

Selected U. S. Studies on the Costs and Benefits of Consolidating Balancing Authorities

美国关于整合平衡区的成本收益研究

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Larger Balancing Areas Improve the Ability to Manage Variability

扩大平衡区可提高波动性管理能力

- The pooling of load, wind, and solar power into a larger balancing area results in less per-unit variability because of the diversity of load, wind and solar.
负荷、风能、太阳能汇集到更大平衡区，由于多样性增加导致单位变化减少。
- Consolidating balancing areas and sharing the variability of the wind and load forecast errors across a broader region provides a natural aggregation impact.
合并平衡区、在更大区域分担风电的波动和负荷预测误差，会产生自然加合效应。
- Aggregation reduces the per-unit variability of the net load that must be met by the conventional generation fleet.
加合使得净负荷的单位变化减少，而对这些变化的管理通常需要传统发电来解决。
- A larger balancing area increases access to a broader resource mix, therefore increasing ramping capability.
更大的平衡区会增加资源的多样性，因此可以加强调节能力。

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- The ramping capability of multiple balancing areas is the sum of the ramping capability of each balancing area. Therefore, the need for ramping increases less than linearly, while the ramping capability increases linearly.

多平衡区的调节能力是单个平衡区的加总。因此，调节需求低于线性增长，但是调节能力却以线性增长。

- Because wind and solar increase net-load variability, the benefits of balancing area consolidation/coordination increase with wind and solar penetration → however, there are strong benefits to consolidation/coordination even in the absence of wind and solar.

因为风能和太阳能增加净负荷波动性，平衡区合并/协调有利于大规模风能和太阳能并网→即使不存在太阳能和风能并网问题，平衡区合并/协调仍然有很大益处。

Background 背景

- There are two means of consolidating balancing areas: 整合平衡区有两种方法:
 - Physical consolidation, where the number of balancing areas are reduced and day-ahead scheduling, unit commitment, or ancillary services are partly or fully combined and provided across the consolidated footprint. 实体合并：平衡区数量减少，日前发电计划、机组组合、辅助服务部分或全部合并，并为整个合并区域提供服务。
 - Virtual consolidation, whereby balancing areas **are not** consolidated but certain functions are shared across multiple balancing areas, such as area control errors or energy imbalances. 虚拟合并：平衡区并没有合并，但是某些功能会在多个平衡区中共享，例如管理区域控制误差或电能失衡。
- This presentation summarizes three recent cost and benefit studies related to balancing area consolidation/coordination conducted by the Midwest ISO, the Western Electric Coordinating Committee (WECC), the National Renewable Energy Laboratory (NREL) and the Southwest Power Pool . 这个报告总结了最近三个关于平衡区合并/协调的成本收益研究。分别由中西部独立系统运营商（MISO）、西部电力协调委员会（WECC）、国家可再生能源实验室（NREL）和西南电力库（SPP）完成。

Midwest ISO (MISO)

中西部独立系统运营商 (MISO)

- MISO is a regional transmission organization (RTO) that encompasses all or most of North Dakota, South Dakota, Nebraska, Minnesota, Iowa, Wisconsin, Illinois, Indiana, Michigan and parts of Montana, Missouri, Kentucky and Ohio. MISO是一个区域输电组织（RTO），它的业务范围包括全部或大部分北达科他州、南达科他、内布拉斯加、明尼苏达州、衣阿华州、威斯康星州、伊利诺伊州、印第安纳州、密歇根州，以及部分蒙大拿州、密苏里州、肯塔基州和俄亥俄州。
- MISO annually evaluates the benefits of being a regional RTO as compared to multiple individual balancing authorities. Below are MISO's **DRAFT** estimates for 2011: MISO 每年评估区域输电组织相对于多个单独平衡机构的好处。以下是它的2011年初步评估结果：
 - Between \$199 and \$219 million annually in benefits from improved commitment and dispatch. 每年因改善机组组合和调度能带来1.99-2.19亿美元的收益
 - A reduction in regulation from 1,126 MW to 396 MW, resulting in \$176 to \$195 million in annual benefits. 调节资源从1,126 MW 降至 396 MW，年收益1.76-1.95亿美元
 - A reduction in spinning reserves from 1,143 MW to 932.9 MW, amounting to \$51 to \$56 million in annual benefits. 旋转备用从1,143 MW 降至 932.9 MW，年收益5100-5600万美元
 - A reduction in planning reserve margins from 17.4% to 12.06%, resulting in annual benefits between \$785 and \$942 million. 计划备用从17.4% 到 12.06%，年收益7.85-9.42亿美元

