PSE PUGET SOUND ENERGY

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Benefits Analysis of Puget Sound Energy's Participation in the ISO Energy Imbalance Market

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Energy+Environmental Economics

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Acronyms

BA	Balancing Authority
BAA	Balancing Authority Area
CAISO	California Independent System Operator
DA	Day-ahead
EIM	Energy Imbalance Market
FERC	Federal Energy Regulatory Commission
HA	Hour-ahead
NPV	Net Present Value
NVE	NV Energy
PAC	PacifiCorp
PSE	Puget Sound Energy

Executive Summary

This report examines the benefits of Puget Sound Energy's (PSE) participating in the energy imbalance market (EIM) operated by the California Independent System Operator (ISO). The ISO's EIM is a regional 15- and 5-minute balancing energy market, including real-time unit commitment capability, which will go live with binding settlements in November 2014 between the ISO and PacifiCorp, with NV Energy planning to participate starting in October 2015. In this study, the ISO, PacifiCorp, and NV Energy are referred to as "current EIM participants", and they are assumed to be already participating in the EIM before PSE's participation would commence, which is assumed to be in 2016.[1]

This report estimates the benefits of PSE's participation in the EIM for two scenarios with alternative sub-hourly transmission transfer capability levels between PSE and current EIM participants.[2] For the 2020 study year, participation in the EIM is estimated to bring sub-hourly dispatch efficiency and flexibility reserves savings to PSE in the range of $18.3 to $20.1 million per year.

Since an EIM increases operational efficiency and flexibility, it also could facilitate cost effective renewable integration. If feasible, this could allow PSE to save an

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[1] Throughout this report, Balancing Authorities (BAs) that participate in the EIM are described as "EIM participants". These participating BAs are referred to in the ISO's EIM Business Practice Manual and tariff as "EIM Entities". See CAISO (2014b).

[2] All benefits are reported in 2014 dollars.

additional $9.1 million per year in wind integration costs. PSE also anticipates that, under certain conditions, EIM participation could help PSE obtain additional cost savings of up to $0.8 million per year related to avoiding curtailment of renewable energy resources if PSE were to balance all of its wind resources within its Balancing Authority Area (BAA).[3]

For the 2020 study year, PSE's participation is also expected to provide benefits of $3.5 to $4.2 million per year for the current EIM participants, and create no incremental implementation costs to those entities. All incremental costs are expected to be recovered from PSE through fixed and administrative charges.

PSE has evaluated the costs and benefits reported in this study and concluded that its participation in the EIM is likely to provide a low-risk means of achieving operational net benefits for PSE and current EIM participants. PSE staff has estimated that PSE would incur one-time EIM startup costs of $14.2 million including contingency costs, and ongoing costs of approximately $3.5 million per year. These startup costs, taken together with a 20-year series of ongoing costs and annual benefits consistent with the level identified in this report, would produce a Net Present Value (NPV) of $153.7 million to $174.4 million.[4] These results also provide further confirmation that total expected EIM benefits can

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[3] A Balancing Authority Area (BAA) is the collection of generation, transmission, and loads within the metered boundaries of a BA, which is responsible entity that maintains load-resource balance within this area, integrates resource plans ahead of time, and supports Western Interconnection frequency in real-time. See NERC (2014).

[4] NPV has been estimated for the year 2014. The calculation assumes 20 years of sub-hourly dispatch and flexibility reserves benefits and annual ongoing cost from 2016 through 2035. PSE's participation in the EIM is estimated to go live in Fall 2016 with benefits and ongoing costs assumed to begin then. Startup costs are assumed to be incurred during 2015 and 2016. All values have been discounted using PSE after-tax weighted average cost of capital (WACC) of 6.7% nominal, consistent with PSE's 2013 Integrated Resource Plan (IRP), and have assumed annual inflation rate of 2%. Increasing the NPV calculation to include 30 years of benefits and ongoing costs would raise the NPV range to $190.2 to $216.3 million.

increase as additional participants join the EIM and broaden the regional diversity and footprint of the real-time market.

Two additional material benefits have not been quantified. First, the study team conservatively assumed that PSE’s behavior and actions in the hour-ahead (HA) and day-ahead (DA) market would not be influenced by the continuous information flowing from participation in the EIM market; we expect that such information could create learning and additional cost savings for PSE in the HA and DA market over time, but those additional savings are not quantified in the analysis for this report. Second, the study team did not quantify the potential reliability benefits tied to the increased situational awareness and resource control that the EIM creates. Although both of these benefits are difficult to quantify, they are important to consider qualitatively as they are likely to produce substantial benefits.

EIM Background

Changes in the electricity industry in the Western U.S. are making the need for greater coordination between Balancing Authorities (BAs) increasingly apparent. Recent studies have suggested that it will be possible to reliably operate the current Western electric grid both with greater efficiency and higher levels of variable renewable generation. Doing so will require improving and supplementing the bilateral markets used in the Western states with mechanisms that allow shorter time intervals for scheduling and more optimized coordination. The EIM provides such a mechanism.

The EIM is a balancing energy market that optimizes generator dispatch within and between participating BAAs every 15 and 5 minutes. The EIM does not replace the DA or HA markets and scheduling procedures that exist in the Western Interconnection today.

By allowing BAs to pool load and generation resources, the EIM lowers total flexibility reserve requirements and minimizes curtailment of variable energy resources for the region as a whole, thus lowering costs for customers. The EIM is complementary to Federal Energy Regulatory Commission (FERC) Order 764, which emphasizes 15-minute scheduling over interties. The EIM builds value on top of this 15-minute scheduling capability by: (1) using software tools to identify sub-hourly transactions that produce an optimized dispatch and minimize production costs, while respecting reliability limits (known as “Security Constrained Economic Dispatch”, or “SCED”); (2) bringing this optimized dispatch down to a 5-minute interval level; (3) incorporating optimized real-time unit commitment of quick-start generation; and (4) enabling better use and compensation of flexible ramping capacity in real-time, which reflects the diversity of loads and resources across the EIM footprint, allowing EIM participants to individually reserve a smaller amount of committed capacity for sub-hourly flexibility, further reducing total operational costs to reliably serve customers.

In advance of the November 2014 go-live date for EIM operations with binding settlements, the ISO and PacifiCorp have worked with stakeholders to finalize details of the EIM’s structure and functions, and have received FERC approval for tariff changes that enable EIM implementation.[5] Throughout the EIM stakeholder process, the ISO has emphasized that the EIM is being designed to

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[5] For the latest details of the ISO EIM, see CAISO (2014c).

enable other BAs throughout the Western Interconnection to participate. The ISO has established an EIM Governance Transitional Committee, whose members includes stakeholders from throughout the Western Interconnection, to further lead EIM development in a manner that is beneficial for many participants in the region, and to provide participants confidence that their perspectives are reflected in this process.

This Report

PSE and the ISO worked together to jointly assess the potential benefits of PSE's participation in the EIM and retained Energy and Environmental Economics, Inc. (E3), a consulting firm, to conduct an economic study quantifying those potential benefits. To support the study, Energy Exemplar provided technical support by running sub-hourly production simulations cases using PLEXOS, a production simulation modeling tool, to calculate a portion of the benefits. This report describes the findings of E3 and Energy Exemplar, who are together referred to as "the study team" throughout the report.

The report evaluates benefits using an approach that builds upon E3's EIM analyses for the ISO, PacifiCorp, and NV Energy.[6] In addition, the study leverages the modeling improvements summarized in Pacific Northwest National Laboratory's (PNNL) Phase 1 EIM analysis for the Northwest Power Pool (NWPP).[7] This study focuses on the incremental benefits related to PSE's participation in the EIM, while assuming that the ISO, PacifiCorp and NV Energy are already EIM participants in the base case. This study incorporates additional details provided

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[6] See E3 (2013 and 2014).
[7] See Samaan et al. (2013).

by PSE to improve the accuracy of PSE's generation and transmission system represented in the production cost simulations.

The primary scenarios in this report assess different categories of potential cost savings from expanding the EIM to include PSE, allowing PSE and the current EIM participants to further improve dispatch efficiency and take advantage of additional diversity in loads and generation resources provided by PSE. Specifically, the participation of PSE in the EIM would yield two principal benefits:

- *Sub-hourly dispatch benefits*, by realizing the efficiency of optimized combined 15- and 5-minute dispatch and real-time unit commitment across PSE and the current EIM footprint, compared to bilateral transactions typically done on an hourly basis under business-as-usual (BAU) practice for PSE; and
- *Reduced flexibility reserves*, by reflecting the diversity of load, wind and solar variability and uncertainty across PSE and the footprint of current EIM participants.

In addition, if PSE were to integrate its remote wind resources to within its BAA, the EIM could help PSE realize savings from *reduced wind curtailment*, by allowing PSE to export or reduce imports of renewable generation when they would otherwise need to curtail their own resources, as well as *additional renewable balancing cost savings* related to incremental flexibility reserves required for PSE to balance external wind plants itself.[8]

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[8] The PacifiCorp-ISO EIM and NV Energy-ISO EIM analyses modeled a wide range of potential avoided curtailment in the ISO as a result of the EIM. This report assumes that PSE's incremental participation in the EIM would not

E3's PacifiCorp-ISO EIM study included a separate benefit category, intraregional dispatch savings, which arises from PacifiCorp generators being able to be dispatched more efficiently through the ISO's automated nodal dispatch software, reducing transmission congestion within the PacifiCorp BAAs. Based on PSE's experience that there is little internal congestion within the PSE transmission system, the study team assumed this benefit would be small and therefore did not include it in this analysis.

In addition to the quantifiable benefits described above, the EIM is expected to provide additional reliability benefits that are not quantified in this report. A recent FERC staff report identified additional reliability benefits that may arise from an EIM.[9] These include enhanced situational awareness, faster delivery of replacement generation after the end of contingency reserve sharing assistance, and enhanced integration of renewable resources.

Benefit Methodology and Scenarios

The study team estimated the benefits of PSE's participation in the EIM using the PLEXOS production cost modeling software to simulate operations in the Western Interconnection for the calendar year 2020 with and without PSE as an EIM participant. The PLEXOS software and 2020 database developed by PNNL for the NWPP Phase 1 EIM study was selected to leverage the improved characterization of transmission and generation in the Northwest, and to improve the comparability of results from PSE's perspective.

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provide incremental avoided curtailment savings for the ISO, PacifiCorp and NV Energy beyond that enabled through the current EIM; thus, curtailment savings included in this study are strictly related to wind plants owned by PSE.

[9] See FERC (2013).

Like the NWPP Phase 1 EIM study performed by PNNL, this analysis used a three-stage simulation process, including DA, HA, and real-time simulations to mirror actual power system operations. The DA and HA stages are simulated on an hourly basis. The real-time stage is simulated with a 10-minute time-step and incorporates the variability and uncertainty associated with load, wind, and solar. The study team's analysis also incorporates California's greenhouse gas regulations and the associated dispatch costs.

