Senate Bill 350 Study

Volume XII: Review of Existing Regional Market Impact Studies

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Senate Bill 350 Study

The Impacts of a Regional ISO-Operated Power Market on California

List of Report Volumes

Volume XII: Table of Contents

Volume XII. Review of Existing Regional Market Impact Studies

A. Introduction

We reviewed a number of other studies that have estimated the benefits of organized regional electricity markets. While most other studies analyzed markets different from those projected for California and the West, they offer relevant information and helpful reference points. Many of these studies employ analytical frameworks similar to those used in this SB 350 study. Taken together, the studies show that the magnitude of benefits from regionalizing markets is generally consistent across various regions, circumstances, and time periods.

Some of the studies we reviewed analyzed circumstances similar to those explored in this SB 350 study. For example, the SPP Retrospective Study (2015) estimated the benefits of moving from an imbalance market similar to California's Energy Imbalance Market to a full Day-2 Market. This study is particularly relevant for SB 350 because SPP resembles WECC in other ways, albeit on a smaller scale. Much like WECC, SPP has a mix of natural gas, coal, and renewable generation with major load centers in one portion of the footprint (the southeast) and distant areas with low-cost renewable generation (the Great Plains). Additionally, the Basin/WAPA Study (2013) explored the benefit of regional market participation to public power entities similar to those found in WECC. The Entergy-MISO Study (2011) analyzed the benefits of the expansion of a regional market.

A few of the reviewed studies specifically focused on WECC and explored the benefits of improved regional market design and renewable integration. For example, and as discussed further below, the Low Carbon Grid Study (2016) simulated the WECC for a 2030 study year with very similar study assumptions, yielding very similar results for both California and the broader WECC region.

B. Market Integration Studies Reviewed

Figure 1 below summarizes the types of studies reviewed to provide background and reference levels for the analysis of the impacts that regional market integration and region-wide independent system operations would likely have on California and the surrounding regions.

Figure 1: Studies Reviewed

Study Type	Examples of Studies
Day-2 Market Studies Evaluate benefits of moving from de-pancaked transmission and energy imbalance market to full Day-2 market	SPP Retrospective (2015), SPP Prospective (2009), Navigant Markets Study (2009), Chan Efficiency Study (2012), MISO Value Proposition Report (2015), MISO Retrospective Study (2009), Wolak Nodal Study (2011), NYISO Plant Efficiency Study (2009), ERCOT Nodal Study (2014)
RTO Participation Studies Evaluate benefits and costs to a utility of joining an existing RTO	E3 PAC Integration Study (2015), Basin/WAPA Study (2013), Entergy-MISO Study (2011), Entergy SPP/MISO Cost-Benefit Analysis (2010), Mansur PJM Efficiency Study (2012)
Post Order 2000 RTO Studies Benefit-cost studies of forming RTOs that followed issuance of FERC Order 2000 in late 1999	LBNL Review Study (2005), RTO West Study (2002), National RTO Study (2002)
EIM Studies Evaluate the benefits of the Western EIM, or the benefits of a utility joining the EIM	WECC-Wide EIM (2011), APS-EIM (2015), PGE-EIM (2015), NV Energy-EIM (2014), Puget Sound-EIM (2014), PacifiCorp-EIM (2013)
European Market Integration Studies Evaluate the benefits of market integration in the European context	EPRG Integrating European Markets (2015), DNV-GL European Renewable Integration Study (2014)
Renewables Studies Studying the challenges of higher penetration of renewable resources	NREL/DOE WWSIS 2 (2013), Low Carbon Grid Study (2016), WGA Integration Study (2012), SPP Wind Integration (2016)
Markets-Based Renewables Studies Discussing the function of markets in facilitating renewables development beyond RPS requirements	Brookings Clean Economy Study (2011), AWEA Green Power Superhighways (2009), Hogan Markets In a Low Carbon Future (2010), COMPETE Markets and Environmental Challenges (2014), ISO/RTO Metrics Report (2015), IRC Increasing Renewables Study (2007), LBNL Wind Technologies Market Report (2015), NREL Voluntary Green Power (2015)

While the scopes and objectives of some of these studies differ markedly from the requirements under SB 350, most of them estimate the cost savings and price impacts of regional market integration. This provides a useful reference point for the ratepayer impact analyses required under SB 350. Additional industry studies were reviewed in the context of regional markets' facilitation of renewable generation developments. These studies and the related industry data is discussed in Volume XI of this report.

C. Most Prospective Regional Market Integration Studies Show Production Cost Savings Ranging from 1% to 3%

The transition to regional markets impacts both investment-related (fixed) costs and production-related (variable) costs. The impact of regional markets on variable production costs has been studied extensively in many analyses from both a prospective (*ex ante*, before the fact) and

retrospective (*ex post*, after the fact) basis. The prospective studies we reviewed generally report production cost savings associated with transitioning to a regional market in the range of 1% to 3% of the system's total production costs. Note, however, that the magnitude of intermittent renewable generation present in the regions analyzed in most of these studies is well below the magnitude of existing and projected future renewable generation in California and the WECC.

These studies typically use production cost models to simulate a "Without Regional Market" (or "Smaller Regional Market") case to compare with a "With Regional Market" case. Savings are then estimated based on the difference between the two cases' production costs. The market design features that are simulated to represent the "Without Regional Market" and "With Regional Market" cases differ across the studies. The most common market design feature used to represent a "With Regional Market" case is to have a full "Day-2" market (consisting of integrated day-ahead energy, real-time energy, and ancillary services markets) in which the transmission charges are fully de-pancaked within the study region. The de-pancaking of transmission charges means that, within the regional market, energy transactions between the individual areas of the regional market are not subject to any variable transmission charges.[1]

Most of the production cost simulations do not incorporate uncertainties in load or generation between the time when conventional generation is committed (mostly on a day-ahead basis) and the real-time dispatch of these resources against load. A few of the studies differentiate between the day-ahead commitment time frame and the real-time market to capture the potential impact caused by unanticipated changes in load and generation between the two time frames. Some of the studies analyze the potential impact of more efficient utilization of the existing transmission system due to automated, security-constrained economic dispatch for the entire region. Collectively, these prospective studies embody a representative range of analytical approaches used to estimate production cost savings from regional market integration.