Western Wind and Solar Study and WECC Energy Imbalance Market

西部风电和太阳能并网研究--以及WECC电能失衡市场

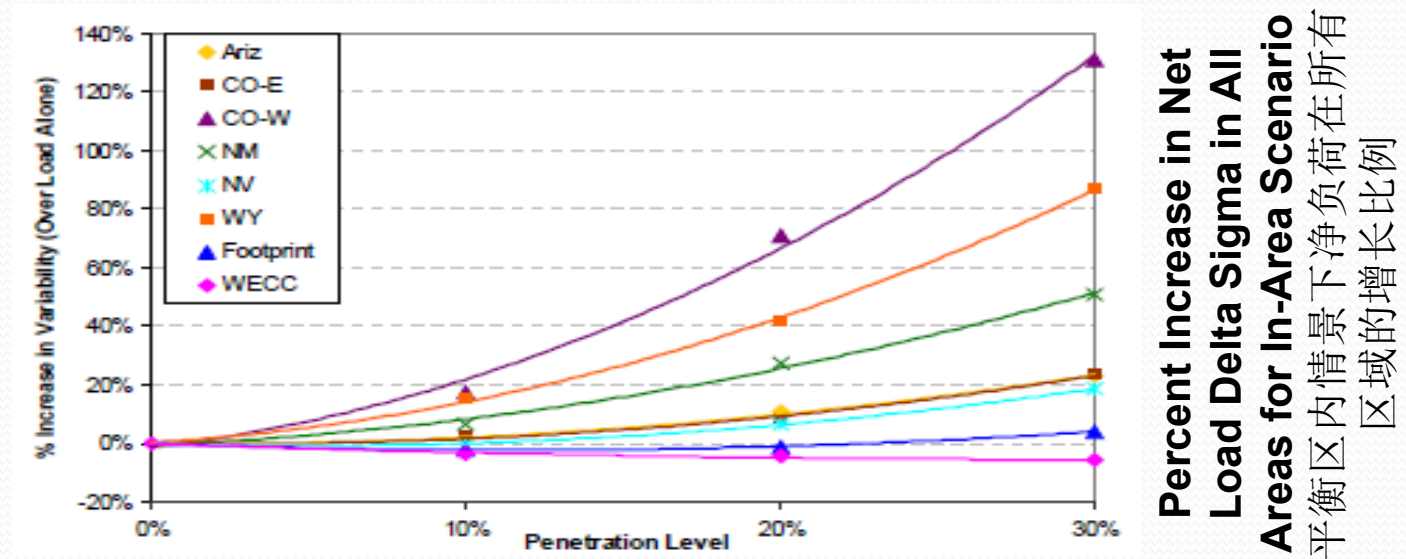
- The *Western Wind and Solar Integration Study*, produced by GE Energy and NREL in 2010, compared variability within individual states with the WestConnect footprint and WECC level, for three levels of variable generation penetration.

西部风电和太阳能并网研究（GE能源和NREL，2010），对比了在WestConnect系统和WECC范围内，三种穿透率情景下，可变发电在各州的变化性

- Found that the variability for small areas increases significantly as renewable penetration increases, while there is only a slight increase in variability with increased renewables penetrations when balancing areas are aggregated.