The study team modeled flexibility reserve benefits by analyzing coincident sub-hourly load, wind, and solar generation for each of the EIM members. Within the model, BAs not participating in the EIM are required to maintain flexibility reserves to meet 95% of the upward and downward deviations of their own BAA's 10-minute real-time net load compared to their HA forecast. On the other hand, EIM participants are allowed to collectively meet a joint flexibility reserve requirement. By pooling load, wind and solar variability across a wider geographic area, EIM participants can lower the total variability and forecast error of their net load. As a result of this net load diversity, EIM participants can reduce the amount of flexibility reserves they require compared to the sum of flexibility reserves that they would require as individual non-participants. PSE's participation in the EIM is expected to enable an incremental reduction in flexibility reserve requirements for the current EIM participants, as well as to reduce PSE's own flexibility reserve requirement. The study team valued this reduction in flexibility reserve requirements using historical flexible ramping constraint shadow prices for the ISO from 2013.

The estimated benefits are sensitive to several key assumptions regarding the expected level of real-time transfer capability available for the EIM between PSE and the current EIM participants, as well as the real-time transfer capability over COI that connects the ISO and PacifiCorp. Table 1 below summarizes the real-time transfer capability for the BAU case, in which PSE does not participate in the EIM, and two scenarios that include PSE's participation in the EIM, with different levels of real-time transfer capability between BAs participating in the EIM. These two EIM scenarios produce different levels of sub-hourly dispatch benefits relative to the BAU case.

Table 1. Overview of Scenario Assumptions

Case Name	**Real-time Transfer Capability**		
	PAC-PSE	**CAISO-PAC**	**CAISO-NVE**
BAU	NONE	400	1500
<u>PSE EIM Scenarios:</u>			
Low Transfer	300	400	1500
High Transfer	900	700	1500

Notes: Real-time transfer capability represents the maximum amount (in MW) which a BA's net transfer over a path is allowed to differ in real-time, relative to its HA schedule. PAC-PSE transfer capability utilizes a combination of PSE, PacifiCorp, and BPA transmission.

<u>Benefit Results</u>

Across the two PSE EIM participation scenarios, the study team estimates that PSE's participation in the EIM would produce annual savings to PSE ranging from $18.3 to $20.1 million in 2020. Table 2 shows the range of sub-hourly dispatch and flexibility reserve benefits for each scenario; all benefits shown represent cost savings relative to the BAU scenario.

Table 2. Annual Benefits to PSE by Scenario (2014$ million)

PSE EIM Scenario	Sub-hourly Dispatch	Flexibility Reserves	Total Benefits
Low Transfer	$16.7	$1.6	**$18.3**
High Transfer	$18.5	$1.6	**$20.1**

In addition to the savings shown in Table 2, participation in the EIM may enable PSE to obtain up to $9.1 million per year in incremental balancing cost savings, as well as up to $0.8 million per year in avoided curtailment costs if PSE were to balance all of its wind resources within its BAA.

The study team also estimated the benefits that accrue to the current EIM participants as a result of PSE's participation, as shown in Table 3.

Table 3. Annual Benefits to Current EIM Participants by Scenario (2014$ million)

PSE EIM Scenario	Sub-hourly Dispatch	Flexibility Reserves	Total Benefits
Low Transfer	$0.6	$2.9	**$3.5**
High Transfer	$1.2	$2.9	**$4.2**

PSE's participation provides the opportunity for current EIM participants to realize incremental dispatch cost savings of $0.6 million to $1.2 million, depending on the transmission transfer capability level assumed. PSE's participation in the EIM would also create incremental load, wind, and solar diversity for the EIM, further reducing flexibility reserve requirements for the current EIM participants. This study also estimates that the incremental diversity from PSE's participation would bring $2.9 million in flexibility reserve savings to the current EIM participants. Flexibility reserve savings are the same across both EIM scenarios, because the range of EIM transfer capability levels assumed does not constrain potential flexibility reserve requirement reductions.

Across all scenarios, the incremental sub-hourly dispatch and flexibility reserve benefits for all EIM participants, including PSE, range from \$21.8 to \$24.3 million per year as a result of PSE's participation in the EIM.

1 Introduction

Puget Sound Energy (PSE) and the California Independent System Operator (ISO) retained Energy and Environmental Economics, Inc. (E3) to estimate the economic benefits of PSE's participation in the energy imbalance market (EIM) operated by the ISO. This report details our approach to identify and quantify the benefits of PSE's participation in the EIM, and presents the results of our analysis. Throughout the study process, the study team of E3 and Energy Exemplar worked closely with PSE and the ISO to refine scenario assumptions and data inputs, and to estimate benefits consistent with how each entity operates today, as well as with their expectation of future operations.

1.1 Background and Objectives

Changes in the electric industry in the Western Interconnection are making the need for greater coordination among Balancing Authorities (BAs) increasingly apparent. In particular, increasing penetrations of variable energy resources is driving interest in options to cost-effectively integrate those resources. One option to improve coordination is an EIM, which has been successful in other regions, such as the Southwest Power Pool (SPP). An EIM optimizes generator dispatch to resolve energy imbalances across multiple Balancing Authority Areas (BAAs), and can capture the value of geographic diversity of load and generation resources.

Several recent studies have examined the potential benefits of an EIM in the Western Interconnection. In 2011, E3 and the Western Electricity Coordination Council (WECC) examined the benefits of an EIM throughout the Western Interconnection, excluding the ISO and Alberta Electric System Operator (AESO).[10] In 2013, the National Renewable Energy Laboratory (NREL), on behalf of the Public Utility Commissions Energy Imbalance Market (PUC EIM) Group, extended the E3-WECC analysis by using a sub-hourly production simulation model.[11] In 2013, the Northwest Power Pool (NWPP) Market Assessment Committee (MC) Initiative examined the benefits of an EIM across the NWPP footprint through a study led by Pacific Northwest National Laboratory (PNNL), and the NWPP is continuing to evaluate opportunities for better regional coordination.[12] Each of these studies identified positive dispatch cost savings attributable to implementation of an EIM.

Starting in 2012, the ISO and PacifiCorp began actively developing a regional EIM in the Western Interconnection. The proposed EIM has received Federal Energy Regulatory Commission (FERC) approval for tariff changes in June 2014. The EIM is expected to go live with binding settlements in November 2014 with the ISO, PacifiCorp East, and PacifiCorp West BAs as the initial participants. In 2014, NV Energy obtained approval by FERC and the Public Utilities Commission of Nevada (PUCN) to begin participating in the EIM in Fall 2015.[13]

PSE has been actively exploring potential benefits of all regional coordination options, including participation in the NWPP MC Initiative. PSE and the ISO also

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[10] See E3 (2011).
[11] See Milligan et al. (2013)
[12] See Samaan et al. (2013)
[13] See CAISO (2014f) and PUCN (2014).

engaged E3 to assess the impact of PSE's participation in the EIM. This report summarizes the findings of our analysis, with a focus on sub-hourly dispatch benefits and savings from reductions in flexibility reserve requirements. In addition to those benefits, this report also summarizes the potential cost-savings to PSE if the EIM can enable PSE to balance its own wind plants that are currently balanced in real-time by other BAs.

1.2 Structure of the Report

The remainder of this report is organized as follows:

- **Section 2** describes the methodologies and assumptions used to estimate the benefits of PSE's participation in the EIM;
- **Section 3** presents the main results of the study;
- **Section 4** summarizes the additional potential savings if the EIM enables PSE to balance its wind resources that are currently balanced outside its BAA; and
- **Section 5** provides the conclusions of the study.

2 Study Assumptions and Approach

2.1 Overview of Approach

The EIM allows Western BAs to voluntarily participate in the ISO's real-time energy market. EIM software will automatically dispatch generation across participating BAAs every 5 minutes to solve imbalances using security constrained economic dispatch (SCED), as well as commit quick-start generation every 15 minutes using security constrained unit commitment (SCUC). Each BA participating in the EIM is still responsible for meeting its own operating reserve and planning reserve requirements, and the EIM does not replace participating BAs' existing operational practices in advance of real-time.

PSE's participation in the EIM is expected to result in two principal benefits resulting from changes in system operations for PSE and the current EIM participants:

1. **Sub-hourly dispatch benefits**. Today, each BA outside of the EIM dispatches its own generating resources to meet imbalances within the hour, while holding schedules with neighboring BAs constant. The EIM nets energy imbalance across participating BAs, and economically dispatches generating resources across the entire EIM footprint to

manage the imbalance, resulting in operational cost savings. PSE's participation in the EIM enables incremental dispatch efficiency improvements relative to the current EIM.

2. **Flexibility reserve reductions**. BAs hold flexibility reserves to balance discrepancies between forecasted and actual net load within the hour. *Load following flexibility reserves* (referred to in this report as simply "*flexibility reserves*") provide ramping capability to meet changes in net load between a 5-minute and hourly timescale.[14] By pooling load, wind, and solar output across the EIM footprint, the EIM allows participants to benefit from greater geographic diversity of forecast error and variability by reducing the quantity of flexibility reserves they require. PSE's participation in the EIM would bring added load and resource diversity to the current EIM footprint, resulting in additional reserve savings.

In addition, if PSE were to integrate its remote wind resources to within its BAA, then the EIM could help PSE realize wind curtailment savings and additional renewable integration cost savings. Participation in the EIM could help PSE reduce or eliminate reliability curtailments of its wind resources by using the EIM to export energy that PSE would otherwise need to curtail, or through reducing energy import in real-time compared to PSE's HA schedule. Through the EIM, PSE would also reduce incremental flexibility reserves required to

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[14] Regulating reserves, which address the need for resources to respond to changes on a sub-5 minute interval basis, are sometimes categorized in operational studies as a second type of flexibility reserve product. Since the EIM operates with 5-minute intervals, it is does not directly affect regulating reserve requirements. To be concise, all references to *flexibility reserve* in this report are related to load following reserves; *regulating reserves*, where referenced, are explicitly described by name.

balance external wind plants itself. These savings are addressed separately in Chapter 4 of this report.

Our general approach to estimating the benefits of PSE's participation in the EIM is to compare the total cost under two cases: (1) a "business-as-usual" (BAU) case in which PSE is not an EIM participant, and the operational efficiencies of the "current EIM" (including the ISO, PacifiCorp, and NV Energy) is already reflected; and (2) a "PSE EIM" case in which the PSE BA also participates in the EIM. The cost difference between the BAU and PSE EIM cases represents the incremental benefits of PSE's participating in the EIM.

Sub-hourly dispatch benefits are estimated over a range of real-time transmission transfer capabilities using production simulation modeling. The difference in WECC-wide production costs between the PSE EIM simulations and the BAU simulation represents the societal benefit of PSE's participation. To estimate cost savings from reduced flexibility reserve requirements, the study team used statistical analysis to determine the quantity of incremental flexibility reserve diversity that PSE's participation would bring to the EIM, and then applied that quantity to historical flexible ramping constraint shadow prices from the ISO to calculate operational cost savings.