Figure 2 summarizes the features of the Regional Markets that are analyzed across various prospective studies and thereby represent the benefits that the various studies are able to capture through the production cost simulations. The last row in the figure shows the estimated production cost savings (as a percentage share of total production costs) reported by the studies.

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[1] In other words, while loads pay for transmission at the withdrawal point, they can be served from any resource within the region without incurring additional, transaction-specific transmission charges.

Figure 2: Market Features and Production Cost Savings Captured in Prospective Market Integration Studies (expressed as a % of system production costs)

Market Design Features Captured in Production Cost Savings	National RTO (2002) [1]	LBNL Review (2005) [2]	RTO West (2002) [3]	SPP Prospective (2009) [4]	Basin/ WAPA (2013) [5]	Entergy-MISO (2011) [6]	E3 PAC Integration (2015) [7]
Transmission Charge De-Pancaking	✓	✓	✓	✓	✓	✓	✓
Day-Ahead Market	no	✓	no	✓	✓	✓	✓
Full Real-Time Imbalance Market	✓	Varies	✓		✓	✓	Varies
Ancillary Services Market	no	Varies	✓	✓	no		Varies
Improved Transmission Utilization	✓	Varies	✓	no	no	✓	Varies
Generator Efficiency and Availability Improvements	✓	Varies	no	no	no	no	Varies
% Reduction in Total Production Costs	0.3%–5%	<1% to 8%	Not Reported	1.3%–2.0%	0.9%–2.1%	3.4%–3.8%	1.6%–3.6%

Sources and Notes:

[1]: The range represents savings in the "Transmission Only" scenario (de-pancaked transmission charges and increased transmission capacity) on the low end and "RTO Policy" scenario (includes 6% efficiency and 2.5% availability improvement for fossil units) on the high end. This study used a single-stage dispatch model to estimate benefits. It did not model unit commitment.

[2]: This was a study review report. Studies in the review modeled different market designs. Inter-quartile range of reported savings was 1%–3%. Some of the reviewed studies reported other savings in addition to production cost (*e.g.*, congestion revenues).

[3]: Study did not provide baseline production costs, so % savings could not be calculated.

[4]: Total production cost savings over 2009–2016 time horizon with low end of range from across case I (DA market-only) and high end from case IIB (DA + AS markets).

[5]: WAPA 'Enhanced Adjusted Production Cost" savings of joining SPP as a percentage of "Standalone" LMP-based charges. Range reflects 2013–2020 savings.

[6]: Range reflects Entergy adjusted production cost savings of joining SPP and MISO as estimated using production cost simulation. Savings do not include spinning and regulation reserve savings estimated using MISO's Value Proposition methodology.

[7]: This was a study review. Studies in the review modeled different market designs.

Of the studies summarized in Figure 2, two represented a review of several other analyses. Specifically, the LBNL Review Study (2005) reviewed 11 RTO studies from the early 2000s. From those studies reviewed, LBNL found that the reported production cost savings ranged from less than 1% to 8% of total production costs, though most of the reviewed studies reported

estimated production cost savings between 1% and 3%.[2] Further, the E3 PAC Integration Study (2015) surveyed several prior market integration studies and found that estimated production cost savings ranged from 1.6% to 3.6%.[3] Overall, these results show that the production cost benefits of regional market integration tend to range from 1% to 3%.

D. Limitations in the Analytical Approaches Used for Prospective Studies Tend to Underestimate the Benefits of Regional Markets

The prospective studies of regional markets' production cost savings commonly acknowledge that their analytical methodologies omit some of the benefits provided by regional markets. These studies generally underestimate benefits because they (1) do not capture the full production cost benefits of market integration, and (2) do not capture non-production cost related benefits. We first discuss common set limitations related to the deterministic approaches of the analyses and the fact that production cost simulations capture only fuel and other variable generation cost savings.

Most of the prospective studies reviewed put the estimated benefits into perspective by either (1) discussing limitations of their analytical framework which tend to understate the estimated production cost savings; or (2) discuss benefits beyond production cost savings that have not been quantified. We first summarize the types of production cost benefits that are not typically captured due to the limitations generally found in market simulation analyses. We later discuss the second set of limitations—that studies rarely estimate investment cost benefits, such as reductions in generation investments needed as a result of greater load and resource diversity across larger footprints.

Most prospective production cost studies tend to understate production cost savings due to one or more of the following limitations: (1) they simulate only normal system conditions; (2) they do not analyze the extent to which regional markets optimize the use of the existing grid; (3) they do not capture the impact of stronger incentives to improve plant efficiencies; and (4) they do not capture increased competition and improved market monitoring and mitigation. Regional markets additionally (5) improve system reliability, and (6) improve regional operational and system planning, which offers benefits not fully captured in production cost savings.

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[2] Eto and Hale (December 2005).

[3] Energy + Environmental Economics (October 2015)

1. Production Cost Simulations Typically Do Not Capture Cost Savings Associated with Non-Normal System Conditions

Most studies that rely on production cost models estimate savings only by simulating normal system conditions. This means that the simulated load generally is weather normalized without any potential large swings and differences in regional loads due to different weather conditions. In addition, transmission outages are not typically considered in the analyses. Both of these omissions were discussed in the Basin/WAPA study (2013). That study states that the production cost simulations used in its analysis will yield a conservative estimate of benefits because it does not address important aspects of actual market operations such as transmission outages, actual weather patterns that deviate from normal weather, and any load and generation uncertainties between day-ahead and real-time operations. Due to these limitations, simulation results will tend to underestimate the level of transmission congestion and the extent to which improved congestion management through a regional market with security-constrained economic dispatch can reduce overall production costs.

