valley (TREAS)
Sacramento Municipal Utility District	Los Angeles Department of Water and Power
(SMUD)	(LADWP)
Turlock Irrigation District (TID)	Nevada Power (NEVP)
Bonneville Power Administration (BPA)	Northern Nevada (Sierra Pacific Power (SPPC))
PUD No 1 of Chelan County (CHPD)	Northwest Energy (NWE)
PUD No 1 of Douglas County (DOPD)	Northwest Montana (NWMT)
PUD No 1 of Grant County (GCPD)	Western Area Upper Missouri (WAUM)
Seattle City Light (SCL)	Pacificorp East (PACE)
Tacoma Power (TPWR)	Pacificorp Idaho (PACE_ID)
British Columbia Transmission Corporation	Pacificorp Utah (PACE_UT)
(BCTC)	Pacificorp Wyoming (PACE_WY)
California Independent System Operator (CAISO)	Pacificorp West (PACW)
Pacific Gas & Electric (PG&E)	Portland General Electric (PGN)
Southern California Edison (SCE)	Public Service Company of Colorado (PSCO)
San Diego Gas & Electric (SDGE)	Public Service Company of New Mexico (PNM)
Comision Federal de Electricidad (CFE)	Puget Sound Energy (PSE)
El Paso Electric (EPE)	Salt River Project (SRP)
Imperial Irrigation District (IID)	Tucson Electric Power (TEP)
	Western Area Colorado Missouri (WACM)
	Western Area Lower Colorado (WALC)

# Contingency Reserve Sharing Areas

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- **Alberta Electric System Operator (AESO)**
- **Balancing Authority of Northern California (BANC includes SMUD and TID)**
- **British Columbia Transmission Corporation (BCTC)**
- **California (includes PG&E, CFE, SCE, and SDGE)**
- **Northwest (includes FAR EAST, MAGIC, PACE, SPPC, TREAS, AVA, BPA, CHPD, DOPD, GCPD, NWMT, PACW, PGN, PSE, SCL, TPWR, WAUM)**
- **Rockies (includes PSCO and WACM)**
- **Southwest (includes AZPS, EPE, NEVP, PNM, SRP, TEP, WALC, IDD, LADWP)**

# Generator Joint Ownership Modeling

- **3 plants, for which complete ownership information was provided, are modeled to represent the joint ownership.**
  - **BPA hydro power plant**
    - The owners of the BPA hydro power plants are already within the BPA balancing authority area, so no model changes were needed
  - **Hoover hydro power plant**
    - Owned by WALC, APS, SRP, NEVP, LDWP, CA
    - Since the Hoover plant is connected radially to the rest of the system, it was decided that individual units could be connected to the nearest bus of a joint owner through a fictitious DC line with minimal impact to surrounding power flows
    - Unit capacity is included in the owner's commitment and reserve requirement constraints
    - Power flows from Hoover hydro plant to the owners are not subject to the hurdle rates
  - **Colstrip thermal power plant**
    - Owned by NWMT, PSE, AVA, NWMT, PACE, PGN, PSE
    - Because of the interconnected transmission network around the Colstrip plant, no fictitious DC lines were used to connect these units to their owner's system. The potential impact of such fictitious lines on parallel power flows was deemed too high.
    - Unit capacity is included in the owner's commitment and reserve requirement constraints
    - Power flows are subject to the hurdle rates