2.2 Key Assumptions

Five key modeling assumptions are important for understanding the results of this study: (1) sub-hourly dispatch; (2) real-time transmission capability; (3) hurdle rates; (4) flexibility reserves; and (5) hydropower modeling.

2.2.1 SUB-HOURLY DISPATCH

In existing operational practice, BAs in the Western Interconnection exchange energy primarily on an hourly basis using hourly or multi-hour schedules, which require long lead times between scheduling the transaction and actual dispatch.[15] Within the hour, each BA resolves imbalances by manually dispatching generating resources inside its BAA, without the assistance of other BAs. By contrast, the EIM optimizes dispatch of available generating resources in real-time across all of the participating BAAs using 15-minute unit commitment and 5-minute dispatch. These sub-hourly processes increase the efficiency of resolving imbalances.

The study team quantifies the benefit of sub-hourly dispatch capability using a three-stage simulation process in PLEXOS consistent with the approach developed for the WECC Variable Generation Subcommittee (VGS) and refined in PNNL’s Phase 1 Report for the NWPP MC Initiative. This methodology is described in detail in the PNNL report, as well as Section 2.3 below.

A PLEXOS simulation was run with hourly intervals in a DA stage, and then in an HA stage, using DA and HA forecasts of expected load, wind, and solar output. In the final stage, a real-time PLEXOS simulation is run with 10-minute intervals, using actual wind, load, and solar output for each interval. During the real-time simulation, BAs not participating in the EIM must maintain a net exchange with neighboring BAs that is equal to the HA exchange level. EIM participants, on the other hand, can re-dispatch generation and exchange power with the rest of the

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[15] The ISO and AESO are the exceptions.

EIM footprint during each of the 10-minute intervals, subject to transmission transfer limitations, which are discussed in Section 2.2.2 below.[16]

In E3's analyses assessing the benefits of PacifiCorp and NV Energy participating in the ISO EIM, GridView, an hourly production cost model, was used with input data largely based on TEPPC's 2022 Common Case. The 10-minute time-step capability of PLEXOS allows us to better represent the EIM's 5-minute dispatch interval relative to GridView's hourly time-step capability.[17]

2.2.2 REAL-TIME TRANSMISSION TRANSFER CAPABILITY

Previous studies have indicated that transmission can constrain EIM benefits by limiting the amount of power that can be transferred in real-time between EIM participants. For this sub-hourly modeling analysis, the study team specified the maximum amount, in both the positive and negative direction, by which a BA's net transfer over a path is allowed to differ in real-time, relative to the HA scheduled transfer.[18] For example, if the HA scheduled transfer between two BAAs is 1,000 MW and there is 500 MW of real-time transfer capability modeled, then the real-time transfer over that path may range from 500 to 1,500 MW throughout the hour.

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[16] While the EIM will operate down to a 5-minute level, the most validated sub-hourly WECC dataset available for this analysis includes 10-minute intervals. Using the 10-minute intervals is a practical but conservative compromise of modeling 15-minute optimization with higher EIM transfer capability and modeling 5-minute optimization with potentially more limited EIM transfer capability across paths limited by dynamic transfer limitations across COI and BPA network.

[17] The WECC GridView database is currently developing a sub-hourly modeling capability, but this functionality and the sub-hourly data required were not available at the time of this analysis.

[18] In certain studies in the Northwest, real-time transmission transfer capability has also been termed as "Transfer Variability Limit" or "TVL". See, for example, Columbia Grid (2011).

For the BAU case, the study team adopted real-time transmission transfer capability assumptions from earlier EIM benefit analyses. The study team modeled 400 MW of capability between PacifiCorp and the ISO, and 1,500 MW of capability between the ISO and NV Energy.[19] For the PSE EIM simulation, the study team modeled two scenarios where the real-time transfer capability between PSE and PacifiCorp ranged from 300 to 900 MW, and the capability between PacifiCorp and the ISO ranged from 400 to 700 MW. Figure 1 below characterizes the range of real-time transfer capabilities used in this analysis.

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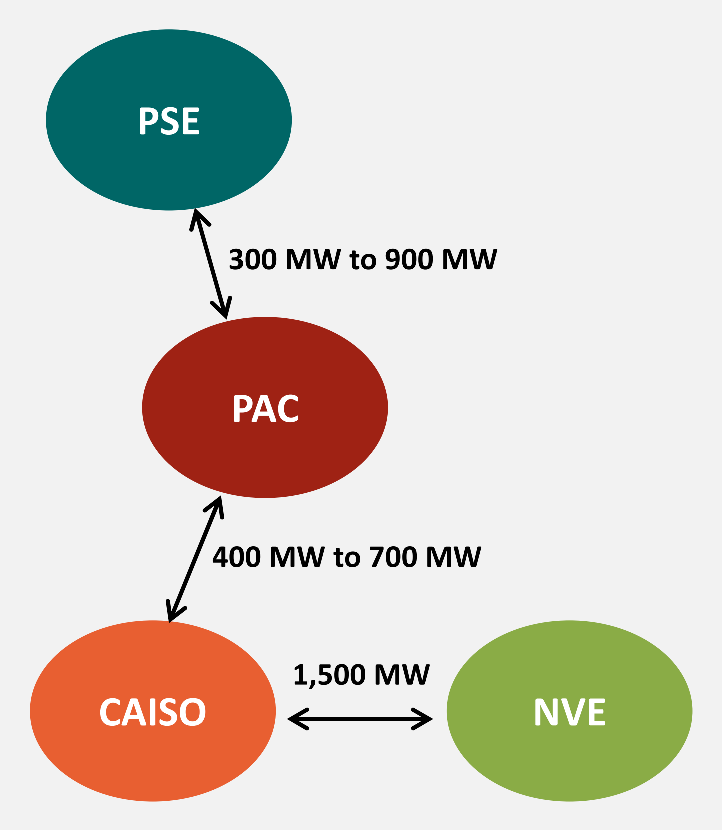
[19] These values are informed by capacity rights owned or controlled by the current EIM participants. Total maximum and minimum flow levels between zones in the model (including HA flow plus incremental changes in real-time) are also subject to physical transmission constraints on rated paths. The flexibility of real-time transfer capability over COI is the subject of an ongoing study by Columbia Grid. The flexibility between ISO and NV Energy is assumed to include transactions over direct interties between the two BAAs, as well as over co-owned transmission facilities. NV Energy and ISO each co-own transmission rights with the Western Area Power Authority (WAPA) to the Mead substation, and NV Energy and the Los Angeles Department of Water and Power (LADWP) co-own transmission rights over the 500 kV lines connecting the Crystal and McCullough Substations. This study conservatively assumed that interties between NV Energy and the PacifiCorp East system will not be utilized for the EIM.

Figure 1. Real-time Transfer Capabilities across the EIM Footprint



2.2.3 HURDLE RATES

Within the Western Interconnection’s bilateral markets, there are a number of impediments to efficient trade of energy across BAA boundaries. These include:

- The need, in many cases, for market participants to pay for the fixed costs of the existing transmission system by redirecting or acquiring additional point-to-point transmission service in order to schedule transactions from one BAA to another;

- The current tariff practice of requiring short-term transactions to provide real power losses for each transmission provider system that is utilized, resulting, in some cases, in multiple or "pancaked" loss requirements that are added to the fixed costs described above; and
- Inefficiencies related to having illiquid bulk power and transmission service markets and imperfect information, such as the standard 16-hour "Heavy-Load Hour" and 8-hour "Light-Load Hour" DA trading products defined by the Western Systems Power Pool, minimum transaction quantities of 25 MW, and the bilateral nature of transaction origination and clearing.

These real-world barriers to trade are reflected in production cost simulations as "hurdle rates", $/MWh price adders applied to interfaces between BAAs. Hurdle rates inhibit power flow over transmission paths that cross BAA boundaries, and reduce economic energy exchange between BAAs.

An EIM eliminates the barriers listed above during real-time operations by performing security-constrained economic dispatch across the entire EIM footprint, allowing more efficient (i.e., lower cost) dispatch. Our production simulations in PLEXOS capture this effect by removing hurdle rates between EIM participants during the real-time simulations, while maintaining hurdle rates between non-participants.[20] In the DA and HA simulations, hurdle rates are

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[20] Market participants must also acquire CO2 allowances to deliver "unspecified" energy to California BAAs (i.e., the ISO, LADWP, BANC and IID), as required by California's greenhouse gas cap-and-trade program developed in compliance with AB32. In all production simulation cases modeled, a component of the hurdle rates is used in the model to reflect the need to acquire these allowances when delivering electricity from neighboring states into California.

maintained between all BAAs, including between EIM participants.[21] The study team believes this is a conservative assumption regarding the expected adaptation of DA and HA markets based on information identified by the EIM. In reality, we would expect that BAs would adjust their DA and HA scheduled transactions more efficiently over time based on learning the dynamics of the real-time market results. This learning does not imply a shift away from DA and HA scheduling, but rather a more efficient and better informed selection of scheduling levels for any hour based on learning from real-time market participation. To the extent it is realized, this learning and improved DA and HA efficiency is a non-quantified benefit that would be additional to those quantified in this report.

The removal of hurdles rates in our analysis mirrors proposed changes under the EIM. This modeling is consistent with the FERC-approved ISO tariff amendment associated with the EIM. This modeling approach is also consistent with previous analyses performed to assess the benefits of PacifiCorp and NV Energy participating in the ISO EIM.

2.2.4 FLEXIBILITY RESERVES

BAs hold excess capacity as reserves to balance discrepancies between forecasted and actual net load within the operating hour; these within-hour reserves are in addition to the spinning and supplemental reserves carried against generation or transmission system contingencies.[22] Regulating reserves

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[21] This approach—to maintain hurdle rates for the DA and HA simulation and remove them in the real-time simulation run—is consistent with the methodology used by PNNL in the NWPP's MC Phase I EIM Benefit study.

[22] This study assumes that contingency reserves would be unaffected by an EIM, and that PSE would continue to participate in its existing regional reserve sharing agreement for contingency reserves.

automatically respond to control signals or changes in system frequency on a time scale of a few cycles up to 5 minutes. Load following reserves (referred to in this report simply as “flexibility reserves”) provide ramping capability to meet changes in net load between a 5-minute and hourly timescale.

Higher penetrations of wind and solar increase the quantity of both regulating and flexibility reserves needed to accommodate the uncertainty and variability inherent in these resources, while maintaining acceptable BA control performance. By pooling load and resource variability across space and time, total variability can be reduced, decreasing the amount of flexibility reserves required to ensure reliable operations. This reduces operating costs by requiring fewer thermal generators to be committed and operated at less efficient set points.

