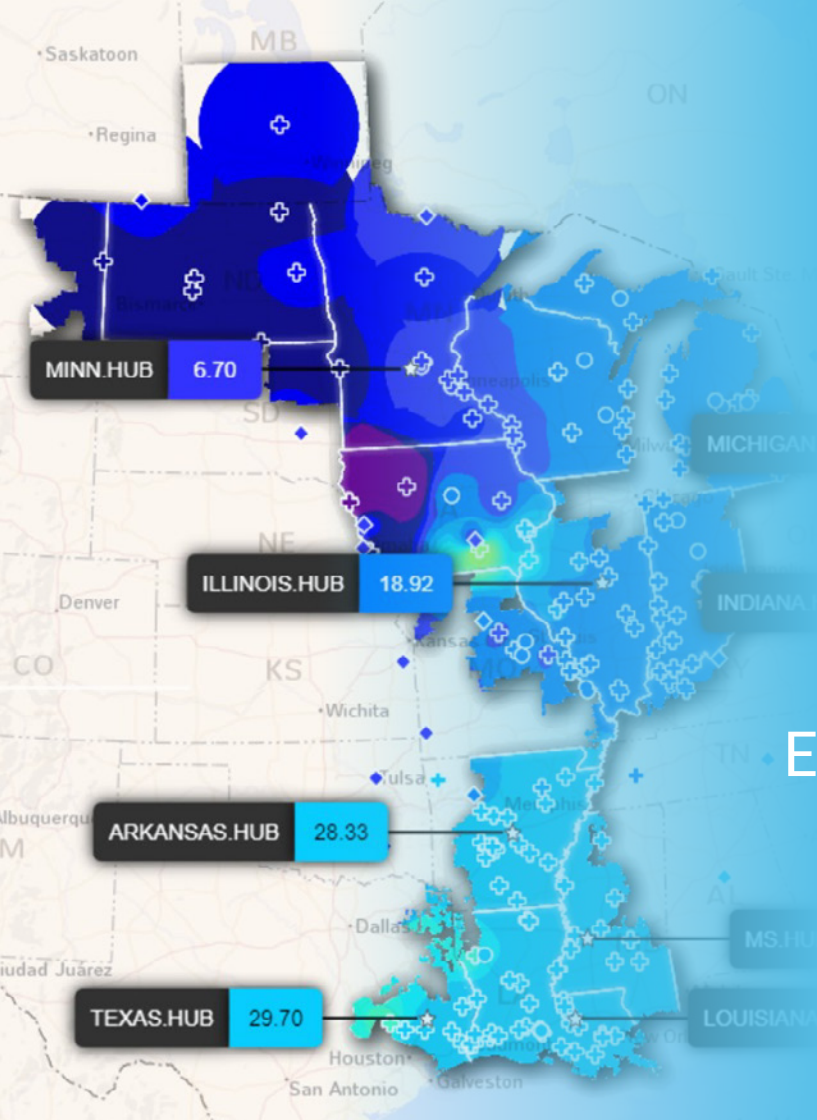


DECEMBER 2020

REDEFINING ENERGY AND ANCILLARY SERVICES MARKETS



MISO faces a reliability imperative as the region undergoes transformational change.

Highlights

- Redefining energy and ancillary services markets will ensure that markets signal system needs and compensate valuable capabilities.
- While the fundamentals of markets remain the same – to clear load and supply and account for the unique requirements of power systems – markets must adapt to the changing resource mix and explicitly account for a range of possible outcomes and optimize amidst increasing uncertainty.
- MISO will focus on managing uncertainty to address risk, enhancing resource models to improve flexibility, addressing locational constraints to enhance availability, and advancing coordination to gain sufficient visibility.



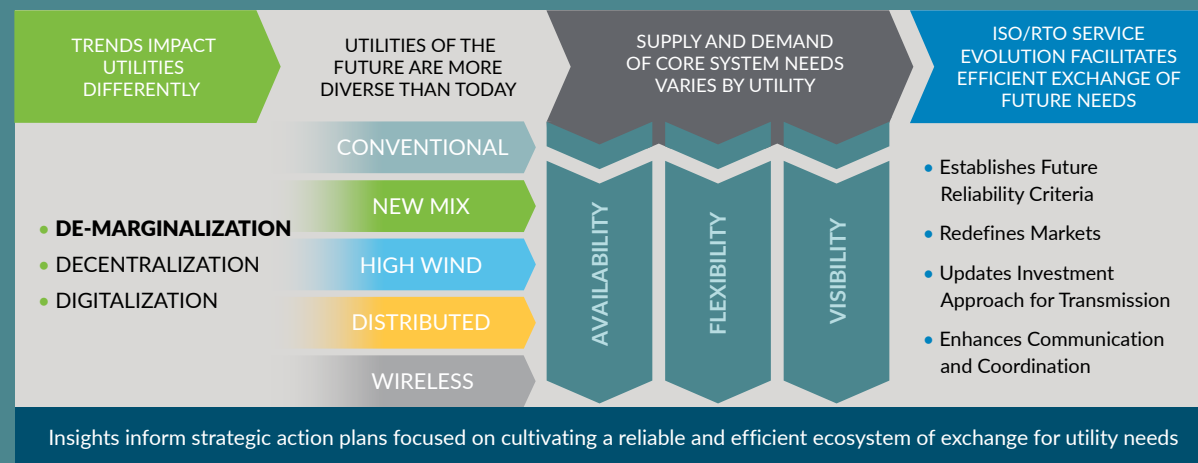
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De-marginalization Decentralization Digitalization