2. Markets Can Improve the Utilization of the Existing Transmission Grid by More than is Reflected in Production Cost Simulations

The RTO West Study (2002) suggests, but does not quantify, that an RTO would increase the effectively Available Transmission Capacity (ATC) over major transmission lines. The benefits associated with increased ATC are incremental to the production cost savings that result from de-pancaked transmission charges and region-wide security-constrained dispatch.[4] The Basin/WAPA study (2013) makes the qualitative point that—because congestion management based on point-to-point transmission reservations and the curtailment of scheduled transactions[5] is less efficient than how congestion is managed in production cost simulations—the savings associated with participation in an RTO would be underestimated.[6] Similarly, the Entergy SPP/MISO Cost-Benefit Analysis (2010) notes that the inefficiencies at the seam between the Entergy and the SPP systems in the "Not-Joint-RTO" case, if they were fully simulated, would increase the value of integration compared to model results.[7]

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4 Zobian, *et al.* (March 2002), at p. 49

5 Such curtailments are undertaking through "flow mitigation events" in the WECC and Transmission Loading Relief or "TLR" in the Eastern Interconnection.

6 Celebi, M., *et al.* (March 8, 2013), at p. 6

7 Charles River Associates and Resero Consulting (September 30, 2010).

The extent to which markets can utilize the existing grid more fully has been documented by analyzing how much of the available transmission capability remains unutilized in traditional bilateral markets. For example, an analysis of RTO market benefits by the U.S. Department of Energy (DOE) assumed that improved congestion management and internalization of power flows by ISOs result in a 5–10% increase in the effective transfer capabilities on transmission interfaces.[8] Similarly, a study of congestion management in MISO's "Day-1" market found that, during 2003, available flowgate capacities were underutilized by between 7.7% to 16.4% on average within MISO sub-regions during curtailment (so-called "TLR") events.[9] Our own analysis of unused capacity on WECC transmission paths during flow mitigation events similarly shows that between 5% and 25% of available transmission capabilities is left unutilized in the current bilateral market structure even at times when existing transactions are being curtailed.[10]

3. Production Cost Simulations Typically Do Not Capture Cost Savings Associated with Stronger Incentives to Improve the Efficiency and Availability of Power Plants

The stronger exposure to market forces of a regional market can lead to improvements in generator efficiency and availability. A number of studies have examined such efficiency improvements. As pointed out by the 2005 LBNL Review Study, operating within RTOs can create incentives for generators to invest in "enhancements or improvements to the efficiency" of existing generators.[11] The LBNL review noted that prospective studies typically do not capture such generator efficiency improvements because of the challenges of making assumptions about those efficiency improvements and benchmarking them against actual experiences.

An indication of possible plant efficiency gains is provided by several industry studies. For example, the Chan Efficiency Study (2012) used an econometric analysis to estimate the efficiency improvements in coal plants operated by investor-owned utilities over the period from 1991 through 2005 when restructuring policies were implemented and several regional

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8 U.S. Department of Energy, DOE/S-0138 (April 30, 2003), pp. 7–8 and 41–42.

9 McNamara, Ronald R., Docket ER04-691-000 (June 25, 2004), p. 14

10 See slide 167 of the CAISO stakeholder presentation, "Clean Energy and Pollution Reduction Act Senate Bill 350 Study: Preliminary Results," May 24, 2016, available at: https://www.caiso.com/Documents/Presentation-May24_2016-SenateBill350Study-PreliminaryResults.pdf

11 Eto and Hale (December, 2005), p. 40.

electricity markets were formed in the U.S. The study found that the efficiency of coal plants improved by 2%–3% in restructured states compared to non-restructured states.[12]

An increasing trend of power plant availability has been documented by various regional system operators as well. For example, the 2015 MISO Value Proposition report includes "Generator Availability Improvement" as a benefit of operating within the RTO and estimates its magnitude by using observed increases in availability since the start of market operations. The study found that availability improved by 1.5% from 2000 to 2014 and estimated associated annual savings of $210 million to $260 million per year. Other informal assessments, including ones conducted by the Electric Power Supply Association, NYISO, and Navigant, report increased power plant efficiency coincident with the introduction of markets.[13] The Navigant Markets Study (2009) reported that the availability of nuclear units operating in NYISO, MISO, and PJM had increased from 81% in 1996 (before regional markets were implemented) to 93% in 2007 (after Day-2 markets were established in all these regions.).

If these plant efficiency and availability gains materialize due to the increased transparency and competition of a regional market, the potential impacts on California and the rest of the WECC could be significant. While power plants in California are operating in such a market environment, the rest of the region is not. For example, the 2002 National RTO study evaluated a scenario featuring a 6% improvement in fossil generation efficiencies and a 2.5% increase in fossil unit availability. That study found that the assumed efficiency and availability improvements associated with market integration would reduce production cost by an additional 4.5%. While California generators are subject to strong market-based incentives, given California's dependence on imports, the state would benefit from the efficiency improvements across the WECC.

4. Organized Markets Can Increase Competition and Mitigate Uncompetitive Behavior, a Benefit Not Generally Captured by Market Simulations

Organized regional markets create price transparency in the wholesale market and thereby increase competition among generation and demand-side resources. The RTO West study (2002)

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12 Chan, *et al. (*August 2012).

13 Babcock, *et al.* (April 2009); EPSA (May, 2007).

notes that RTOs would reduce transaction costs, reduce overall production costs, and improve market liquidity.[14] Regional markets greatly facilitate the market monitoring of competitive behaviors and implementing mitigation practices. Anti-competitive practices tend to be less visible and more difficult to monitor and mitigate in a bilateral market construct.

Since production cost simulations typically represent existing systems as perfectly efficient systems without significant internal transactions costs (unless specifically added), the resulting comparisons commonly understate the potential competitive benefits of enlarging the regional markets. Production cost simulations generally assume fully competitive bidding behavior with bids reflecting true marginal costs. This does not capture the extent to which the additional competitive pressures and improved market monitoring that is present in larger-regional markets reduce bid-cost mark-ups and thus yield additional benefits.

