MISO Energy Storage Study
DRAFT Scope

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1. **Introduction**

The Energy Storage Study endeavors to test several hypotheses around battery, compressed air, and pumped hydro energy storage. This study will explore reliability, market, and planning benefits. It will seek to determine the economic potential of storage technologies. It will estimate the price inflection point at which energy storage may become economically feasible. Finally, the study will suggest potential MISO energy and operating reserve markets enhancement products, if appropriate.

These results will provide insight into numerous related issues under simultaneous evaluation including, but not limited to:

- **Impact of storage on MISO Ancillary Service market** - Energy storage can be short-term (seconds to minutes) storage and long-term (few hours) storage. The short-term is more of an ancillary services provider and the long-term caters more towards shifting blocks of energy. This study aims to investigate both short- and long-term storage, realizing the modeling nuances (e.g., market modeling) and interactions within the ancillary services market.

- **Impact of storage on wind** - Focus is on managing flexibility on a system level (e.g., ramp management / load following). Energy storage resources have a great potential to increase system flexibility (e.g., ramp capability) which, in turn, can be translated to greater system capability to absorb more renewable resources. Intuitively, this would also be expected to improve the system economics.

2. **Study Objectives**

The primary objectives of the Energy Storage Study are to:

1. Identify economic potential for energy storage technologies with longer term capabilities such as battery storage, compressed air energy storage (CAES), and pumped hydro storage
2. Identify the value of storage under existing Ancillary Services Market (ASM) tariff for energy storage (i.e. Stored Energy Resource)
3. Identify the need for enhancements relative to the existing tariff for energy storage
   - Recommend enhancements to existing tariff or suggest new tariff such as consideration of a ramping-based market product.
4. Recommend guidelines for modeling of stored energy resources in reliability planning studies for generator interconnection and expansion planning
5. Identify Key Impacts
   - Storage costs relative to other existing supply side and demand side alternatives
   - Wholesale Energy and ASM and consumer rate impacts
   - Wholesale Capacity Market (if applicable)
Impact of EPA regulations  
Capabilities of gas infrastructure and supply to meet storage outcomes
6. Engage stakeholders to actively participate throughout the study process, and, if appropriate, form a new stakeholder committee reporting to the Planning Advisory Committee (PAC)
7. Neighboring ISO/RTO evaluation for cross border impacts

3. Study Drivers
The main drivers for this Energy Storage Study are:

1. Primary impact driver: Federal Energy Regulatory Commission (FERC) in its order accepting MISO's Stored Energy Resource filing has requested MISO to address long term storage. Additionally, MISO received multiple requests from stakeholders to better understand energy storage potential within the MISO footprint. MISO and its stakeholders need to be prepared for changes in this area and determine how storage impacts resource adequacy, market prices and reliability within MISO and neighboring areas.

2. Secondary impact driver: MISO needs to better understand the potential of storage technologies to help integrate intermittent energy sources. Hence, MISO needs to effectively model battery storage, compressed air energy storage (CAES), and pumped hydro storage in capacity expansion (i.e. EGEAS), reliability planning and economic analysis (i.e. PLEXOS) models.

3. Other drivers: Needed in support of the MISO Transmission Expansion Plan (MTEP) 2012 (futures), the Organization of MISO States (OMS), and the annual reliability assessment analyses including near- and long-term resource adequacy of the MISO system.

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1 FERC Order on Compliance Filing and Stored Energy Resources Proposal issued Dec 31, 2009 (Docket No's: ER07-1372-014, ER09-1126-000)
4. **Study Description**

This study will be conducted by MISO in two primary phases. The work plan can be seen in Figure 2. The work to be completed is expected to address the stated objectives and provide MISO stakeholders with an analysis of the merits and risks of storage technologies being reviewed.
The three energy storage technologies this study aims to investigate include:

- **Battery Storage:** Long-term energy storage using batteries can involve many different types of batteries, including, but not limited to, flow batteries, liquid-metal batteries (i.e. NaS) and Ni-Cd batteries. The battery is charged during times of excess power generation and then discharged during times of need. Some key benefits of batteries include very few locational constraints, very rapid response times and high levels of efficiency (often 90% or higher).
  - Xcel Energy and MISO are conducting a series of tests that are evaluating the performance of a long-term storage device (i.e. a 1 MW, 7.2 MWh NaS battery) when performing the market service of frequency regulation. Xcel Energy and MISO are testing the battery under a variety of state-of-charge (SOC) scenarios to better understand how MISO’s dispatch algorithm dispatches the device under varying conditions and to determine any differences that may arise between a long-term storage device and a short-term storage device. Lastly, Xcel Energy and MISO will evaluate settlement data to determine the corresponding financial value of the SER under the current market tariff for both the day-ahead and real-time submission process into the ASM.
• **Compressed Air Energy Storage (CAES):** CAES facilities utilize large underground caverns to store air which is compressed during off-peak hours. The compressed air is then fed into a natural gas combustion turbine (CT) to provide power back to the grid during peak demand periods. Key benefits of CAES include relatively lower capital costs (versus other storage technologies), lower carbon emissions (versus conventional combined-cycle facility) and greater options for siting (versus pumped hydro).

• **Pumped Hydro Storage:** Pumped hydro has existed for 40-plus years as a proven storage technology. These facilities utilize large, aboveground reservoirs to store water at different elevations. The facility draws energy from the grid to pump water from the lower to the higher reservoir, and supplies energy to the grid when the water that is allowed to run back down to the lower reservoir drives a water turbine that powers the generator. The pumping typically occurs during off-peak hours when electricity is cheapest, and generation most often occurs during peak times. Key benefits of pumped hydro include quick response times and no direct fuel requirement.

**Phase I**

**Storage Technologies Evaluation**
Phase I of the process will consist of MISO staff researching the current energy storage modeling technologies specific to the PSS/E, EGEAS and PLEXOS models.

**Deliverables:**
- PSS/E, EGEAS and PLEXOS energy storage presentations.

**Evaluation of Storage under existing MISO tariff**
Phase I will also evaluate and communicate the value of storage under existing MISO energy and ancillary services market. At present, regulation is not a net zero energy market product. There are several market initiatives underway at MISO related to ramp management, such as load following products, look-ahead commitment and dispatch, and others. This project seeks to evaluate and communicate these ongoing initiatives as part of Phase I, including covering the co-optimization of storage in both the energy and operating reserve markets.

**Deliverables:**
- Energy storage presentation under existing MISO tariff.
- Identification of possible opportunities for tariff enhancements.

**Initial EGEAS Assessment**

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2 Which, in concept, accounts for both load and generation aspects of storage devices.
Initially, MISO will apply evaluation information and the modeling techniques to the EGEAS economic resource expansion model. The initial model development will utilize economic, resource, and demand and energy projections identified within the MTEP 11 Planning Advisory Committee (PAC) Business as Usual (BAU) future with medium demand and energy growth. See Table 4-1 for basic information and Section 9.5 of the MTEP 10 report for a more detailed discussion of MISO staff’s past storage modeling experiences.

| Table 4-1: PAC Business as Usual general assumptions |
|-----------------|-----------------|
| Demand Growth   | 1.26% annual growth |
| Energy Growth   | 1.26% annual growth |
| Natural Gas Costs | Base price of $5 per MMBTU |
| Carbon Costs    | Base price of $0 per ton |

The EGEAS capacity expansion model will be used because it performs production cost evaluation on the system without transmission constraints and can do this calculation within minutes over a 20 year time period. However, because of the lack of transmission impacts on congestion costs, the model runs short of a full detailed analysis. Hence this evaluation will be used as a screening tool to identify potential impacts and modeling adjustments which may be required prior to more detailed and time consuming evaluation.

Deliverables:
- Fully functional EGEAS models for battery, compressed air and pumped hydro storage technologies.

Initial PLEXOS Assessment
Additionally, MISO will apply EGEAS assessment information and the modeling techniques to the intra-hour PLEXOS economic model. The initial model development will utilize economic, resource, and demand and energy projections identified within the MTEP 11 cycle.

PLEXOS is a production cost model that integrates generation dispatch, transmission power flow, and ancillary services dispatch altogether. It also has the intra-hour simulation capability that can handle the quick response time of the regulation and spinning reserve requirement. PLEXOS can be used to model any type of energy storage and evaluate its cost impacts associated with the regulation and spinning reserve markets.