发现随着可再生能源比例提高，小平衡区的波动性显著提高；然而当平衡区增大时，新增可再生能源仅会引起系统波动性的少量增加。

Western Wind and Solar Study and WECC Energy Imbalance Market (cont.) (续)



- The *Western Wind and Solar Integration Study* also found cost savings resulted from balancing area consolidation, because reserves can be pooled instead of acquired on an individual balancing area basis. 此项研究还发现平衡区合并能节省成本，因为备用资源可以从一个共享的大资源库获取，而不必依靠单个小平衡区。
 - Results show \$2 billion (\$1.7 billion in 2009) savings in WECC operating costs, in their case with 10% wind penetration. 结果表明在10%风电比例下，WECC运营成本可节省20亿美元（2009年17亿美元）。
 - Significant savings accrued from sharing reserves over larger regions, irrespective of the amount of renewable energy on the grid. 在更大区域分享备用，还可以带来与可再生能源无关的大规模成本节省。

WECC Efficient Dispatch Toolkit

WECC 高效调度工具包

- The proposed WECC Efficient Dispatch Toolkit would create a voluntary Western Energy Imbalance Market and a Congestion Re-Dispatch Service, and is currently being studied by WECC. 所提议的高效调度工具包，希望建立一个自愿性的西部电能失衡市场以及拥堵再调度服务。WECC正在对此开展研究。
- This presentation focuses on the proposed WECC Energy Imbalance Market. 本报告着重讲WECC电能失衡市场。
- The proposed Energy Imbalance Market would essentially create a virtual balancing area across the Western Interconnection, excluding Alberta and the area served by the California Independent System Operator, as both already have energy markets. 所提议的电能失衡市场本质是建立一个虚拟的横跨西部互联电网的平衡区，不包括阿尔伯塔和已经有加利福尼亚独立系统运营方提供服务的地区，因为这些地区已经有电能市场。
- The proposed Energy Imbalance Market would not result in regional unit commitment, and local balancing areas would still procure regulation. 所提议的电能失衡市场不要求大区域范围内的机组组合，且平衡区仍然需要购买调节资源。
- Benefits would be greater if regional unit commitment and regulation procurement were also included. 若包括区域范围内的机组组合和调节资源购买，收益则会更大。

WECC Efficient Dispatch Toolkit (cont.)

WECC 高效调度工具包（续）

- Overall regulation requirements are still expected to decline because of the setting of energy imbalances region-wide, instead of by balancing area. 由于电能失衡区域范围的扩大，每个平衡区的调节资源需求还是会减少
- The proposed Energy Imbalance Market would aggregate the variability of generation and load over many balancing areas, lowering the amount of load-following reserves needed. 提议的电能失衡市场将对多个平衡区的发电和负荷变化进行加合，从而减少所需要的负荷跟踪备用量。
- The proposed Energy Imbalance Market would also allow market participants to use the lowest cost generation to balance loads and generation across multiple balancing areas. 提议的电能失衡市场还可以使市场参与者能够利用多个平衡区中的最低成本发电实现负荷和电力平衡。

Cost-Benefit Analysis of Proposed WECC Energy Imbalance Market WECC 电能失衡市场的成本收益分析

- A WECC cost-benefit analysis projected \$141 million in total savings from the Energy Imbalance Market for 2020. WECC成本收益分析预测，通过电能失衡市场，2020年可实现1.41亿美元的成本节约。
 - \$10 million is from EIM-wide procurement of reserves
其中1000万美元来自EIM范围的备用资源购买。
 - \$90 million is from a reduction in the amount of reserves that are needed.
9000万美元来自备用资源需求量的减少。
 - \$42 million is from greater dispatch efficiencies.
4200万美元来自调度效率的提高。
- Because participation in WECC's proposed Energy Imbalance Market is voluntary, projected benefits are contingent on which balancing areas participate. 由于提议的WECC电能失衡市场是自愿参与的，所估计的收益能实现多少，取决于平衡区参与的情况。

Cost-Benefit Analysis of Proposed WECC Energy Imbalance Market (cont.) WECC 电能失衡市场的成本收益分析（续）

- Removing balancing areas in the Pacific Northwest and British Columbia, as well as the Western Area Power Administration, reduces projected 2020 savings to \$54 million. 如果不包括西北太平洋和加拿大的不列颠哥伦比亚省，以及西部电力局管辖区，2020年的预计成本节约将降至 5400万美元。
- Adding greater coordination with the California Independent System Operator, which has its own balancing market, would increase projected benefits to \$182 million. 如果能与有自己电能平衡市场的加利福尼亚独立电力系统运营商有更多协调，预计收益会增加到1.82亿美元。
- Projected reduction of 1,000 MW in reserves needed to manage wind and solar variability, with an estimated implicit unit value of reserve savings of \$10-11/MWh. 管理风能和太阳能波动性的备用资源需求预计可减少 1000 MW，单位节省成本约为 10-11 美元/MWh。