5. Organized Markets Can Improve System Operating Reliability, a Benefit not Fully Captured by Production Cost Simulations

Region-wide coordinated outage planning, operations management, and real-time monitoring will improve system reliability. The value of such reliability improvements is not fully captured in the production cost simulations. Because of the challenges to fully reflect real-world conditions, the models typically simulate the region for normal system conditions, without transmission outages, and with perfect foresight of system conditions, generation outages, loads, and renewable generation levels. This will understate the benefits of a larger regional market and its ability to more efficiently and more quickly respond to forced outages, extreme events, and unexpected system conditions. The RTO West study (2002) notes that RTOs would improve reliability by allowing coordinated outage management, reducing failure propagation, improving outage restoration, voltage/frequency management, and loop/parallel path flow management,[15] but those benefits are above and beyond those captured by conventional analyses. Similarly, the LBNL Review study (2005) mentions that additional benefits (not usually quantified by prospective analyses) to forming RTOs include reliability benefits that stem from facilitating coordinated scheduling of maintenance outages, improving reserve procurement, and managing frequency and voltage in real time, and contingency response.[16]

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[14] Zobian, *et al.* (March 2002), at p. 53

[15] *Id.*, pp. 47-49.

[16] Eto and Hale (December, 2005), p. 38.

6. Regional System Operations Improve System Planning

More coordinated regional planning and operations can increase the value of regional transmission investments and allow resources across larger footprints to be used more optimally. This can help the region meet its public policy goals at lower costs and simultaneously avoid redundant transmission projects that aim to meet similar needs in different areas within the large region. The RTO West study (2002) discusses that RTO-level transmission planning would "elevate the system planning process from a narrow focus on local or subregional needs to a broader focus on regional needs, thereby reducing the cost of transmission for the larger footprint."[17]

E. Retrospective Studies of Regional Market Integration Document Benefits Higher than those Estimated in Prospective Studies

Several studies evaluated the benefits of implementing a regional Day-2 market on an after-the-fact basis. Because the retrospective studies use actual market performance data, the analyses are more likely to capture impacts of market integration. By contrast, analyses conducted prospectively need to make assumptions about how the eventual operation of the market would perform relative to the status quo, which requires simulating complex bilateral markets or suboptimal coordination across operations and planning. Further, most prospective production cost studies do not or cannot estimate certain benefits (as discussed above), thus underestimating the overall production cost benefits of market integration (and before even considering any investment cost savings). Figure 3 describes the market features evaluated by each retrospective study as well as the savings reported by each one.

Three of the retrospective studies we reviewed focused on production cost savings. While one of these studies estimated only the incremental benefit of transitioning from a zonal to a nodal Day-2 market (Wolak Nodal Study 2011), the other two studies (MISO Retrospective Study 2009 and SPP Retrospective Study 2015) evaluated the benefits of transitioning from no centralized markets (*i.e.*, only bilateral transactions facing pancaked transmission charges), to full regional Day-2 markets (*i.e.*, de-pancaked transmission, nodal markets, and consolidated balancing areas). These latter two studies estimated the full production cost benefits of forming Day-2 markets and found notably larger production cost savings than the prospective studies we reviewed.

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[17] Zobian, *et al.* (March 2002), at p. 52

The 2009 MISO Retrospective Study used econometric methods to estimate achieved generation cost savings based on actual market performance.[18] The study found that MISO's transition from "no centralized market" to a region-wide Day-2 market produced a 4% reduction in production costs. The study separately estimated the benefits of (1) moving from a bilateral market with pancaked transmission charges, to a regionally de-pancaked but still bilateral "Day-1" market; and (2) additionally consolidating balancing areas and implementing a nodal Day-2 market design with regional day-ahead, real-time, and ancillary services markets. The analysis showed that 'more than half of the overall benefits (2.6% out of 4%) were attributable to the transition from MISO's Day-1 market to its current Day-2 market design.

Similarly, a 2015 SPP Retrospective study of its Day-2 market performance used actual market bid offers and real-time load to estimate the savings during the first year of SPP's "Integrated Marketplace."[19] The results documented an 8% reduction in production costs attributable to SPP's transition from purely bilateral markets with pancaked transmission charges to its current Day-2 market design. SPP evaluated separately (1) the benefits captured by its initial energy imbalance services (EIS) market with fully de-pancaked transmission rates; and (2) those provided incrementally by the consolidation of balancing areas and its implementation of a nodal Day-2 market design with day-ahead, real-time, and ancillary service markets. The SPP study found that, out of the 8% in total production cost savings from regional market integration, more than half (4.8%) is attributable to the transition from SPP's EIS imbalance market to the full Day-2 market design.[20] SPP resembles WECC (on a smaller scale) with a mix of natural gas, coal, and renewable generation, major load centers in one portion of the footprint (the southeast), and distant areas with low-cost renewable generation (the Great Plains).

The authors of the LBNL Review Study (2005) made a similar observation when they reviewed 11 prospective and retrospective market integration studies conducted in the early 2000s. They observed that retrospective studies would more accurately capture the value of RTO formation and discussed that many potentially much larger benefits (and costs) of RTO formation were not

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18 Reitzes, *et al.* (October 1, 2009).

19 Davis (April, 2015).

20 In contrast to the EIM, SPP's Energy Imbalance Service (EIS) market was a fully de-pancaked market (including bilateral transactions) and made use of all available transmission.

captured by prospective production cost modeling. They recommended that retrospective studies "should become the standard for assessing the impacts of FERC's policies."[21]

Two other retrospective studies more narrowly focused on the benefits of changing from a zonal Day-2 market to a nodal market design. The Wolak Nodal Study (2011) estimated production cost savings for the CAISO footprint to transition from a de-pancaked zonal market (with a bilateral day-ahead market, a real-time imbalance market, and an intra-zonal congestion management process) to a full nodal market with integrated day-ahead, real-time, and ancillary services markets. The study used econometric techniques to estimate improvements in the efficiency of the 258 natural gas power plants in the California ISO associated with the new nodal market design and found that the efficiency of these units increased by 2.5%—leading to a 2.1% reduction in the variable cost of CAISO generation (after controlling for changes in gas prices).