For this study, the study team used statistical analysis to estimate the reduction in flexibility reserves that would occur if PSE participates in the EIM. Flexibility reserve requirements for each BA are a function of the difference between the actual 10-minute net load in real-time versus the HA net load schedule. As a result of geographic diversity, the combined net load profiles for participating BAs have less variability and forecast error than the individual profiles of each BA, resulting in lower flexibility reserve requirements under the EIM.

Units that provide regulating reserves must respond faster than the EIM’s 5-minute dispatch interval, so EIM participants are assumed here to receive no regulating reserve diversity savings as a result of participating in the EIM.

There are two implicit assumptions embedded in this approach: (1) that PSE and the current EIM participants would carry the calculated levels of flexibility reserves; and (2) that the EIM includes a mechanism to take advantage of increased net load diversity by reducing the quantities of flexibility reserves that would need to be carried.

With regard to the first assumption, while there is currently no defined requirement for BAs to carry flexibility reserves, all BAs must carry a level of operating reserves in order to maintain Control Performance Standards (CPS) within acceptable limits, and reserve requirements will grow under higher renewable penetration scenarios. In December 2011, the ISO implemented a flexible ramping constraint in the five-minute market optimization to maintain sufficient upward flexibility in the system within the hour.[23] Generators that are chosen to resolve a constraint are compensated at the shadow price, which reflects the marginal unit's opportunity cost. Furthermore, the ISO is in the process of introducing a flexible ramping product, which would allow economic bids to be submitted to procure upward and downward ramping capability.

With regard to the second assumption, while the specific design of the flexible ramping products has not been finalized, it is logical to assume that the ISO's flexi-ramp requirements (for the product or the flexi-ramp constraint) would be calculated in such a way as to maximize diversity benefits across the entire EIM footprint, within the context of its 5-minute operational time-step.[24] It should be noted that this is a product that may not be in place by the time PSE would begin to participate in the EIM, and EIM participants may require a period of

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[23] See CAISO (2014d and 2014e).

[24] For a detailed discussion of the proposed approach for determining, procuring and allocating flexibility requirements under EIM, see Section 3.4.3 of CAISO (2013).

operational experience before the full benefits of flexibility reserve savings can be achieved.

At a minimum, however, when the EIM becomes operational, the flexible ramping constraint and settlement will be implemented. The ISO will determine flexible ramp constraint requirements for the ISO and each EIM participant based on the aggregate load, wind, and solar resource forecasts and expected variability. By establishing the requirements based on the aggregate profiles, the benefits of diversity will be realized with the current EIM implementation. Furthermore, the EIM design will compensate resources for their contribution to meeting the flexibility constraint. As a result, the EIM will provide an opportunity both for resources to be compensated and also for load serving entities to efficiently meet their flexibility requirements with recognition of the load and resource diversity benefits.

2.2.5 HYDROPOWER MODELING

Previous EIM analyses indicate that benefits are sensitive to the availability of hydropower to provide flexibility reserves.[25] Dispatchable hydroelectric resources rarely generate at levels that approach maximum nameplate capacity due to limitations on water available for power generation. On many facilities, a portion of the "unloaded" capacity — the difference between the nameplate capacity and the actual generation — can be used to provide contingency and flexibility reserves. However, this unloaded capacity varies by facility and with continually-fluctuating river conditions, making it challenging to generalize for

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[25] For example, see E3 (2011) for a discussion of this issue in the context of a WECC-wide EIM excluding the ISO and AESO.

modeling purposes. This leads to uncertainty in the calculation of operating costs using production simulation models.

Generally, EIM benefits are higher when hydro’s flexibility is restricted, because a higher proportion of reserves are provided by thermal resources. Conversely, there are fewer production cost savings available when hydro provides a large quantity of flexibility with zero variable costs.

PSE’s share of the Mid-Columbia (Mid-C) hydroelectric generating facilities is its primary source of flexibility, and gas-fired simple- and combined-cycle plants provide the remainder. This necessitates a more accurate characterization of hydro resources in the production cost simulations.

The NWPP Analytical Team spent considerable effort improving the modeling of hydro plants in the Northwest, including: (a) specifying hydro units as following a fixed schedule or dispatching using hydro-thermal coordination (HTC); (b) limiting reserve provision from specific hydro plants; (c) correcting ramp rates; and (d) reducing hydro generating capacities to reflect O&M and head obligations.[26] These modeling improvements are particularly important given that both PSE and PacifiCorp have contractual shares of Mid-C hydro plants. This analysis uses the same modeling assumptions and input data from the NWPP EIM Phase 1 Analysis.

The study team made one modification to the approach developed by the NWPP Team for the purposes of this study, optimizing the real-time dispatch of

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[26] See Section 2.4 of Samaan et al. (2013) for a detailed discussion of hydropower plant modeling in the NWPP Phase 1 EIM Analysis.

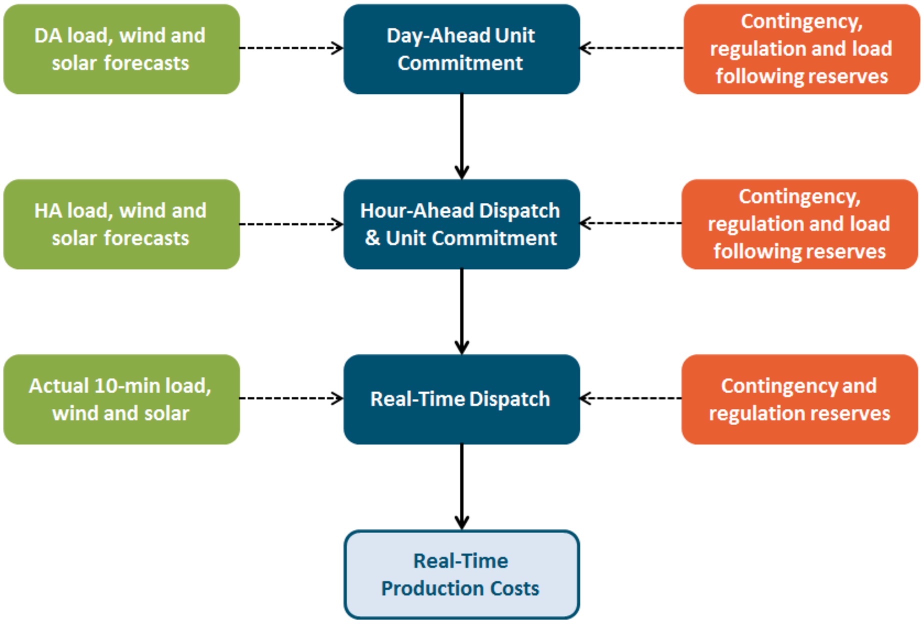
flexible hydro units in 6-hour increments rather than the 1-hour increments used in the NWPP study. This change was based on input from both PSE and the ISO, who felt that the 1-hour hydro optimization was overly restrictive of hydro flexibility. The use of 6-hour increments for hydro energy optimization results in a more conservative estimate of EIM benefits than a 1-hour hydro energy optimization window, because the 6-hour incremental reduces the amount of inefficiency in the BAU case that remains possible for an EIM to address. Importantly, this update also allowed the analysis to largely avoid the impact of hydro energy constraint violations (also termed "excess hydro") on EIM benefits that arose during modeling for the NWPP EIM Phase 1 study.

2.3 Sub-hourly Dispatch Benefits Methodology

2.3.1 PRODUCTION COST MODELING

The study team used PLEXOS, a sub-hourly production cost model, to estimate sub-hourly dispatch benefits in 2020. PLEXOS, like other production cost models, simulates bulk power system operations by minimizing the variable cost of operating the system subject to a number of constraints. PLEXOS includes a three-stage sequential simulation process to model DA, HA, and real-time operations, as shown in Figure 2 below.

Figure 2. PLEXOS Three-Stage Sequential Simulation Process



The primary purpose of the DA simulation is to generate daily unit commitment schedules for long-start units, while the HA simulation determines the HA dispatch and interchange schedules between BAs. During the real-time simulation, the “actual” load, wind, and solar data are used to generate dispatch, and flexibility reserves are “released” so that the capacity reserved from the HA simulation is allowed to serve real-time imbalances.

The DA, HA, and real-time (DA-HA-RT) sequential simulation approach allows PLEXOS to differentiate operations for BAs participating or not participating in an EIM. When a BA is not participating in an EIM, then: (a) hurdle rates apply during the DA, HA and real-time simulations; (b) interchange is unconstrained during the DA and HA simulations; and (c) during the real-time simulation, the

HA interchange schedule is locked down, resulting in the BA managing its imbalances with its own generation. In contrast, when two or more BAs are participating in an EIM, then hurdle rates on transfers between the participating BAs are removed during the real-time stage and generation from anywhere in the footprint can solve imbalances, subject to imposed transmission constraints.

The study team estimated sub-hourly dispatch benefits of PSE's participation in the EIM by running pairs of production cost simulations using PLEXOS. Under each simulation scenario, there is a pair of BAU and PSE EIM cases. In the BAU case, PSE solves its real-time imbalances with internal generation while maintaining interchange equal to the schedule from the HA simulation. Intra-hour interchange is allowed to vary to allow economic transfers between the ISO, PacifiCorp and NV Energy, reflecting the operational efficiencies of the current EIM. The PSE EIM cases simulate the operations of an EIM consisting of the ISO, PacifiCorp, NV Energy and PSE BAs. Hurdle rates between the BAs are removed in real-time and intra-hour interchange is allowed up to the real-time transfer capabilities specified in each scenario. The study quantifies the societal benefit of PSE's participation in the EIM by measuring the reduction in production costs from the BAU case to the PSE EIM case.

2.3.2 INPUT DATA

The initial dataset used for this report is the database used in PNNL analysis for the NWPP's Phase 1 EIM benefit assessment, which was built on the Transmission Expansion Planning Policy Committee (TEPPC) 2020 PC0 database.[27] The NWPP Analytical Team made numerous modeling updates for the purposes of their study, with a particular focus on improving the representation of BAAs in the Northwest.[28] Utilizing this database allowed this study to reflect the best available compiled representation of BAAs in the Northwest, as well as leverage the hourly DA, HA forecast and sub-hourly real-time data which PNNL developed for load, wind, and solar output.

For the purposes of this study, the study team made the following key updates:

- **Zonal transport model**. The transmission network in PLEXOS was modeled at the zonal level rather than the nodal level. This change was made to more accurately represent commercial behavior of two BAs scheduling transactions between each other through the Mid-C trading hub. Using the zonal model also significantly reduces model run time.
- **Topology updates**. The transmission transfer capability between PSE and neighboring zones was modeled according to PSE's typical monthly total transmission capability (TTC).[29] The remaining transmission topology and hurdle rate assumptions are based on the zonal model used for the ISO's 2012 Long-Term Procurement Plan (LTPP).
- **CT commitment during real-time**. Quick-start combustion turbines were allowed to commit and dispatch in the real-time simulations to reflect the ISO's addition of the 15-minute real-time unit commitment process for the EIM.