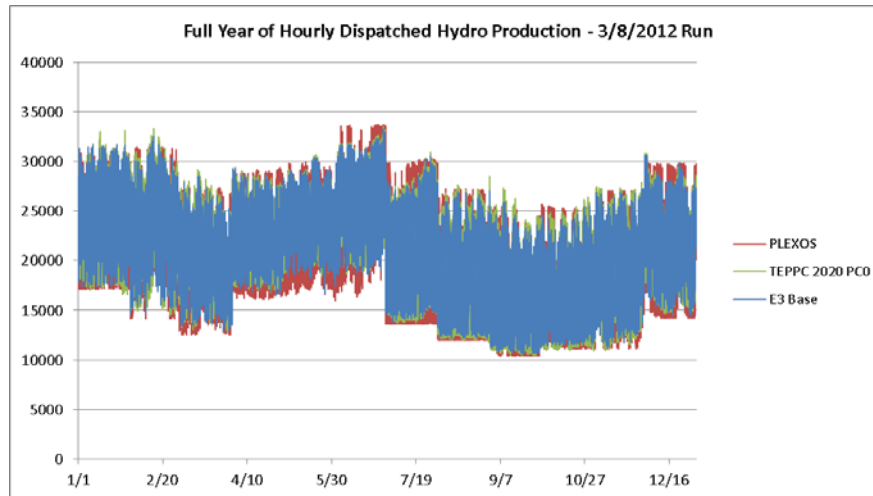
# Transmission Rights Modeling

- **Information on transmission rights for 4 major ties was provided and modeled**
  - PG&E has transmission rights to the California-Oregon Transmission Project (COTP). The COTP from Captain Jack (bus 43035 BPA) to Olinda (bus 30020 PG&E) was re-configured to Olinda west (bus 37565 SMUD).
  - CAISO has transmission rights to the Pacific Northwest DC tie. One of the BPA bi-pole DC-lines from Celilo (BPA) to Sylmar (LADWP) was re-configured to Sylmar SCE (bus 242417 SCE).
  - CAISO also has transmission rights to the Inter-mountain DC tie. The DC-line from Inter-mountain (bus 26114 LADWP) to Adelanto (bus 26003 LADWP) was split into two DC-lines. One DC-line has capacity 1526MW to Lugo (bus 24086 SCE).
  - After the above re-configurations, the power flows representing these transmission rights were not subject to the hurdle rate.
  - IID has transmission rights to the Southwest Power Link (SWPL). A fictitious DC-line is created with the capacity of 195 MW from SRP (bus 15090) to IID (bus 21025). The fictitious line is in the interface, AZPS-IID, which was subject to the hurdle rate.



# Hydro Models

- Good match to TEPPC hydro modeling



- Types of models

- Fixed profiles for run of river
- To emulate HTC (hydro thermal coordination), hourly or 10-minute hydro profiles were developed based on monthly energy requirements and unit minima and maxima. These profiles are input to the security constrained economic dispatch and may be modified in this step to respect chronological unit constraints (e.g., ramp rates), transmission constraints, or to respond to price signals.

# Allocation of EIM Benefits to Individual BAs

- **WECC/E3 developed the “Benefits Allocation Roadmap” to fairly allocate the savings (or costs) associated with the EIM**
- **Need to reflect 2 categories of cost/revenues for the total picture**
  - Changes in production costs
  - Changes in imports and exports
    - Higher production costs may be from an increase in generation and increased export which has accompanying revenue
    - Lower production costs may be from a decrease in generation and increased import which has accompanying cost
- **Requires post-processing of simulation results to determine adjusted production cost (APC)**
  - $APC = \text{Total variable production costs for the area} + \text{Imports priced at load-weighted LMP} - \text{Exports priced at generation-weighted LMP}$
  - Area APC is calculated for each interval in the year and then totaled
  - Area savings is the difference in APC between the BAU and EIM cases
- **Values are cost increase for EIM**
  - Negative production and purchase values are savings
  - Negative export revenues represent additional revenue

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# **EIM SAVINGS FROM HOURLY BAU**

# Benefit Allocation to Participants

	EIM Cost Change (PLEIM - PLHBAU) For EIM Participants (\$k)			Adjusted Production Cost Increase
	Production Cost	Purchase	Export	
APS	(29,035,929)	13,635,219	15,064,120	(336,589)
AVA	(4,524,021)	(40,947,578)	(116,194)	(45,587,793)
BCTC	(6,280,554)	5,307,300	28,239,600	27,266,346
BPA	(40,200,026)	9,195	353,487,522	313,296,691
CHPD	0	1,438,695	4,608,468	6,047,163
DOPD	0	1,205,994	2,762,376	3,968,370
EPE	(11,842,519)	2,770,229	1,371,744	(7,700,546)
GCPD	0	(2,526,936)	4,507,227	1,980,291
IID	(2,402,510)	(149,407)	9,264,417	6,712,501
IPC	2,200,780	(3,580,605)	3,153,125	1,773,300
LADWP	(22,500,569)	(67,258,016)	26,093	(89,732,492)
NEVP	(33,162,086)	9,798,922	16,563,740	(6,799,425)
NWE	23,295,244	(6,145,910)	(41,070,972)	(23,921,638)
PACE	97,300,047	(19,578,407)	(156,476,259)	(78,754,619)
PACW	(10,609,072)	(54,062,192)	(13,050)	(64,684,313)

# Benefit Allocation to Participants

EIM Cost Change (PLEIM - PLHBAU) For EIM Participants (\$k)				
	Production Cost	Purchase	Export	Adjusted Production Cost Increase
PGN	(11,178,927)	(64,431,447)	9,673	(75,600,701)
PNM	10,482,833	(794,967)	(17,480,684)	(7,792,817)
PSCO	(40,773,039)	(64,837,991)	(5,106,662)	(110,717,692)
PSE	10,331,984	(113,305,550)	(192,340)	(103,165,905)
SCL	0	(24,197,959)	165,138	(24,032,821)
SMUD	(28,560,456)	(12,455,812)	(73,710)	(41,089,978)
SPP	(9,909,609)	(13,539,048)	25,912	(23,422,745)
SRP	(51,346,971)	(4,131,806)	23,380	(55,455,397)
TEP	(12,345,308)	(6,823,760)	4,565,354	(14,603,714)
TID	(3,878,990)	(7,472,275)	8,365	(11,342,901)
TPWR	0	(8,710,208)	451,430	(8,258,778)
WACM	5,889,046	(2,799,571)	(3,894,152)	(804,676)
WALC	(10,204,491)	56,627	32,112,421	21,964,557
WAUM	0	(3,722)	(7,370,165)	(7,373,887)
EIM Participant Total	(179,255,141)	(483,530,984)	244,615,918	(418,170,207)