Similarly, the ERCOT Nodal Study (2014) estimated the effect of ERCOT's transition from a zonal market (with a bilateral day-ahead market) to a nodal market structure with integrated day-ahead, real-time, and ancillary-services markets. Using a regression analysis to control for changes in load, price caps, natural gas prices, and the treatment of congestion costs, the authors estimated that implementing the nodal market resulted in a 2% reduction in real-time energy prices.

The MISO Value Proposition (2015) is an annual assessment of the overall benefits to MISO market participants. Taking advantage of data from the operation of its markets, the study estimates a number of different benefits ranging from improved reliability, dispatch of energy, regulation, spinning reserves, wind integration, compliance, footprint diversity, generator availability improvement, and demand response integration. The most recent 2015 study reported annual net benefits (net of MISO operating costs) to market participants ranging from $2.1 billion to $3.0 billion per year.

The Mansur PJM Efficiency Study (2012) examined the expansion of the PJM footprint to include the AEP and Dayton control areas that occurred in October 2004. Prior to the expansion of the footprint, these regions had traded electricity via bilateral arrangements. However, the study authors observed that the more effective matching of buyers and sellers facilitated by

[21] Eto and Hale (December, 2005), p. 37.

PJM's formal markets increased the volume of trade by a factor of three. Additionally, the authors found that the total gains from trade (*i.e.*, the total reduction in production costs compared to a scenario with no trading) were 48% ($163 million in the first year) higher under organized markets compared to bilateral markets.[22]

Figure 3 summarizes the results of the reviewed retrospective market integration studies. The studies report different savings metrics, although many focus on production cost savings. As shown, production cost savings range from 1.4% (for moving to a de-pancaked bilateral Day-1 market in MISO) to 8.0% (for moving from pancaked bilateral markets to consolidated balancing areas with nodal markets in SPP). Other retrospective studies reported decreased wholesale power prices, improved generating plant availability, and improved generating plant efficiencies (heat rates) associated with regional market integration.

[22] Mansur and White (January, 2012).

Figure 3: Market Formation Benefits as Reported By Retrospective Studies

Study	Region	Metric	Savings
MISO Retrospective Study (2009)	MISO	Production Cost Savings	1.4% Implementing a regional, de-pancaked bilateral market + 2.6% Consolidating BAs and implementing nodal DA, RT, and AS markets = 4.0% Total
SPP IM Retrospective Study (2015)	SPP	Production Cost Savings	3.2% Implementing a de-pancaked regional imbalance energy market (EIS) + 4.8% Consolidating BAs and implementing nodal DA, RT, and AS markets Markets), = 8.0% Total
MISO Value Proposition Report (2015)	MISO	Reduced production costs, generation investment needs, wind integration cost; improved reliability; net of MISO costs	Total of $2.1–$3.0 Billion/year
Wolak Nodal Study (2011)	CAISO	Production cost savings	2.1% Moving from de-pancaked zonal Day-2 market to full nodal DA, RT, and AS markets
ERCOT Nodal Study (2014)	ERCOT	Wholesale power price reductions	2.0% Moving from de-pancaked zonal Day-2 market to full nodal DA, RT, and AS markets
Navigant Markets Study (2009)	PJM, MISO, and NYISO	Improved Availability of Nuclear Units and Heat Rates of Large Coal Units	Nuclear Unit Availability Increased from 81% to 93% and Large Coal Unit Heat Rates Improved by 9.4% from 1998 to 2007
Chan Efficiency Study (2012)	U.S.	Improved Heat Rates of Large Coal Units	2%–3% increase in restructured markets compared to non-restructured regions
NYISO Plant Efficiency Study (2009)	NYISO	Improved Heat Rates of Fossil Fueled Units	21% Improvement in market-wide heat rates from 1999 to 2008
Mansur PJM Efficiency Study (2012)	PJM	Gains from Trade	Gains from trade were 48% higher in an organized market compared to a bilateral market

F. In Addition to Reducing Production Costs, Regional Markets Can Reduce the Need for Generating Capacity and Associated Investment Costs

By diversifying load fluctuations across a larger region, market integration reduces the total generation capacity needed to meet regional peak demand and assure resource adequacy under adverse system conditions. This reduces the generation investment cost of ensuring resource adequacy. Several of the reviewed studies quantitatively estimated this benefit and several

discuss the benefit in a qualitative manner. Figure 4 summarizes the capacity savings reported in three studies that made a detailed assessment of the load diversity capacity savings enabled by regional markets. The savings range from 0.6% of peak load (savings to CAISO of PacifiCorp joining a regional market) to 8% of peak load (savings to PacifiCorp of joining a regional market with CAISO). Several studies reported savings ranging from 6% to 8% of peak load.

Figure 4: Load Diversity Capacity Savings in Other Studies

Study	Reported Capacity Reduction (% of Peak Load)	Note
MISO 2015 Value Proposition[1]	**6%–7%**	Capacity savings to all MISO members of participating in the RTO market
Entergy-MISO(2011)[2]	**6%**	Capacity savings to Entergy of joining MISO
E3 PAC Integration (2015)[3]	**0.6% (ISO)** **8% (PAC)**	Capacity savings with an integrated market consisting of the California ISO (ISO) and PacifiCorp (PAC)

Sources and Notes:

1. MISO (January 21, 2016).
2. Entergy (May 12, 2011).
3. Energy + Environmental Economics (E3) (October, 2015).

In the MISO 2015 Value Proposition Report, a retrospective analysis, MISO estimates that the investment cost savings achieved by its members are equivalent to reducing the region's capacity requirements by 9,300 MW to 11,250 MW (6% to 7% of peak load), compared to balancing areas assuring resource adequacy individually in the absence of a regional market. The value of those savings is estimated at $1.2–$2.0 billion per year in the entire MISO market.[23]

The National RTO Study (2002) estimated the value of resource adequacy by assuming that RTO formation would reduce planning reserve margins across the country from 15% to 13%, with an associated reduction in generation capacity requirement of approximately 2%.[24] Translating these investment cost savings to annualized cost reductions, they are equivalent to an approximately 1.6%–2.5% additional decrease in total production costs.[25]

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23 MISO (January 21, 2016).