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[27] It is based on PNNL's Base Case (1.86a) for the NWPP, which itself was modified from a data set and had been developed for use with the PLEXOS sub-hourly model for PNNL's 2012 study for the WECC Variable Generation Subcommittee (VGS).

[28] See Section 2 of Samaan et al. (2013) for a detailed discussion of the updates the NWPP Analytical Team made to improve upon the TEPPC PC0 case.

[29] See PSE (2014).

- **Hydro optimization window**. As discussed in Section 2.2.5, the simulations optimize the real-time dispatch of flexible hydro units across a 6-hour window rather than a 1-hour window.
- **Nuclear generation**. All nuclear plants throughout the WECC were modeled as must-run at their maximum capacity to avoid any unrealistic intra-hour changes in nuclear generation.
- **Generation updates in California**. A few generation updates were made to reflect anticipated system changes that PSE and the ISO believed were important to the analysis. In California, the San Onofre Nuclear Generation Station (SONGs) was taken out of service, as well as applying the ISO's current best estimate of retirement and repowering of once-through cooling generators by 2020; the ISO's share of Hoover generation was also changed to match the values in the 2012 LTPP.
- **Generation updates in PSE**. A 200 MW quick-start CT generator was added pursuant to PSE's most recent Integrated Resource Plan. The portion of the Colstrip coal plant owned by PSE was moved into the PSE BAA so that its output could be changed in real-time based on PSE's needs, because PSE indicated that they can dispatch its share of Colstrip in real-time through a dynamic transfer.

Overall, the study team's modeling assumptions seek to be consistent with projections for calendar year 2020 in terms of generation, transmission and fuel prices across the WECC. At the same time, the study team sought to limit the number of changes in input data from the information used for the NWPP Phase 1 study.

2.3.3 SCENARIOS

Table 4 summarizes the assumptions used for each case modeled using production simulation: the BAU case (where PSE is not an EIM participant), and two PSE EIM participation scenarios with different levels of real-time transfer capability between BAs participating in the EIM.

Table 4. Overview of EIM Scenario Assumptions

Case Name	Real-Time Transfer Capability		
	PAC-PSE	CAISO-PAC	CAISO-NVE
BAU	NONE	400	1500
PSE EIM Scenarios:			
Low Transfer	300	400	1500
High Transfer	900	700	1500

As noted in Section 2.2.2, the study team anticipated that the real-time transfer capability between EIM participants would affect benefits, so PSE and the ISO worked to develop a range that would characterize low and high end expectations of real-time flexibility of transfers between PSE and PacifiCorp utilizing direct connections between them through their own transmission systems and other transmission system connections. PacifiCorp provided useful descriptions about their system and operations to help develop this range. In addition, PSE believes that it should be able to use a portion of its current Dynamic Transfer Capability (DTC) over the Bonneville Power Administration (BPA) system to enable further real-time EIM transactions for PSE when economic. In total, the study team selected a real-time transfer capability of +/- 300 MW between PSE and PacifiCorp for the PSE EIM Low Transfer Case and +/- 900 MW for the PSE EIM High Transfer Case.

In the BAU and PSE EIM Low Transfer scenarios, real-time transfer capabilities between current EIM participants are consistent with the assumptions in the NVE-ISO EIM study: 1,500 MW for the ISO-NV Energy real-time transactions, and 400 MW for PacifiCorp-ISO transactions, which is also the value for the middle level of transfer capability in the PacifiCorp-ISO EIM study. In the PSE EIM High Transfer Case, the study team increased the capability between PacifiCorp and the ISO by an additional 300 MW (to 700 MW total) to investigate the impact that additional COI transfer capability for the EIM could have on benefits to PSE.

2.3.4 ATTRIBUTION OF BENEFITS TO EIM PARTICIPANTS

WECC-wide production cost savings represent the societal benefits resulting from PSE's participation in the EIM. The study team attributes these benefits to PSE and the current EIM participants by calculating the "Total Operations Cost" for both parties, which is the sum of the following components: (1) HA net import costs, equal to net imports times the zone's locational marginal price; (2) real-time generator production costs; and (3) real-time imbalance costs, equal to imbalance times an EIM-wide market clearing price. The "Total Operations Cost" represents a proxy for the total cost to serve load in a given area, including the production costs to run local generators and the cost of importing power (or revenues from exporting power). The reduction in "Total Operations Costs" under an EIM case versus the BAU case represents the EIM benefit for a given participant.

Since the EIM does not affect HA operations, there is no change in HA net import costs between the BAU and EIM cases. The EIM-wide market clearing price used to calculate real-time imbalance costs is the imbalance-weighted average of the participating BAs. Table 5 is an example of calculating the EIM-wide market clearing price for a single 10-minute interval. The EIM-wide market clearing price is only applied to imbalance transactions.

Table 5. Example of EIM-wide Marketing Clearing Price Calculation

Category	CAISO	PAC	NVE	PSE
Real-time Price ($/MWh)	73.0	56.5	61.9	59.8
HA Net Import Schedule (MW)	7,635	(2,592)	1,463	110
Real-time Net Imports (MW)	7,449	(2,769)	1,587	350
Imbalance (MW)	-186.0	-177.2	123.4	239.9
Absolute Value of Imbalance (MW)	186.0	177.2	123.4	239.9
Share of Imbalance (%)	25.6%	24.4%	17.0%	33.0%
EIM-wide Market Clearing Price ($/MWh)	**62.7**			

2.4 Flexibility Reserve Savings Methodology

The study team estimates the operational cost savings from reduced flexibility reserve requirements using the following methodology. First, a statistical analysis is used to estimate the quantity of flexibility reserve reductions from PSE’s participation in the EIM. Next, the avoided cost of flexibility reserves is determined by observing historical flexible ramping constraint shadow prices from 2013. Finally, to estimate the total EIM reserve savings from PSE’s participation, the average shadow price from 2013 is applied to the flexibility reserve quantity reductions.

2.4.1 FLEXIBILITY RESERVE REQUIREMENT

To determine flexibility reserve requirements, the study team used the actual (10-minute) and HA schedule load, wind, and solar data from the NWPP EIM study. This data is used to calculate a distribution of flexibility needs (i.e., real-time net load minus the HA net load schedule). Each BA's flexibility reserves requirement for each month and hour are calculated using a 95% confidence interval (CI), where the 2.5th and 97.5th percentiles determine the flexibility down and up requirements, respectively.[30]

For the BAU case, the study team calculates flexibility requirements for the current EIM by summing the net load profiles for the ISO, PacifiCorp and NV Energy BAs before calculating the 95% CI.[31] PSE's requirements are calculated as a standalone entity. In the PSE EIM case, flexibility requirements are calculated for the Expanded EIM by summing the ISO, PacifiCorp, NV Energy and PSE BA net load profiles. Figure 3 shows the average upward flexibility requirements in 2020 across the BAU and PSE EIM cases. PSE's EIM participation results in a "diversity benefit" that reduces upward flexibility requirements by 74.5 MW on average.[32]

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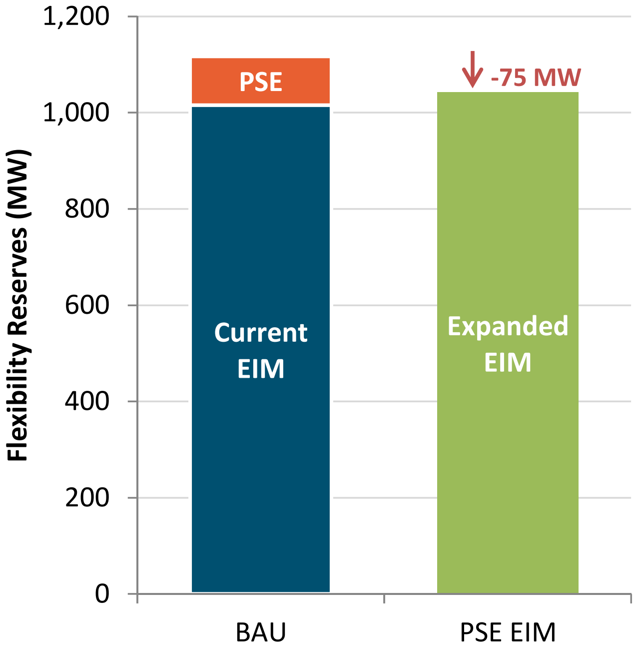
[30] Using the 95% confidence interval to calculate flexibility reserve requirements is consistent with the approach used in the NWPP EIM Phase 1 study.

[31] Due to diversity in forecast error and variability, the 95th percentile of aggregated real-time deviation from HA forecast for the entire EIM is a smaller level (relative to the size of the BAs) than it would be for the sum of individual EIM members.

[32] This reduction is subject to real-time transmission transfer capability limits, and cannot be larger than the levels between individual EIM participants and the rest of the EIM. However, the reduction levels quantified for PSE were well under the levels for the PSE Low Transfer Case, so transmission was assumed to not have a binding impact on flexibility reserve reductions for the PSE EIM scenario, and the resulting flexibility reserve savings are the same for all three PSE EIM scenarios. The reserve savings for PSE would change if PSE had a different renewable generation portfolio, which is addressed in Chapter 4.

Figure 3. Average Upward Flexibility Requirement

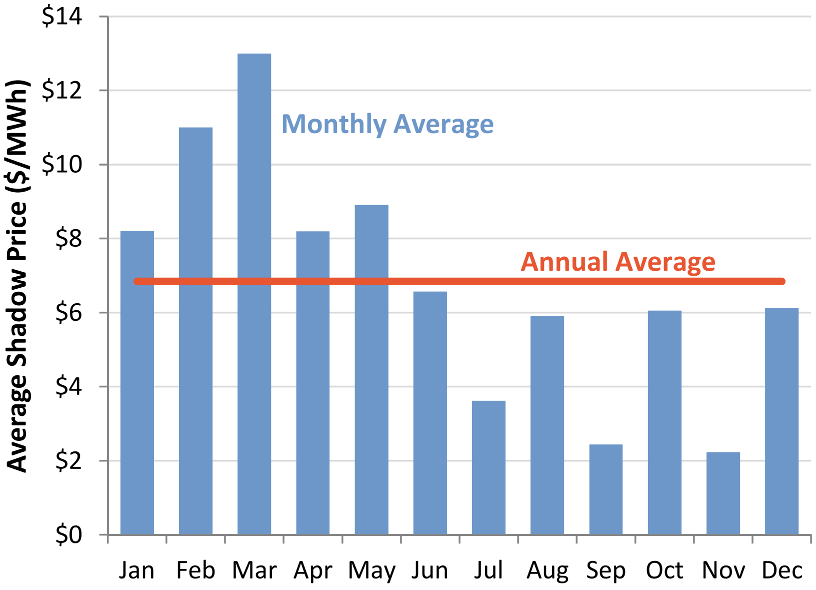


Note: Current EIM consists of the ISO, PacifiCorp and NV Energy BAs. “Expanded EIM” consists of the ISO, PacifiCorp, NV Energy and PSE.