Several different cases will be run to see how Battery/CAES/Pumped hydro storage units behave in PLEXOS and also to see what changes from the base case. The base case would include the current tariff, and the change case would simulate different dispatch scenarios. The steps are as follows:
1. Run a base hourly run for the entire year 2016.
2. Run 5-minute base cases for summer, winter and a shoulder month as determined by the hourly run.
3. From the results, reassess how the Battery/CAES/Pumped hydro storage units are modeled and make any changes.
4. Run any other cases identified as needing a more detailed analysis, based on previous simulations.

Deliverables:
- Fully functional PLEXOS models for battery, compressed air and pumped hydro storage technologies, including detailed PLEXOS outputs.

Sensitivity Analysis Impacts

Within this phase of analysis, MISO staff will focus on the following key drivers impacting the business case for energy storage.
- Environmental Protection Agency (EPA) regulations impact on the carbon emissions produced within the existing and future power generation fleet. EPA constraints can make or break the business case for storage technologies. Because of this, EPA regulations will also be included in the risk evaluation of the storage technologies.
- Mandated wind from the Renewable Portfolio Standards (RPS) with and without Carbon taxes.
- Natural gas price sensitivities.
- Finally, a combination of the sensitivity cases will be run in EGEAS, specifically to inform the PLEXOS model.
Table 4-2 lists the scenarios that will be evaluated.

<table>
<thead>
<tr>
<th>Scenarios to be evaluated</th>
<th>EGEAS</th>
<th>PLEXOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 Current system</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>S2 - Low EPA Regulations Impact (as appropriate from the EPA analysis)</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>S2 - High EPA Regulations Impact (as appropriate from the EPA analysis)</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>S3 - Low Mandated RPS Wind Impact + Carbon tax @ $0/ton</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>S3 - High Mandated RPS Wind Impact + Carbon tax @ $100/ton</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>S4 - Low Natural gas costs at $4 / MMBTU</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>S4 - High Natural gas costs at $10 / MMBTU</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>S5 Combinations of scenarios 2 through 4</td>
<td>√</td>
<td>As applicable</td>
</tr>
</tbody>
</table>

Deliverables:
- Aggregated information will be provided for stakeholder review and comment.
- Detailed information will be provided to the individual stakeholders wherever they have provided detailed model data.
- Modeling techniques and updated database provided to PLEXOS analysis.
- Summarize results by the useful maximum output duration of alternatives (i.e. output hours possible at full capacity).
- Summarize results by the required charging duration (i.e. hours needed to fully re-charge).
  - Short duration hours might be competitive for ASM needs, whereas long duration hours may have potential for backing up wind, for example.

**Phase II**

Results of the initial EGEAS and PLEXOS models will provide MISO staff a sense for how storage operates specifically. Phase II provides for the bulk of the work associated with the impact of the modeled energy storage on various supply side alternatives. Within this work effort, potential impacts on the existing fleet will be evaluated further through cost of replacement capacity and retro-fits on the system, including energy and ancillary service markets.

The inclusion of storage on the system will alter the interaction of the fleet within the PLEXOS production cost model. To determine the impacts of the rules on the energy markets, an additional set of PLEXOS runs will be made to evaluate the cost impacts of the existing and new fleet operation to meet demand and energy requirements across a detailed transmission system as part of MTEP 11 cycle.
This analysis may have an impact on identifying the need for additional market products for energy storage within MISO. These products can be evaluated with the PLEXOS model. The PLEXOS model allows for intra-hour dispatching and will be used to evaluate cost impacts associated with the regulation and spinning reserve markets.

Deliverables:
- Storage cost impacts on energy and ancillary service markets including capacity markets (if applicable) provided to stakeholders for review and comments. For example, if the net load factor for dispatchable resources is higher, that may indicate need for a higher PRM in the capacity market. PRM effects would need to be studied using GE MARS and the Resource Adequacy (RA) provisions in Module E of the Tariff.