24 ICF (February, 2002), p. 37

25 Because total investment costs are not available in most studies, we report investment cost savings as a percentage of total *production costs* in order to enable comparison across regions.

The Entergy-MISO Study (2011) applied the MISO resource adequacy framework to estimate the investment cost savings of joining the RTO. Entergy compared the reserve margin it required as a standalone entity (17%–20% over the study period) to the effective reserve margin of approximately 12% of its internal peak load that it would need to hold as a MISO member. The reduction in planning reserve margin reflects the load diversity benefit between the original MISO and Entergy systems. Entergy's estimated reduction in generating capacity needs was approximately 1,400 MW or 6% of Entergy's peak load.[26] Entergy estimated the value of such savings to be approximately $35/kW-year or $49 million per year, equivalent to an additional 1.3% reduction of total production costs. In 2015, after joining MISO, Entergy confirmed that the anticipated capacity savings had in fact been achieved.[27]

Similarly, the E3 PAC Integration study (2015) estimated the value of load diversity between PacifiCorp and CAISO by calculating coincidence factors between the loads of the two entities. The study determined that PacifiCorp's capacity needs would decrease by up to 900 MW (approximately 9.5% of PacifiCorp's peak load), but that the savings to PacifiCorp would be limited by the 776 MW of available transmission capacity from California when integrated with CAISO. The study estimated that PacifiCorp's' reduced generation capacity need of 776 MW represented approximately 8% of PacifiCorp's internal (non-coincident) peak load. Similarly, the estimated generation investment savings for the CAISO footprint are 284 MW, which represents approximately 0.6% of the CAISO's internal (non-coincident) peak.[28] The associated annual cost savings of $90 million/year are equivalent to approximately 0.5% of the total CAISO plus PacifiCorp annual production costs.

Load diversity benefits were discussed in the RTO West Study (2002) as well. While it did not estimate the value of generation-related investment cost savings, it recognized that "As the [participation in] RTO results in lower capacity requirements, benefits will be recognized in the long run through reduced need for additions to generating capacity."[29] Similarly, the

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[26] Entergy also performed a similar calculation for the case of joining SPP, which we do not report here.

[27] Entergy (August, 2015).

[28] Based on PacifiCorp and CAISO 2024 peak loads of 9,550 MW and 47,000 MW.

[29] Zobian, *et al.* (March, 2002), p. 52.

Basin/WAPA Study (2013) noted that ISO-membership would have resource adequacy benefits in addition to the quantified production cost savings.[30]

G. Market Integration Can Improve Access to Low-Cost Renewable Resources and Reduce the Investment Cost of Meeting RPS Goals

In the context of ambitious renewable generation targets, gaining access to lower cost and higher-quality renewable resources through a regional market can significantly reduce the capital costs necessary to comply with those public policy goals. By enabling renewable generators to access a larger market, regional markets can reduce the need to curtail renewable generation output during times of high output, thus further reducing renewable capacity by avoiding the "over build" that would be necessary to offset the curtailed production.

Both MISO and SPP have shown that their larger footprints allow the regions to access lower-cost renewable energy resources to help meet various states' public policy goals. Specifically the high-capacity-factor wind resources in western MISO and SPP allowed the utilities and other buyers in the regions' footprint to access lower-cost renewable resources to meet their procurement preferences or requirements under the various states' RPS. In fact, the low cost and high quality of wind resources in the Great Plains means that these resources have (with the help of production tax credits) become competitive with conventional generation such that some utilities and other buyers are entering into renewable energy contracts well beyond those needed to comply with their states' RPS.

The LBNL Wind Technologies Market Report (2014) documents trends in wind installations and the cost of Power Purchase Agreements across the country and over time.[31] The report discusses that SPP's 2014 market integration and consolidation of its balancing areas helped the SPP states access the high-quality wind resources in the Great Plains. The report notes that the now completed Texas Competitive Renewable Energy Zones (CREZ) transmission projects will enable 18,500 MW of low-cost wind development in the state—much of which is constructed or under construction. Furthermore, the additional transmission and an improved regional market design helped to balance wind generation more effectively. ERCOT was able to reduce wind curtailments from 17% of total wind generation in 2009 to 1.2% in 2013. The reduced

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30 Celebi, *et al.* (March 8, 2013), p. 5.

31 Wiser and Bolinger (August, 2015).

curtailments mean that less renewable generating capacity is needed to produce a particular amount of renewable energy production.

Similarly, the E3 PAC Integration study (2015) included in its estimated market integration benefit the savings associated with California's ability to access lower-cost renewable resources in PacifiCorp's balancing areas. The authors found that the low-cost and high-quality Wyoming wind would allow California to reduce the cost of meeting its RPS requirements while providing resource diversification benefits. The study found that the annual value of accessing the lower-cost resource would be range from $150 to $750 million per year, the equivalent of 1%–4% of the combined region's total production costs.

Additionally, the E3 PAC Integration study (2015) estimated investment cost savings associated with reduced renewable generation curtailments. These investment cost savings are associated with avoiding the construction of renewable generation capacity that otherwise would be needed to make up for the curtailed renewable output. The study estimated the additional investment cost benefits of this "More Efficient Over-Generation Management" to range from $50 to $220 million/year, which is equivalent to approximately 0.3%–1.0% of the combined footprint's production costs.

The MISO Value Proposition (2015) likewise estimated the value of access to the higher-quality wind resource enabled by its regional market. MISO estimated the capacity cost savings of providing access to higher-quality resources by comparing the actual capital cost of developing wind in MISO to the cost of meeting state renewables mandates with lower-quality local wind resources. The value proposition deducts the incremental cost of transmission required to reach the low-cost wind resources from the estimated benefits, concluding that the regional market creates $316–$377 million/year in annual renewable capacity cost savings, a benefit the RTO labels "wind integration."