2.4.2 AVOIDED COST OF FLEXIBILITY RESERVES

To value flexibility reserve reductions, the study team first examined flexible ramping constraint shadow prices in 2013. The ISO has applied a flexible ramping constraint in the five-minute market optimization since December 2011 to maintain sufficient upward flexibility. Generators that are chosen to resolve a constraint are compensated at the shadow price, which reflects the marginal unit’s opportunity cost. However, if there is sufficient capacity available, the constraint is not binding, resulting in a shadow price of zero. Figure 4 shows the average shadow price for procuring upward flexible ramping capacity for each month in 2013. Reductions in *upward flexibility* requirements in 2020 are valued at the 2013 annual average flexible ramping constraint shadow price of \$6.98/MWh.[33]

Figure 4. 2013 ISO Flexible Ramping Constraint Shadow Prices



Note: Data from CAISO (2014a).

2.4.3 ATTRIBUTION OF FLEXIBILITY RESERVE SAVINGS

Flexibility reserve savings were attributed to PSE and the current EIM participants by comparing their relative reduction in flexibility reserve requirements in the BAU case compared to the PSE EIM cases. The ISO's Business Practice Manual (BPM) details how the ISO will assign flexibility reserve

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[33] Inflated here from 2013 to 2014 dollars assuming an annual inflation rate of 2%.

requirements among EIM participants. Each participating BA will be assigned a flexibility requirement equal to the BA's standalone flexibility reserve requirement (i.e., if it were not an EIM participant), reduced by an EIM reserve diversity factor that is equal to the combined EIM flexibility reserve requirement (which reflects diversity benefit across the EIM), and then divided by the sum of standalone flexibility reserve requirement quantity for all EIM participants.[34]

Overall, PSE's participation in the EIM creates more diversity to the full EIM footprint, reducing flexibility reserve requirements for current EIM participants by 48.2 MW on average, which is a five percent reduction compared to their requirements in the current EIM. PSE's own flexibility reserve requirement is reduced by 26.3 MW on average, a 26% reduction from its requirements as a standalone BA.

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[34] See CAISO (2014b).

3 Results

3.1 Overview of Benefits Across Scenarios

Table 6 below presents the annual benefits of PSE's EIM participation in 2020 under both transfer scenarios. Each row displays PSE's EIM cost savings in a particular transfer capability scenario relative to the BAU scenario. Annual sub-hourly dispatch and flexibility reserves benefits to PSE range from $18.3 million in the Low Transfer Case to $20.1 million for the High Transfer Case.

Table 6. Annual Benefits to PSE by Transfer Capability Scenario (million 2014$)

PSE EIM Scenario	Sub-hourly Dispatch	Flexibility Reserves	Total Benefits
Low Transfer	$16.7	$1.6	**$18.3**
High Transfer	$18.5	$1.6	**$20.1**

The PSE EIM Low Transfer case, with 300 MW of real-time transfer capability between PSE and PacifiCorp, enables $16.7 million in sub-hourly dispatch benefits for PSE. The High Transfer scenario, in which the PSE-PacifiCorp real-time transfer capability is increased to 900 MW and the PacifiCorp-ISO transfer capability is increased to 700 MW, produces $18.5 million in sub-hourly dispatch benefits for PSE, a modest $1.8 million increase in savings compared to the Low Transfer case. The small size of this incremental savings is discussed later in this chapter, which highlights that the 300 MW of PSE-PacifiCorp real-time transfer capability is sufficient to facilitate most economic real-time transactions in the majority of hours of the year for the simulation of PSE EIM participation.

For both scenarios modeled, the flexibility reserve benefit to PSE is $1.6 million. The Low Transfer scenario uses 300 MW of real-time transfer capability between PSE and the current EIM. This transfer capability is sufficient to not constrain the potential reduction to PSE's flexibility reserve requirement as an EIM participant, which in Section 2.4.3 the study team identified as 26.3 MW on average. Therefore, PSE's flexibility reserve savings are not constrained by the real-tim41e transfer capability in the Low Transfer scenario, and adding additional transfer capability in the other scenario does not produce additional flexibility reserve savings for PSE.

Table 7 below presents the incremental benefit to the current EIM participants as a result of PSE's participation in the EIM. In total, PSE's participation is projected to create $3.5 to $4.2 million per year in incremental benefits for the current EIM participants.

Table 7. Annual Benefits to Current EIM Participants (million 2014$)

PSE EIM Scenario	Sub-hourly Dispatch	Flexibility Reserves	Total Benefits
Low Transfer	$0.6	$2.9	**$3.5**
High Transfer	$1.2	$2.9	**$4.2**

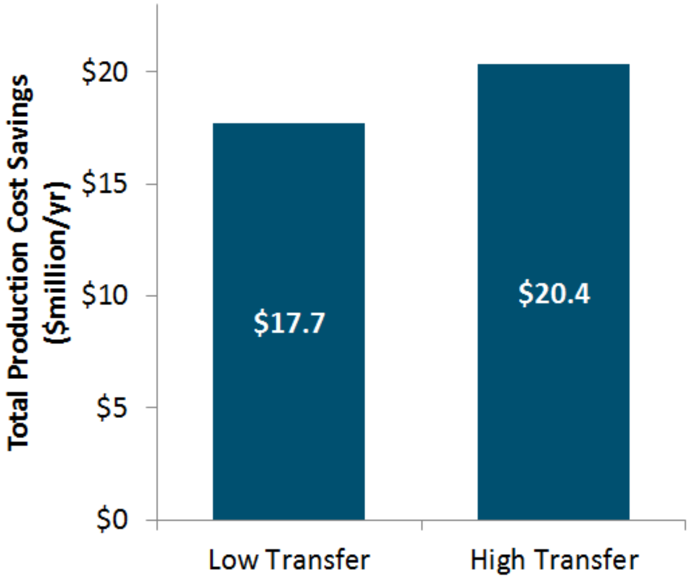
PSE's participation in the EIM provides the current participants opportunities for incremental, sub-hourly dispatch benefits ranging from $0.6 to $1.2 million per year. Under the Low Transfer scenario, current EIM participants see sub-hourly dispatch savings of $0.6 million per year, while under High Transfer scenario, benefits to current participants are $1.2 million. In both of the EIM scenarios considered, PSE's participation in the EIM would also create additional diversity, further reducing flexibility reserve requirements for the current EIM participants and producing $2.9 million in incremental savings for the current EIM participants.

3.2 Detailed Benefit Results by Category

3.2.1 SUB-HOURLY DISPATCH BENEFITS AND IMBALANCE LEVELS

Figure 5 presents the WECC-wide production cost savings under both scenarios of transfer capability between EIM participants. WECC-wide production cost savings from the dispatch analysis should aggregate all transfers between consumers and producers to present the total incremental savings from PSE EIM participation. This total was $17.7 million for the PSE EIM Low Transfer Case and $20.4 million for the PSE EIM High Transfer Case. These totals are slightly larger from the sum of dispatch benefits attributed to PSE and the current EIM participants due to small interactions with BAs outside of the EIM footprint.

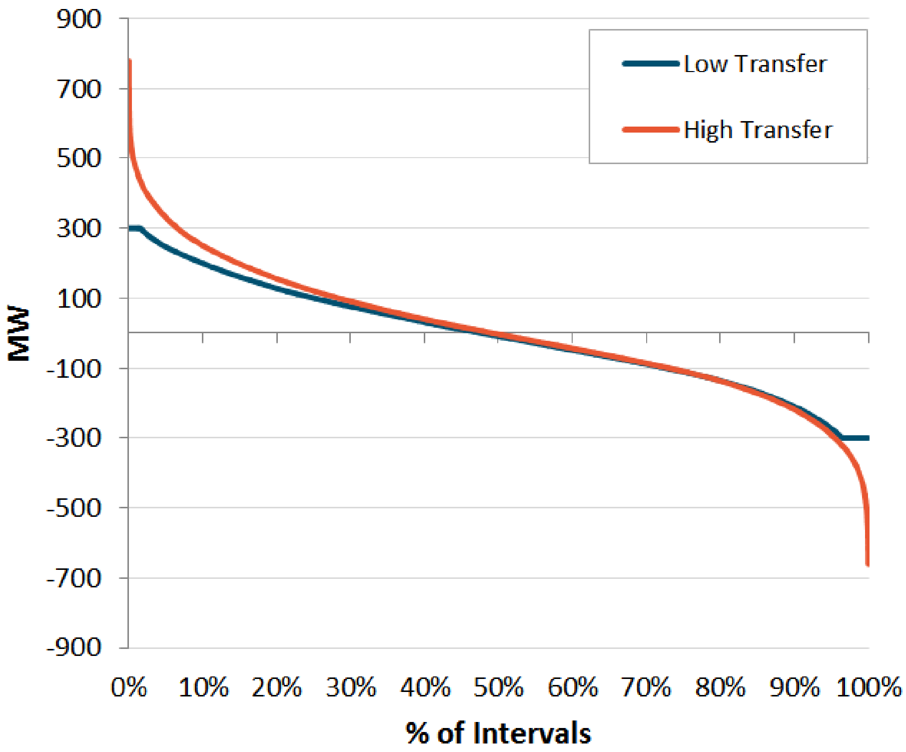
Figure 5. WECC-wide Production Cost Savings



The results presented above highlight that the overwhelming majority of potential sub-hourly dispatch benefits are captured with only 300 MW of real-time transfer capability between PSE and PacifiCorp. A threefold increase in this capability only results in a 15% increase in sub-hourly dispatch benefits. This suggests that there are very few intervals throughout the simulation year where it would be economic for PSE to either increase or decrease its generation dispatch and net exchange with other EIM participants by more than 300 MW.