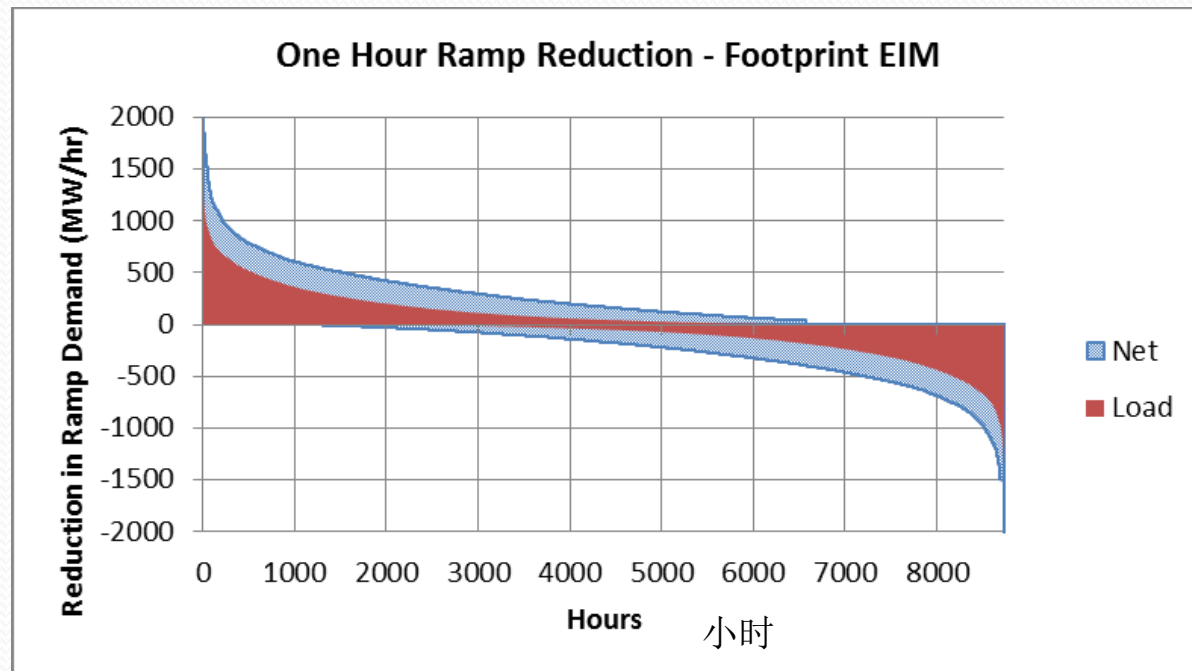
NREL Studies and WECC Energy Imbalance Market

NREL 研究和WECC 电能失衡市场

- In a separate study, NREL found a reduction in ramping requirements with WECC's proposed Energy Imbalance Market of about 260 MW.

另一个研究中，NREL发现利用西部电力协调委员会（WECC）建议的电能失衡市场可以减少260MW的爬坡需求。

减少爬坡需求 (MW/hr)