While the specific assumptions made in these analyses differ across the studies, they uniformly show that regional markets facilitate both the access to and integration of low-cost renewable resources, providing investment cost savings to the entire regional footprint. The studies find that is the case even after netting out the cost of transmission investments that may be associated with providing access to low-cost renewable resources in certain locations.

H. Regional Markets Reduce the Cost of Balancing Variable Renewable Generation Output

The geographic and resource diversity of renewables generation across large regional markets can significantly reduce the overall variability of generation and the quantity of flexible fossil generators and other resources needed to balance the system. In addition to this "quantity benefit," the ability to use the most economic flexible resources across the larger region to provide these balancing services reduces production costs even further.

Regional market integration increases the flexibility of the grid and its ability to "absorb" and "balance" renewable energy. Using this analogy, it is useful to examine how the CEERT/NREL Low Carbon Grid Study (2016) analyzed the value of a flexible grid for accommodating high renewable generation targets in western states. The CEERT/NREL study simulated increased flexibility by allowing WECC-wide resources to satisfy California's RPS, allowing the region's hydro facilities to provide ancillary services, and allowing California to meet more of its load with external resources. While the Low Carbon Grid Study did not specifically analyze the impacts of a regional market, the study's "increased flexibility" assumptions are fully consistent with the typo of increased flexibility that is provided by a regional ISO-operated market.

The Low Carbon Grid Study has many parallels with the SB 350 study. The CEERT/NREL study evaluated scenarios achieving a 50% reduction in carbon emission of the California electricity-sector by 2030. The study also evaluated scenarios with very high renewables penetrations (averaging 56% for supplying California loads) and additional energy efficiency. The CEERT/NREL study modeled the retirement of all California-contracted (out of state) coal plants in meeting the emissions reduction target. Additionally, the study considered additional sensitivity cases, for example, Dry Hydro, High Solar, and High WECC RPS.

Figure 5 shows annual electric sector CO_2 emissions in California and all of WECC in four of the scenarios presented in the Low Carbon Grid study: Baseline Enhanced (33% renewables with additional flexibility), Baseline Conventional (33% renewables with status quo flexibility), Target Enhanced (56% renewables with additional flexibility), and Target Conventional (56% renewables with status quo flexibility). In both the 33% Baseline and the 56% Target cases, enhanced flexibility reduced CO_2 emissions. Emissions assigned to imports actually increased with flexibility, but were offset by larger reductions in emissions from California gas generation. The emissions reductions due to enhanced flexibility were substantially larger in the 56% renewable scenarios.

Figure 5: Annual Carbon Accounting, in Million Metric Tons
Table 10 in the CEERT/NREL Low Carbon Grid Study (2016)

Scenario	CO_2 from CA gas generators	CO_2 assigned to imports and exports	CO_2 assigned to CA load	Change in assigned California CO_2 emissions compared to Baseline	Total WECC CO_2 emissions	Change in WECC CO_2 emissions compared to Baseline
Baseline Enhanced	67.7	6.7	74.4	-	380.9	-
Baseline Conventional	68.9	6.3	75.2	0.8	381.0	0.2
Target Enhanced	43.7	-2.5	41.1	-33.2	345.1	-35.8
Target Conventional	48.9	-3.9	45.0	-29.4	349.3	-32.4

Sources and Notes:

Brinkman, *et al* (January, 2016), Table 10.

Original notes:

Exports in this context include both net exports and specified imports that are not imported. This is zero-carbon energy that is sold out of state.

Total WECC emissions not only include the western United States but also parts of Mexico and Canada (Alberta and British Columbia).

Unspecified imports and exports are assumed to have a 0.432 MT/MWh carbon penalty (or credit). Unspecified imports from the Northwest have a penalty of 20% of 0.432 MT/MWh, which is consistent with the California Air Resources Board 2012 assumptions (CARB 2014) and the California ISO LTPP modeling (Liu 2014). CARB uses 0.022 MT/MWh for data year 2015.

In terms of costs, the study found that increasing grid flexibility through market integration reduced WECC-wide production costs by approximately $600 million/year (2.1% of total production costs) for the 56% California renewable requirement scenario, with $550 million in California savings related to the production, purchase, and sale of electricity for serving California loads. The WECC-wide production cost benefit of increased flexibility was $100 million/year for the 33% RPS scenario, demonstrating that savings are much higher in scenarios with high penetrations of renewables. The study found that increased flexibility reduced carbon emissions in California and in the rest of WECC. This shows that increasing system flexibility significantly reduces operating costs under a high renewables scenario while facilitating emissions reductions. Figure 6 summarizes the study's WECC-wide production cost savings and California emissions reductions of improved flexibility at renewables penetrations of 33% and 56%.

Figure 6: Production Cost Savings and Carbon Emissions Reductions of "Enhanced Flexibility" at 33% and 56% CA Renewables Penetrations

CEERT/NREL Low Carbon Grid Study (2016)

	Renewables Penetration	70% Import Requirement for CA RPS Resources	Limited Ancillary Services from Hydro	Minimum 25% Energy from Local Thermal and Hydro in CA BAs	Total WECC Production Cost ($ millions)	California CO_2 Emissions (million metric tons)
Baseline (33% CA RPS), Conventional Flexibility [1]	33%	✓	✓	✓	$33,760	75.2
Baseline (33% CA RPS), Enhanced Flexibility [2]	33%				$33,660	74.4
Estimated Production Cost Savings and CA emissions reductions of Regional Markets with 33% California Renewables as Difference between [1] Conventional Flexibility Case (as approximation of bilateral markets) and [2] Enhanced Flexibility Case (as approximation of an ISO-operated regional market)					***$100 0.3%***	***0.8 1%***
Target (56% CA renewables), Conventional Flexibility [3]	56%	✓	✓	✓	$29,430	45.0
Target (56% CA renewables), Partially Enhanced Flexibility [4]	*56%*		✓	✓	*$28,990*	*42.3*
Target (56% CA renewables), Enhanced Flexibility [5]	56%				$28,820	41.1
Estimated Production Cost Savings and CA emissions reductions of Regional Markets with 56% California Renewables as Difference between [3] Conventional Flexibility Case (as approximation of bilateral markets) and [5] Enhanced Flexibility Case (as approximation of an ISO-operated regional market)					***$610 2.1%***	***3.9 9%***

Sources and Notes: Results from selected scenarios in the CEERT/NREL Low Carbon Grid Study (2016). Renewables penetration for the non-California portion of WECC in the above scenarios was 16%. CO_2 emissions in the rest of the WECC (not shown in figure) also declined when flexibility improved in both the 33% and 56% renewables cases.