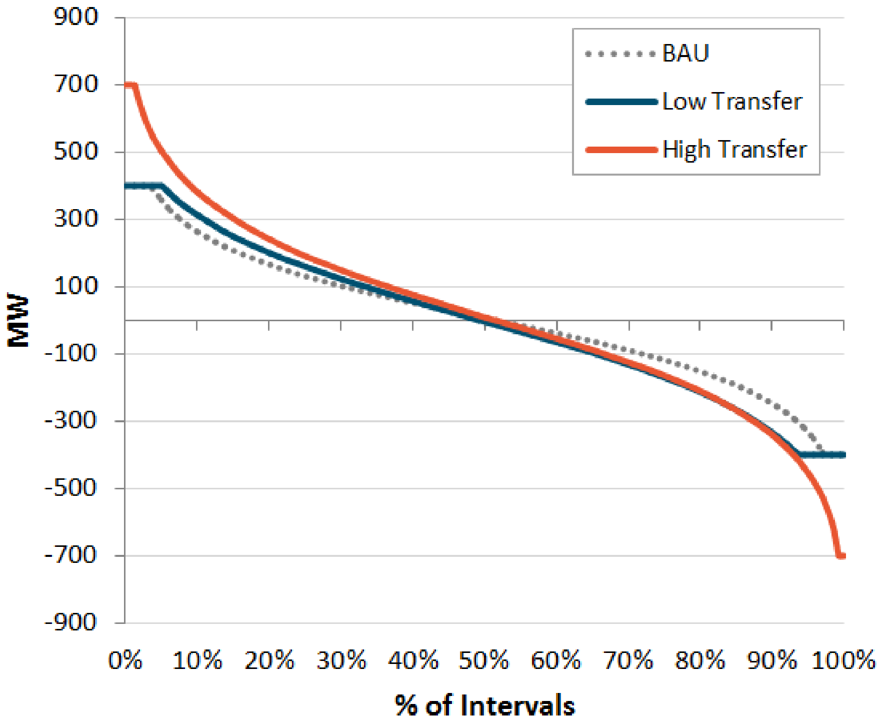
The infrequency of transfers above 300 MW is highlighted in Figure 6. The figure compares imbalance energy duration curves for PSE for the two EIM scenarios. Imbalance shown here is the difference between PSE’s real-time (10-minute) net imports and the HA net import schedule produced from the HA simulation. Positive imbalances represent intervals when PSE is importing more in real-time relative to their HA schedule (or exporting less than in the HA schedule), and vice versa. In the PSE EIM Low Transfer case, imbalances are exactly equal to +300 MW or -300 MW in fewer than 2% of the intervals across the year, suggesting that the transfer capability is rarely a binding constraint on EIM transactions. In the High Transfer case, PSE’s imbalance exceeds +/-300 MW in 11% of the intervals, with imbalances never reaching 900 MW.

Figure 6. PSE Imbalance Duration Curve



PSE's participation in the EIM also results in incremental increases in the EIM transaction volume over COI relative to the current EIM (in both positive and negative directions for certain sub-hourly intervals). This impact is illustrated in Figure 7 below, where the BAU duration curve represents the PacifiCorp-only EIM transactions over COI, and the remaining curves reflect PSE plus PacifiCorp real-time imbalance over the COI for the two PSE EIM cases analyzed. Positive imbalance represents south to north flow, and negative imbalance represents north to south flow. The 400 MW of real-time transfer capability between PacifiCorp and the ISO modeled in the BAU and Low Transfer scenarios is only binding during a small percentage of real-time intervals. Therefore, increasing this capability from 400 to 700 MW in the High Transfer scenario produces a small marginal increase in EIM dispatch benefits.

Figure 7. PSE plus PacifiCorp Imbalance Duration Curve



3.2.2 DRIVERS OF SUB-HOURLY DISPATCH BENEFITS FOR PSE

The study team reviewed detailed outputs on generation dispatch from each of the simulations to identify key drivers of PSE EIM dispatch benefits. The most significant sources of dispatch saving for PSE was the result of the EIM enabling more efficient use of PSE's internal generation and allowing flexibility in the ability to increase or decrease net imports in real-time. In the BAU case, forecast errors and variability of load and wind in real-time resulted in the need for PSE to commit internal peaking generators in real-time during certain periods when PSE required more energy, but was unable to adjust real-time exchanges scheduled with neighboring BAs. By comparison, under both PSE EIM scenarios, participation in the EIM enables PSE to adjust net exchanges with the other EIM participants in real-time. This capability allowed PSE to frequently avoid the need to commit additional internal peaking generators to address real-time generation shortfalls, and, as a result, PSE is able to produce a higher percentage of energy to serve its load with lower-cost base load generation. The EIM also allows PSE to dispatch its lowest-cost generators for export sales to the other EIM participants in intervals when these units have available capacity in real-time and it is economic to do so.

Figure 8compares PSE's real-time net imports in the BAU and PSE EIM Low Transfer scenarios for a three-day snapshot period in December 2020. In the BAU scenario (shown in blue), net imports are fixed to the HA schedule. In contrast, net imports in the EIM Low Transfer scenario (shown in orange) are allowed to vary by the real-time transfer capabilities discussed above, resulting in more variable real-time net imports that are both higher and lower than the HA schedule. This net import flexibility allows PSE to optimize the use of its own generation to resolve imbalances. The flexibility of real-time exchange facilitated by the EIM is further illustrated in Figure 9, which displays the level of imbalance for each participating BA across the same three-day snapshot.

Figure 8. PSE Real-Time Net Imports for Three-Day December Period

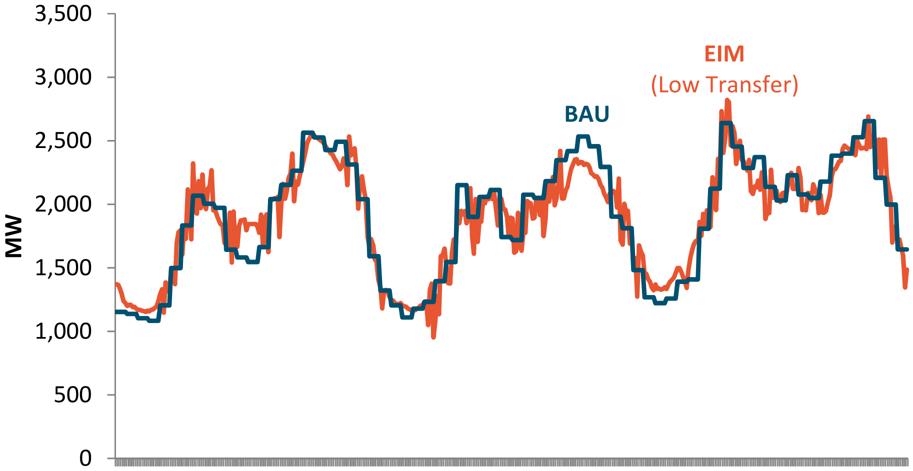
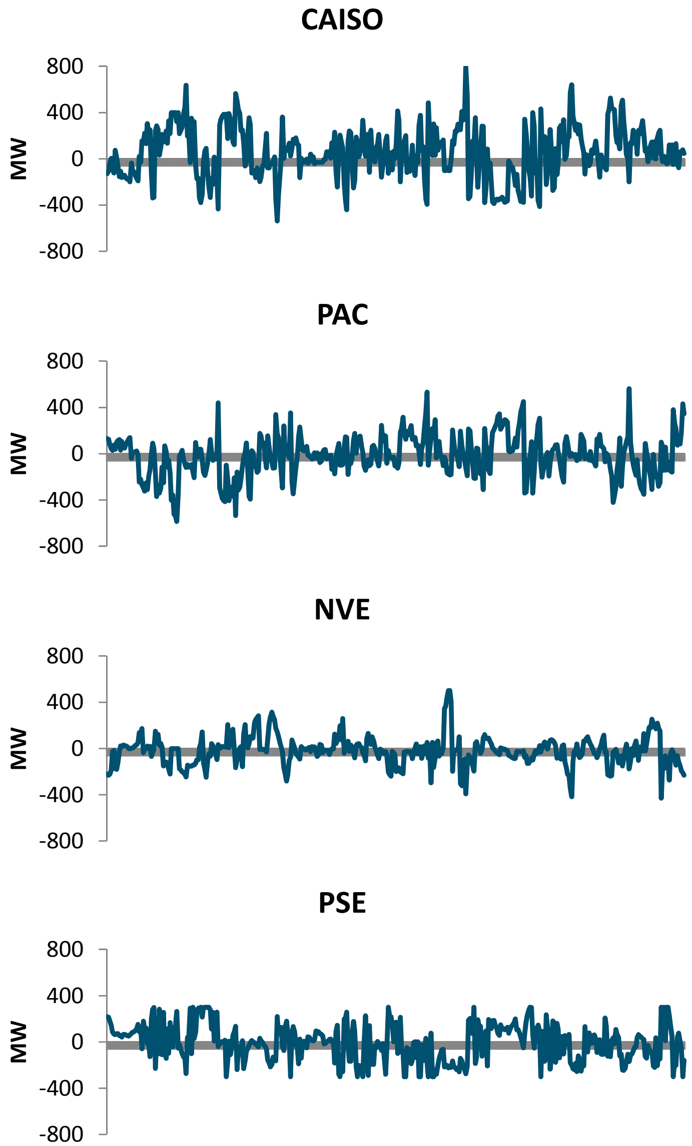


Figure 9. Real-Time Imbalance for EIM Participants for Three Day December Period, Low Transfer Case



Note: sum of imbalances across the four EIM participants is equal to zero for every 10-minute interval.

Table 8 below shows the calculations used to attribute EIM benefits to PSE and the current EIM participants by estimating the "Total Operations Cost" for PSE and the current EIM under the BAU case and both PSE EIM scenarios. Each component is calculated according the methodology described in Section 2.3.4.

Table 8. Total Operations Cost by Component across Scenarios (2014 $ million/year)

	Current EIM (ISO-PAC-NVE)	PSE
BAU		
HA Net Import Cost	$ 2,806.9	$ 489.4
Real-time Imbalance Cost	$ 0.1	$ (0.0)
Real-time Generation Cost	$ 7,727.9	$ 216.4
Total	**$ 10,534.9**	**$ 705.8**
PSE EIM: Low Transfer		
HA Net Import Cost	$ 2,806.9	$ 489.4
Real-time Imbalance Cost	$ 1.6	$ (1.5)
Real-time Generation Cost	$ 7,725.8	$ 201.3
Total	**$ 10,534.3**	**$ 689.1**
PSE EIM: High Transfer		
HA Net Import Cost	$ 2,806.9	$ 489.4
Real-time Imbalance Cost	$ (5.2)	$ 5.3
Real-time Generation Cost	$ 7,732.0	$ 192.7
Total	**$ 10,533.7**	**$ 687.3**

The resulting incremental EIM savings for each participating BA is based on the reduction in total operations cost for that BA in a particular PSE EIM scenario compared to the BAU case. These savings are shown by component in Table 9 below.