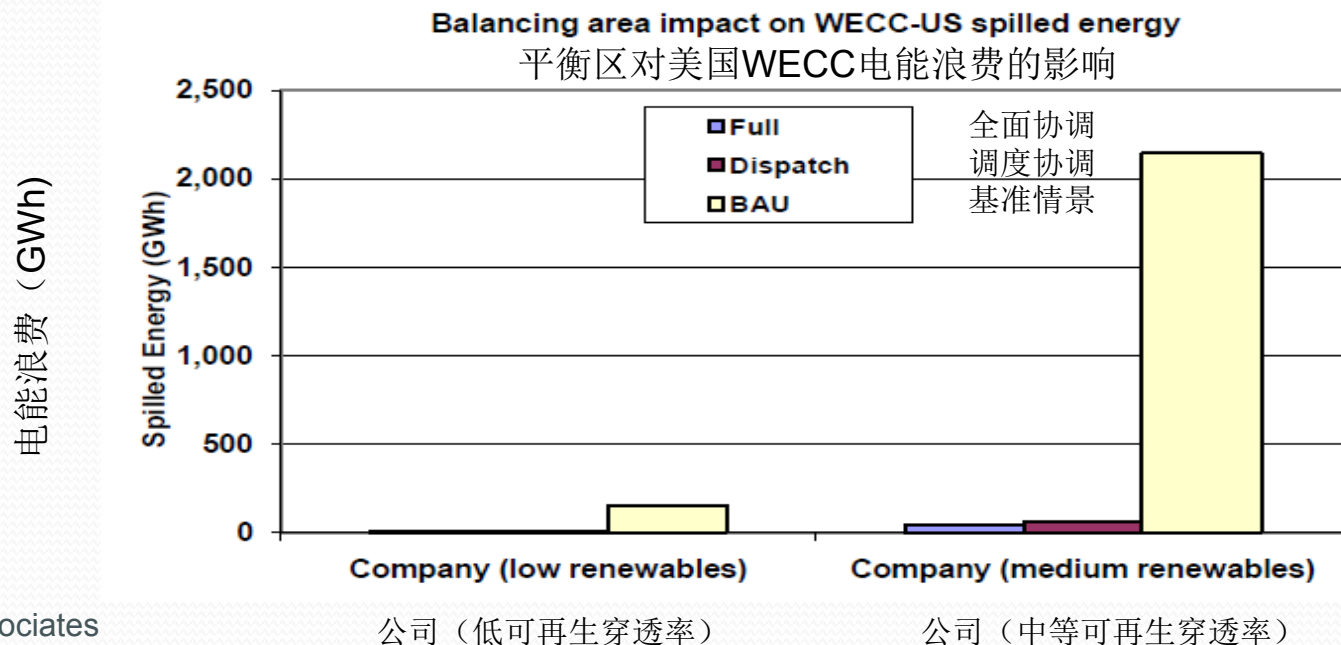


净负荷
负荷

NREL Studies and WECC Energy Imbalance Market (cont.)

NREL 研究和WECC 电能失衡市场（续）

- NREL also found that spilled energy (i.e., renewable energy curtailment) is higher in instances of low balancing area coordination.
NREL研究也发现，在协调度低的平衡区内，电能浪费（例如弃风等）更大。
- Balancing area coordination for economic dispatch alone (but not for unit commitment) will significantly reduce the amount of spilled energy,
仅为经济调度进行平衡区协调（不重新做机组组合）就可以显著减少电能的浪费。