The Western Wind and Solar Integration Study No. 2 (NREL/DOE WWSIS-2 2013) similarly estimated the likely range of savings associated with a reduction in resource variability due to increased geographic diversity in wind and solar generation. The study quantified the resource variability before and after accounting for geographic diversity and found that diversity can dramatically decrease the collective resource variability thereby decreasing the amount of flexible resources needed to balance the system at high renewable deployment levels. The study found that aggregating distributed rooftop PV in southern California reduced variability (as measured by the coefficient of variation of hour-over-hour changes in output) from 4% to 3%

after approximately 3,000 MW were aggregated. The study found that wind variability dropped even faster—from 9% to 2% after approximately 2,000 MW were aggregated.

SPP's recent (2016) Wind Integration Study similarly evaluated the impacts of 30%–60% wind generation in the SPP footprint. The study did not attempt to quantify the wind integration value of its recently-implemented Day-2 market design, but highlighted several ways in which the market is already facilitating the integration of high levels of renewables. The study identified several enhancements that would allow very high penetrations to be achieved in the future and confirmed that the new transmission projects identified through the RTO's recent transmission planning process would be critical in providing access to the high-quality, low-cost wind resources located in the southwest portion of the footprint. It further determined that SPP has sufficient ramping capability to accommodate its projected growth in renewables generation (SPP experienced real-time wind generation equal to 40% of its system-wide load). SPP notes that, as more wind generation is added over the longer-term, the introduction of additional ancillary services may be necessary to provide added flexibility.

The Western Governors' Association's Renewable Integration Challenge study (WGA Integration Study 2012)[32] similarly discussed a number of options for facilitating the integration of renewables in the West. Several of the options include the operation of an integrated market across WECC. As explained in the study, a WECC-wide regional market would include the operation of sub-hourly dispatch and intra-hour scheduling, increased geographic diversity supported by new transmission, and increased reserve sharing—all of which would help to lower the cost of integrating renewable resources.

I. BENEFITS OF REGIONAL MARKET INTEGRATION ARE CONFIRMED BY THE EUROPEAN EXPERIENCE WITH HIGH RENEWABLE GENERATION

The European experience is helpful in documenting the role of regional markets, particularly with respect to integrating increasing amounts of renewable generation. In Europe, the integration of renewable generation is seen as a key pillar to the region's broader energy and climate objectives in reducing emissions, improving security of supply, diversifying energy supplies, and improving Europe's industrial competitiveness. Many European countries have

[32] Western Governors' Association (June, 2012).

high shares of renewable generation and ambitious goals to further increase renewable generation in the next decades.

Germany's share of renewable generation exceeds 30% on an annual basis and reached a high of 83% on August 23, 2015.[33] Because most of Germany's solar power generation is associated with distributed solar installations in southern Germany while most of Germany's wind generation is located in northern Germany and the North Sea, these locational differences create substantial north-south power flows through Germany and its neighboring countries[34] that require close coordination. Such issues are among the motivations for market-integration efforts, such as a European Union-wide "market coupling."[35]

The experience in Denmark serves as another illustration of managing high renewables penetration.[36] In January 2014, wind generation provided 62% of Denmark's monthly power demand, with that share reaching 105% on January 19, 2014. The ability to manage this level of renewable power generation operationally has been attributed primarily to Denmark's strong integration with the neighboring grids of Europe, including the well-developed region-wide Nord Pool markets (Nordic and Baltic day-ahead and intraday markets). Through Nord Pool, Denmark is part of a large market with significant resource diversity (including hydro resources in Sweden and Norway), which means Denmark can buy freely from, and sell power to, its neighbors in order to balance its high renewable generation levels.

The DNV-GL European Renewable Integration Study[37] (2014) finds that having a regional market has become increasingly important to support the integration of higher levels of renewable generation due to its ability to increase system flexibility and security of supply through the exchange of energy between the regional submarkets. This reduces the overall amount of conventional generation capacity required in the system—thereby reducing total system-wide costs.

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33 Graichen, Kleiner, and Podewils (January 7, 2016).

34 Weixin Zha, Marke Strzelecki (July, 2015).

35 Baritaud and Volk (2014).

36 Martinot and White (January, 2015).

37 DNV-GL (June 12, 2014).

Similarly, the EPRG European Market Integration study (2015) evaluated potential savings from integrating the existing country-level electricity markets.[38] The proposed single European market platform, known as Euphemia, would lead to increased utilization of and price convergence across international transmission interties. The proposal would couple the country-level European markets at the day-ahead, intraday, and real-time horizons. (Day-ahead coupling has already been implemented.) The study estimated that the benefits of market coupling were approximately €3.3 billion per year, equivalent to 2% of the total value of wholesale electricity. Approximately one-third of these benefits were estimated to be achieved by day-ahead integration, intraday integration, and region-wide real-time balancing.

In addition to the direct economic impact of reducing price divergence across interties, the study qualitatively discussed some of the value of coordinated European markets. These included pressures to reduce costs and innovate, improved liquidity in markets, and potentially reduced environmental impact. Additionally, increased coordination should lead to increased reliability.

[38] Newbery, Strbac, and Viehoff (February, 2015J).

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