# Benefit Allocation to Non-Participants

	EIM Cost Change (PLEIM - PLHBAU) Effects Outside of the EIM(\$k)			Adjusted Production Cost Increase
	Production Cost	Purchase	Export	
AESO	9,695,098	12,472,652	724,518	22,892,268
CFE	(7,610,338)	5,157,481	2,160,925	(291,931)
PGE	(50,585,089)	(61,777,424)	11,691,622	(100,670,891)
SCE	(51,990,709)	(59,142,733)	6,559,199	(104,574,242)
SDGE	(17,632,459)	(12,429,441)	6,520,069	(23,541,831)
Non Participants Total	(118,123,497)	(115,719,465)	27,656,333	(206,186,628)
EIM Participant Total (from prev. slide)	(179,255,141)	(483,530,984)	244,615,918	(418,170,207)
Total	(297,378,638)	(599,250,449)	272,272,251	(624,356,835)

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# **EIM SAVINGS FROM 10-MINUTE BAU**

# Benefit Allocation to Participants

EIM Cost Change (Full EIM with 10-Minute BAU) For EIM Participants (\$k)				
	Production Cost	Purchase	Export	Adjusted Production Cost Increase
APS	(10,383,001)	(5,666,291)	(1,282,292)	(17,331,585)
AVA	(1,753,016)	(27,377,467)	(151,332)	(29,281,815)
BCTC	(2,936,933)	7,494,735	(8,601,920)	(4,044,119)
BPA	(31,549,559)	(15,216)	205,936,285	174,371,510
CHPD	0	146,056	3,201,848	3,347,904
DOPD	0	447,638	1,950,691	2,398,329
EPE	(11,551,901)	4,848,097	720,743	(5,983,061)
GCPD	0	(1,130,217)	2,452,436	1,322,219
IID	(374,795)	(223,477)	1,923,531	1,325,259
IPC	5,719,791	(2,105,759)	(7,236,315)	(3,622,283)
LADWP	(15,245,976)	(37,955,537)	(657)	(53,202,171)
NEVP	(7,654,056)	(9,834,238)	(6,562,327)	(24,050,621)
NWE	19,202,580	(3,843,802)	(42,171,048)	(26,812,270)
PACE	59,448,032	(8,945,839)	(144,638,479)	(94,136,285)
PACW	(4,092,419)	(31,268,185)	(4,683)	(35,365,287)



# Benefit Allocation to Participants

	Production Cost	Purchase	Export	Adjusted Production Cost Increase
PGN	(10,011,595)	(41,935,025)	19,084	(51,927,535)
PNM	7,249,904	(3,024,359)	(16,446,455)	(12,220,910)
PSCO	(37,765,802)	(43,482,965)	(2,645,455)	(83,894,222)
PSE	9,082,344	(81,449,733)	(256,683)	(72,624,072)
SCL	0	(11,810,593)	(87,856)	(11,898,449)
SMUD	(16,481,796)	(5,765,537)	113,824	(22,133,509)
SPP	(6,718,571)	(8,252,194)	7,072	(14,963,693)
SRP	(32,465,490)	(10,388,538)	18,644	(42,835,383)
TEP	11,804	(7,906,469)	(10,180,274)	(18,074,939)
TID	(3,464,245)	(2,001,298)	22,986	(5,442,557)
TPWR	0	(4,121,675)	143,235	(3,978,440)
WACM	17,501,188	(9,521,405)	(13,417,971)	(5,438,188)
WALC	3,497,863	3,188	(3,407,237)	93,814
WAUM	0	(1,819)	(10,571,325)	(10,573,144)
EIM Participant				
Total	(70,735,649)	(345,087,923)	(51,151,931)	(466,975,503)

# Benefit Allocation to Non-Participants

EIM Cost Change (Full EIM with 10-Minute BAU) Effects Outside of the EIM(\$k)				
	Production Cost	Purchase	Export	Adjusted Production Cost Increase
AESO	25,631,576	(41,597,226)	(238,647)	(16,204,297)
CFE	(7,961,372)	9,009,720	2,749,160	3,797,509
PGE	(30,056,156)	(52,855,619)	4,800,094	(78,111,681)
SCE	(39,219,820)	(19,123,411)	2,085,340	(56,257,891)
SDGE	(23,701,855)	(2,886,429)	5,499,206	(21,089,078)
Non Participants Total	(75,307,626)	(107,452,965)	14,895,154	(167,865,438)
EIM Participant Total (from prev. slide)	(70,735,649)	(345,087,923)	(51,151,931)	(466,975,503)
<b>Total</b>	<b>(146,043,275)</b>	<b>(452,540,888)</b>	<b>(36,256,778)</b>	<b>(634,840,941)</b>