Table 9. EIM Savings (Cost) by Scenario (2014 $ million/year)

	Current EIM (ISO-PAC-NVE)		PSE	
PSE EIM: Low Transfer				
HA Net Import Cost	$	-	$	-
Real-time Imbalance Cost	$	(1.5)	$	1.5
Real-time Generation Cost	$	2.1	$	15.2
Total	**$**	**0.6**	**$**	**16.7**
PSE EIM: High Transfer				
HA Net Import Cost	$	-	$	-
Real-time Imbalance Cost	$	5.3	$	(5.3)
Real-time Generation Cost	$	(4.1)	$	23.8
Total	**$**	**1.2**	**$**	**18.5**

3.2.3 FLEXIBILITY RESERVE SAVINGS

As noted in Section 2.4, the additional diversity from PSE's participation in the EIM would bring an incremental 74.5 MW reduction in EIM-wide flexibility reserve requirements compared to the sum of current EIM reserve requirements plus PSE standalone reserve requirements in the BAU case. The EIM assigns flexibility reserve requirements and allocates the diversity reduction among EIM participants based on their relative share of the sum of standalone reserves if each were operating without an EIM. On average, throughout the year, this methodology results in a 26.3 MW flexibility reserve reduction attributed to PSE and an incremental 48.2 MW reserve reduction attributed to the current EIM participants.

This study values these flexibility reserve reductions based on the average historical flexi-ramp value in the ISO for 2013, which was $6.98/MWh.[35] This value results in total flexibility savings for the year 2020 of $4.6 million, of which $1.6 million is for PSE and $2.9 million is for the current EIM participants.

3.3 Results Discussion

The study team applied a number of conservative assumptions in this analysis, which could results in the benefits quantified above to be lower than the actual savings that would accrue to PSE and to the current EIM participants. These assumptions include:

- **Reliability-related benefits were not quantified.** The study team did not quantify the potential reliability benefits tied to the increased situational awareness and resource control that the EIM will enable. Although these benefits are difficult to quantify, they are important to consider qualitatively as they are likely to produce substantial benefits.
- **Intra-regional dispatch savings were not quantified.** PSE indicated that internal congestion on the PSE system is usually small, so the analysis did not endeavor to quantify if the EIM can help reduce costs or relieve problems within PSE's BAA.
- **Average hydro conditions and current renewable generation policy targets.** The analysis evaluated an average hydro year and renewable generation levels equal to current policy targets. It is possible that high hydro runoff in the Pacific Northwest or higher RPS targets in the ISO could lead to greater BAU scenario renewable energy curtailment. In

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[35] Adjusted from 2013 to 2014 dollars.

such conditions, PSE's participation in the EIM may be able to produce larger savings than the levels included here. In addition, low hydro conditions could reduce PSE's ability to call on its hydro resources for flexibility, which would lead to greater incremental savings from EIM participation.

- **Thermal generators were modeled with flat heat rates.** According to the WECC VGS study and PNNL NWPP Phase 1 EIM analysis, each thermal generator in the PLEXOS database was assigned a single heat rate regardless of the unit's current level of dispatch. Other models such as the WECC TEPPC model in GridView typically use step-function incremental heat rates for thermal generators; such heat rates reflect the fact that a generator will typically have a higher average heat rate when operating at minimum dispatch levels (i.e., Pmin) compared to when operating closer to maximum output (i.e., Pmax). The EIM dispatch savings are driven by identifying efficiency opportunities to reduce dispatch of generation in one BAA and increase dispatch on a lower-cost generator located in a different participating BAA. Modeling thermal units with non-flat heat rates could produce greater variation in heat rates across generators (depending on their operating levels) and result in greater opportunities for EIM dispatch savings.
- **Hydro energy optimization was modeled with a 6-hour horizon**. In the real-time simulation runs with sub-hourly intervals, PLEXOS models dispatchable hydro plants by first allocating each plant's total monthly hydro energy budget to a single hour, or to a window of consecutive hours. The simulation then optimizes overall real-time system dispatch while using the capability to move the hydro energy available during a single hour (or window of hours) among 10-minute intervals within that hour. The simulation uses the hour's available hydro energy during intervals when hydro dispatch has the most value, subject to constraints on generator ramp rates and maximum and minimum output levels for

the hydro plant. This allocation procedure limits the ability of a BA to move hydro energy across a wide time period in the real-time simulation to respond to differences in system need across a day or group of days. In actual practice, hydro operators do not have perfect forecasts of load and variable energy, and they similarly must budget available hydro energy under uncertainty, subject to hydrological and environmental constraints. The PNNL EIM Benefit Phase 1 for the NWPP used a 1-hour hydro optimization window, which prevented BAs in the model from shifting real-time hydro energy forward from one hour to the next and contributed to the hydro energy constraint violation included in that analysis. Based on feedback from PSE regarding its own hydro dispatch capabilities, the study team extended the hydro optimization horizon to a 6-hour window. By simulating a longer hydro energy optimization window this study allows the available hydro energy to be used more optimally and flexibly to address intra-hour dispatch challenges. This assumption results in a more conservative EIM dispatch savings estimate because the hydro improves the efficiency of the dispatch in the BAU case, leaving a smaller remaining opportunity for incremental improvement under an EIM.

4 Additional Wind Balancing Cost Savings

In addition to the savings described in Chapter 3, an EIM may enable PSE to realize incremental savings related to wind resource balancing and reduced curtailment. Under current conditions (i.e., without EIM participation), limitations of PSE’s internal reserve capability motivate PSE to contract with other BAs to provide reserves and balancing services for current and future wind plants in PSE’s generation portfolio.

4.1 Renewable Balancing Cost Savings

Currently, PSE has 500 MW of wind generation located in an external BAA and the energy from that generation is scheduled in hourly block transfers to PSE. PSE expects that it will also need assistance to balance 300 MW of additional wind generation planned by 2020. PSE must pay the external BA for the balancing services it provides, and, based on current balancing service rates, PSE would expect to incur annual costs of $11.5 million to balance the total of 800 MW of external wind resources.

As an EIM participant, PSE would have a lower local flexibility reserve requirement and more opportunities for balancing load and wind variability in sub-hourly intervals. This helpful impact of the EIM would allow PSE to instead provide its own flexibility reserves (with the assistance of the EIM diversity benefit) to balance the PSE wind resources currently integrated by the external BA and thereby avoid all or a substantial portion of the balancing charges it currently incurs each year.

If feasible, this operating change could allow PSE to avoid balancing charges but would require PSE (as an EIM participant) to maintain a higher internal flexibility reserve requirement than it otherwise would as an EIM participant if the 800 MW of remote wind was still balanced outside of the PSE BAA. Using the flexibility reserve methodology described above, the study team estimates that PSE would need to maintain an incremental 22 MW of flexibility reserves, on average, to balance the remote wind as an EIM participant.[36] Based on the ISO's average 2013 flexible ramping constraint shadow price of $6.98/MW-hour, which was used in Chapter 3 of this report to value flexibility reserve requirement savings, the 22 MW increase in average flexibility reserves requirements to balance its remote wind would create $1.3 million in additional cost to PSE. PSE would also need to hold a higher amount of regulating reserves to manage the greater wind variability on a sub-5-minute timescale. Based on previous analysis by PSE, balancing the remote wind internally would also be expected to require PSE to hold an incremental 15 MW of regulating up and 15 MW of regulating down reserves on average. Using the ISO's historical average prices from 2013 of $5.34/MW-hour for regulating up and $3.32/MW-hour for

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[36] It is important to note that this incremental amount is 48 MW lower than the amount of flexibility reserves that PSE would require if it were to attempt to balance the remote wind as a standalone entity.

regulating down as a proxy for PSE regulating costs,[37] the incremental regulating requirement would create $1.1 million in incremental regulating costs for PSE.

The annual net cost savings of PSE balancing these remote wind plants locally with the support of the EIM is $9.1 million per year.[38] This benefit is in addition to the cost savings reported in Section 3.1.

4.2 Renewable Curtailment Savings

Renewable curtailment savings estimates were provided by PSE based on historical curtailment of its wind resources both within and external to its BAA. Wind resources external to the PSE BAA are subject to reliability curtailments from the source BA. In addition, under current operational practice, PSE may need to curtail output of wind plants located in its own BAA during periods of elevated reliability concern, such as spring runoff conditions. If PSE were to internally integrate its remote wind plants, then PSE's historical backcast approach estimates renewable curtailment cost savings for its total wind portfolio range from $0 to $0.8 million per year, depending on a combination of local and regional system conditions. PSE expects that the EIM could help reduce a portion or eliminate all of this curtailment if all of the wind plants were in PSE's BAA. To cover this range, EIM renewable curtailment related savings for PSE have been assessed as a range of annual benefits from $0 to $0.8 million.

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[37] See Section 6.3 of CAISO (2014a). It is not expected that the ISO would provide regulating reserves to PSE under the EIM; rather the ISO's regulating reserve prices were used as a transparent ancillary services market value as a proxy for potential costs that PSE would incur to meet a higher regulating requirement.

[38] This net savings is calculated by taking the difference of $11.5 million in avoided balancing service charges, less $1.3 million in incremental flexibility reserve costs for PSE and $1.1 million in incremental regulating reserve costs for PSE.

The PacifiCorp-ISO and NV Energy-ISO EIM studies included benefits related to the EIM's assistance in reducing renewable energy curtailment inside the ISO. Due to the renewable energy curtailment benefits already captured by PacifiCorp and NV Energy's participation in the EIM, this study conservatively assumes that PSE's participation in the EIM would not enable any additional avoidance of renewable energy curtailment for current EIM participants.

5 Conclusions

This report assessed the incremental benefits of PSE's participation in the ISO EIM. The study team estimated the benefits for PSE as well as current EIM participants. The gross benefits identified to PSE are substantial, even under the low real-time transmission transfer capability scenario, which includes 300 MW of real-time transfer capability between PSE and PacifiCorp. In addition, if the EIM enables PSE to locally balance its remote wind resources and avoid wind balancing service charges, significant additional cost savings could be possible.

Two additional material benefits have not been quantified. First, the study team assumed that PSE's behavior and actions in the DA and HA market would not be influenced by the continuous information flowing from participation in the EIM market. We believe that over time, PSE may be able to obtain additional benefits, which were not captured in this study, by adjusting its positions more optimally in the HA and DA markets based on information obtained through more transparent awareness of the real-time market as a result of EIM participation.

Second, the study team did not quantify the potential reliability benefits tied to the increased situational awareness and resource control that the EIM creates. Although both of these benefits are difficult to quantify, they are important to consider qualitatively as they are likely to produce substantial benefits.

Relative to the EIM startup and ongoing participation costs estimated by PSE staff, the gross benefits presented in this study are significant. The benefits and costs from PSE's participation in the EIM quantified in this report would produce a positive net present value ranging from \$153.7 million to \$174.4 million for PSE over a 20-year period. [39]

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[39] NPV has been estimated for a project start year of 2014. The calculation assumes 20 years of sub-hourly dispatch and flexibility reserves benefits and annual ongoing costs. PSE's participation in the EIM is estimated to go live in Fall 2016, and startup costs are incurred in 2015 and 2016. All values have been discounted using PSE's after-tax weighted average cost of capital (ATWACC) of 6.7% nominal, consistent with PSE's 2013 IRP, and assumed annual inflation rate of 2%. Increasing the NPV calculation to include 30 years of benefits and ongoing costs results in an NPV ranging from \$190.2 to \$216.3 million.

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