Figure 3: Phased-in Project Plan

5. Study High Level Tasks

The current scope of the study provides for work to be completed by the end of the MTEP 2012 cycle. Status report preparation will occur through the month of October for input into the MTEP 11 report. The final report will be published by
June 2012. During the process, mid-project outputs will be available for stakeholder review at planned, open stakeholder meetings, such as the Planning Advisory Committee (PAC). Expected schedule can be identified in Figure 5-1.

### 6. Project Deliverables

It is expected that the final project report will identify and analyze impacts of energy storage on the MISO system. The final report will identify:

- Economic potential for energy storage technologies such as battery storage, compressed air energy storage (CAES), and pumped hydro storage
  - Fully functional EGEAS and PLEXOS models for battery, compressed air and pumped hydro storage technologies
- The value of storage under existing Ancillary Services Market (ASM) tariff for energy storage (i.e. Stored Energy Resource)
- The need for enhancements relative to the existing tariff for energy storage
  - Suggest new products for storage technologies (if applicable)
- Show the key impacts
  - Storage costs relative to other existing supply side and demand side alternatives
  - Wholesale Energy Market and consumer rate impacts
  - Wholesale Capacity Market (if applicable)
  - Impact of EPA regulations
  - Capability of gas infrastructure and supply to meet storage outcomes
  - Feasibility of energy storage as a solution under certain conditions for mitigation of contingencies, and for interconnection of intermittent resources, as an alternative to new transmission investment.
  - Capacity factor changes on non-storage resources
7. **Out of Scope**

The following items are specifically out of scope for the Energy Storage Study project:

- Detailed analysis of transmission projects\(^3\) (e.g. Candidate Multi-Value Projects, System Planning Analysis projects). However, evaluation of storage as a transmission asset is within the scope of the study.
- Design/Re-designing of Ancillary Service Market (ASM) products\(^4\)
- Evaluation of electric vehicles being used as a potential vehicle-to-grid storage alternative.

8. **Project Milestones**

General project schedule is planned to occur during the MTEP study process. Below is a list of the major milestones that are to be met to be on schedule throughout the project.

<table>
<thead>
<tr>
<th>Milestones</th>
<th>Proposed Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Kickoff and Scope Finalization</td>
<td>07/29/2011</td>
</tr>
<tr>
<td>Initial EGEAS Analysis Completion</td>
<td>08/31/2011</td>
</tr>
<tr>
<td>Evaluation of Storage under existing tariff</td>
<td>09/30/2011</td>
</tr>
<tr>
<td>Initial PLEXOS Analysis Completion</td>
<td>10/31/2011</td>
</tr>
<tr>
<td>Initial Sensitivity Analysis Completion</td>
<td>10/31/2011</td>
</tr>
<tr>
<td>Phase 1 report DRAFT</td>
<td>11/15/2011</td>
</tr>
<tr>
<td>Phase 1 complete</td>
<td>11/30/2011</td>
</tr>
<tr>
<td>Include additional storage futures in MTEP 12</td>
<td>01/30/2012</td>
</tr>
<tr>
<td>Final PLEXOS Analysis</td>
<td>03/31/2012</td>
</tr>
<tr>
<td>Final Sensitivity Analysis</td>
<td>05/31/2012</td>
</tr>
<tr>
<td>Final Energy Storage Report</td>
<td>06/30/2012</td>
</tr>
</tbody>
</table>

9. **Communication Plan**

The Planning Advisory Committee (PAC) will be the primary outlet for stakeholder interaction for this study. Updates will be provided by MISO staff through the PAC exploder list as well as during the PAC meetings:

[https://www.misoenergy.org/StakeholderCenter/CommitteesWorkGroupsTaskForces/PAC/Pages/home.aspx](https://www.misoenergy.org/StakeholderCenter/CommitteesWorkGroupsTaskForces/PAC/Pages/home.aspx)

MISO staff will also provide a document folder “Energy Storage” on the MISO website where materials and bi-weekly project updates will be posted:

[https://www.misoenergy.org/Planning/Pages/StudyRepository.aspx](https://www.misoenergy.org/Planning/Pages/StudyRepository.aspx)

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\(^3\) This work is presently performed according to FERC Order 890 Economic planning principles.

\(^4\) This work is presently performed according to FERC approved Energy and Ancillary Services market.
Notification of all new postings will be sent to the PAC exploder list.

10. **Project Personnel**

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