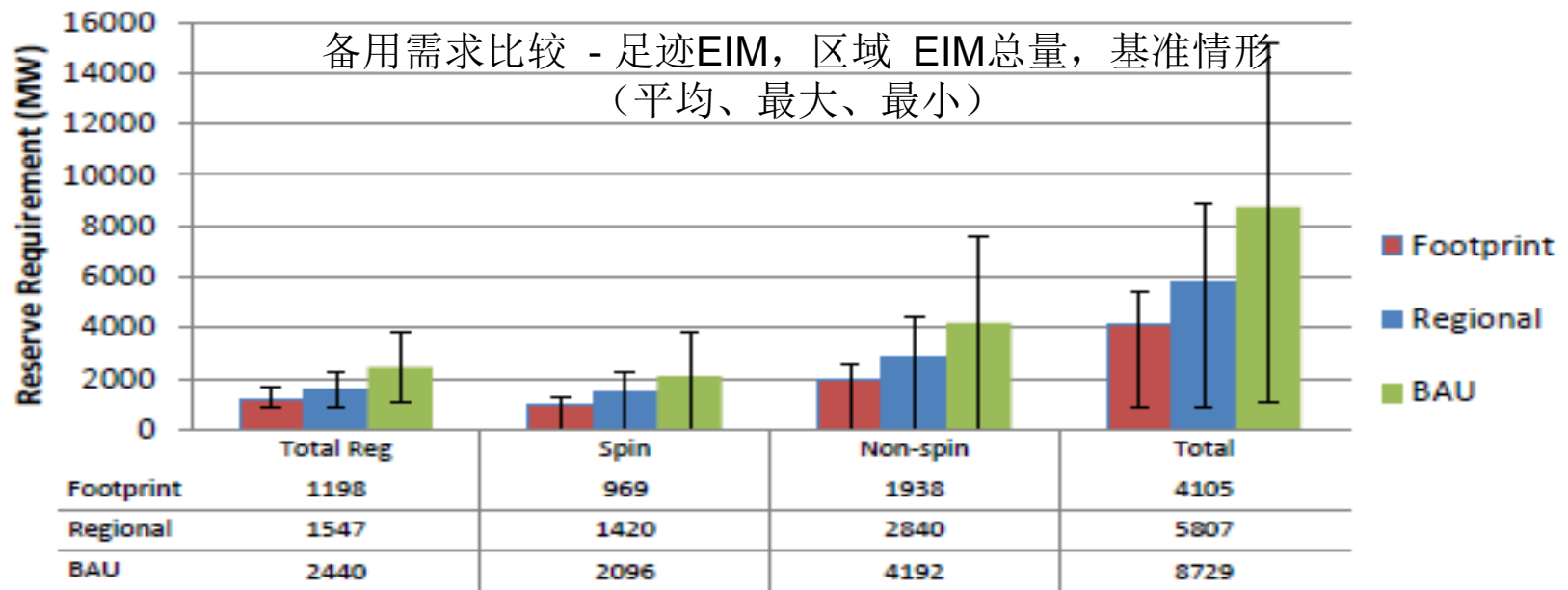


NREL: Average Reserve Values Decrease by 51-54% for West-Wide Energy Imbalance Market, and by Smaller Amounts for Regional Imbalance Markets

NREL: 大西部电能失衡市场的平均备用减少51-54%，区域失衡市场也有少量减少

- BAU is Business as Usual; Footprint is West-Wide and Regional is three separate regional energy imbalance markets. BAU为 基准情景，足迹(Footprint)是大西部地区，区域(Regional) 是三个独立的区域电能失衡市场（EIM）。

Reserve Requirement Comparisons for Footprint EIM, Regional EIM Total, and BAU (Average, Max, and Min)



足迹
区域
基准情景

Southwest Power Pool

西南电力库

- The Southwest Power Pool (SPP) is a RTO in South Central U. S. that encompasses parts or all of Arkansas, Kansas, Louisiana, Mississippi, Missouri, Nebraska, New Mexico, Oklahoma and Texas. 西南电力库（SPP）是美国中南部区域输电组织（RTO），包括部分或全部阿肯色、堪萨斯、路易斯安那、密西西比、密苏里、内布拉斯加、新墨西哥、俄克拉何马州、得克萨斯州。
- Unlike other RTOs, SPP does not have a day-ahead market or an ancillary services market. 不同于其他区域输电组织，SPP没有日前市场或者辅助服务市场。
 - SPP does administer a voluntary energy imbalance market, upon which the WECC Energy Imbalance Market proposal is based. SPP 管理一个自愿电能失衡市场，WECC电能失衡市场的提出就是基于SPP模式。
- SPP is transitioning to a central day-ahead market by 2014 and commissioned a cost-benefit study in 2009. SPP 正向一个中央日前市场转变（2014年前），于是它在2009年做了成本收益分析。

SPP Cost-Benefit Study

SPP成本收益研究

- The SPP's cost-benefit study assessed the benefits and costs of moving from the SPP bilateral market to one of five scenarios. SPP 成本收益研究测算了从SPP双边市场转变到以下五个情景的成本和收益。
 - Day-Ahead Market with Unit Commitment (2009-2016)
有机组组合的日前市场 2009-2016
 - Day-Ahead Market with Unit Commitment and Ancillary Services Market (2011-2016)
有机组组合和辅助服务的日前市场 2011-2016
 - Day-ahead Market with Unit Commitment 2009, 2010, and All Inclusive 2011-2016
有机组组合的日前市场2009-2010，具备所有服务的日前市场2011-2016
 - Ancillary Service Market (2009-10) and All Inclusive 2011-2016
辅助服务市场2009-10，具备所有服务的市场2011-2016
 - Ancillary Service Market Addition Only (2009-2016)
只增加辅助服务市场2009-2016

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Gross Benefits Total	\$679 million	\$889 million	\$1,050 million	\$975 million	\$706 million
SPP and Market Participant Implementation Costs Total	\$278 million	\$258 million	\$308 million	\$278 million	\$128 million
SPP Net Benefits Total	\$400 million	\$632 million	\$742 million	\$697 million	\$578 million

Other Findings of SPP's Cost-Benefit Study

SPP成本收益研究的其他发现

- The study found that costs of changing to a central day-ahead market could be 90% higher and benefits 90% lower, and there still would be positive net benefits.

研究发现，转变为中央日前市场，成本将提高90%，收益减少90%，但仍然会有净利润。

- Combining the day-ahead and ancillary services markets has more favorable cost-benefit impact, more so than implementing each market separately.

将日前市场和辅助服务市场结合起来，能有更理想的成本收益效果，比实施单个市场的收益更大。

- If market implementation is phased in, the biggest benefit is moving to a day-ahead market first.

如果分阶段实施，收益最大的是首先转变为日前市场。

Eastern Interconnection

东部互联电网

- The *Eastern Wind Integration and Transmission Study*, prepared by EnerNex Corporation for NREL in 2010, assumed a high level of coordination between the multiple RTOs and does not directly evaluate the benefit of that coordination, but notes the following benefits in the Eastern Interconnection from larger balancing authorities: 东部风电并网和输送研究，由 EnerNex 集团为 NREL 于 2010 年完成，假设多个区域输电组织之间高度协调，该研究未直接估算这种协调的收益，但评估了大平衡区能给东部互联电网带来的效益：
 - Geographic diversity substantially helps to reduce system variability and uncertainty. 地理多样性显著减少系统可变性和不确定性。
 - Small balancing areas can be significantly challenged by large amounts of wind generation. 大规模风电并网将给小平衡区带来极大程度的挑战。
 - Large operating areas in terms of load, generating units, and geography (when combined with adequate transmission) are the most effective measures for managing wind generation. 建立拥有更多负荷、发电机组和地理面积（且有足够输电能力）的大运营区，是解决风电并网问题最有效的措施。

Conclusions

结论

- Balancing area consolidation/coordination, either physically or virtually, has been found from these studies to be positive from a cost-benefit perspective.
这些研究发现，平衡区无论实体合并或虚拟合并/协调，从成本收益角度来看都是有积极作用的。
- Balancing area consolidation reduces the variability of load, wind and solar and increases access to more generating resources for balancing variability.
平衡区合并可以减少负荷、风能和太阳能的波动，也可以利用更多发电资源来平衡变化。
- Fewer reserves are required with balancing area consolidation, sometimes significantly so.
平衡区合并使得所需备用减少，有时效益会非常显著。
- Ramping of net load is reduced under balancing area consolidation.
在平衡区合并情况下，净负荷爬坡减少。

Conclusions

结论

- Curtailment of renewable energy generation is reduced if balancing areas are consolidated.
平衡区合并可以减少可再生能源弃电
- All of these factors make it easier to integrate larger amounts of wind and solar with larger balancing areas, whether accomplished physically or virtually, though balancing area consolidation/coordination is found to have positive net benefits without consideration of wind and solar
无论实体合并或虚拟合并，这些因素都会使得大平衡区中更容易并入大规模的风能和太阳能；即使在不考虑风能和太阳能情况下，平衡区合并/协调同样具有净收益。

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Appendix 附录

Map of Potential Regional Imbalance Markets in NREL Study

NREL 研究中潜在区域平衡市场地图

- Map of the reduced BA structure considered for this study.

该研究中缩小的平衡区结构地图

- Orange: Columbia Grid
橘红色: 哥伦比亚电网
- Light blue: Northern Tier Transmission Group
淡蓝色: 北方Tier输电集团
- White: WestConnect
白色: 西部各州WestConnect集团电力系统

Source: King, et. al, 2011.