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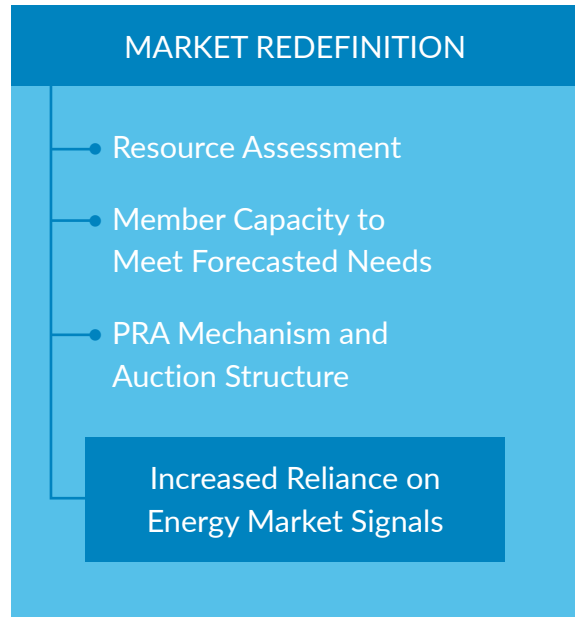
The Redefining Markets report addresses future needs for energy and ancillary markets as identified in the [2020 MISO FORWARD](#) report.



Executive Summary

MISO faces a reliability imperative as the region undergoes transformational change, with large amounts of aging generation; supply increasingly correlated to weather; consumers electrifying loads and employing advanced controls. MISO is already experiencing increased reliability challenges across all seasons of the year and expects these to intensify. This has prompted MISO to identify how planning, markets, and operations must adapt. Aggregating key themes and insights from internal and external sources, Redefining Markets explores what impending changes mean for markets. In 2021, MISO will continue dialogue with stakeholders and develop a sequenced plan for a more defined set of enhancements. MISO recently published the [Reliability Imperative](#) that outlines key areas of change, including “Market Redefinition,” this report introduces a framework for wholesale market evolution.

MISO’s report “Response to the Reliability Imperative” identifies focus areas for redefining markets.



Critical areas of adaption for markets:

- Uncertainty and variability: new ways to manage new risks
- Location: better ways to identify and price sub-regional limitations
- Resource models: more refined reflection of resource capabilities and cost structures
- Coordination: advancements at seams of bulk power systems and at the transmission-distribution interface

MARKETS ARE CRITICAL TO EFFICIENT, RELIABLE OPERATIONS

MISO administers wholesale markets that centrally commit and dispatch resources to facilitate least-cost and reliable energy production and delivery. To accomplish this, wholesale markets signal and value system needs and identify the most efficient way to meet them across the system. Furthermore, because MISO’s markets cover only a portion of the power grid, reliably operating markets entails coordination across interconnected bulk and distribution system boundaries, or “seams.”

MARKETS MUST ADAPT TO A CHANGING INDUSTRY

Changes in the resource portfolio and load alter the nature of variability, uncertainty and risk in the system while offering new resource capabilities and constraints. While the fundamentals of markets remain the same – to clear load and supply and account for the unique requirements of power systems – markets must shift the focus beyond load forecast error and contingency to explicitly account for a range of possible outcomes and optimize amidst increasing uncertainty. Markets will play an important role in signaling the need for availability and flexibility, and valuing resources’ timely contribution, either locally or across the grid. With similar changes occurring across the industry and

emerging from the distribution system, ISO / RTOs must also bolster coordination at the seams, ensuring market optimizations are in sync and not inadvertently countering one another. Ultimately, uncertainty management, locational needs, coordination and resource models will be focal points of any market evolution.

ADAPTATIONS ARE ALREADY UNDERWAY

MISO has begun to adapt its markets. For example, MISO received regulatory approvals in 2020 on a

new short-term reserve product that specifies a 30-minute response capability in addition to the existing 10-minute reserves and ramp products. In 2020, the Resource Availability and Need (RAN) program started an assessment on how uncertainty, variability and system risks are changing. The program identified and evaluated potential improvements related to emergency and scarcity pricing. Further work will expand tools that reflect sub-regional constraints in pricing while exploring new products, resource models and coordination tools.

Context

To identify industry trends, assess implications for wholesale markets and innovate to adapt, MISO has been gathering insights from and collaborating with entities throughout the industry, including utilities, developers, consultants, vendors, think-tanks, state and federal policy makers, large end-users, academia, national labs and other grid operators.

In the [2019 MISO Forward](#) report, MISO identified three global industry trends: de-marginalization, decentralization and digitalization. These trends called for enhanced availability, flexibility and visibility (AFV) of resources within the system. The [2020 MISO Forward](#) report leveraged insights from utilities to explore how the same industry trends are shaping utilities and what they need from a grid operator to efficiently exchange AFV. Five distinct utility of the future personas emerged, along with an urgent call for four specific, transformational solutions to leverage the value of increasing diversity: (1) reliability criteria for the future, (2) redefined markets, (3) an updated approach for transmission and (4) enhanced coordination and communication.

In response, MISO conducted further research and facilitated more stakeholder discussions. The Resource Availability and Need program evaluated reliability criteria for the future in MISO’s August 2020 report on [Changing Reliability Requirements for an Evolving Fleet](#). The [Renewable Integration Impact Assessment](#) also explored the implications of high renewable portfolios. MISO’s Transmission Expansion Planning Futures development process encompassed a much wider range of insights and variables this year, resulting in more differentiated scenarios. And the November 2020 report, [MISO and DER: Ensuring Grid Reliability Through Visibility and Communication](#), framed potential solution paths for enhanced coordination across the transmission and distribution seam. Further lessons have been gleaned from operational events such as Hurricane Laura, like the importance of coordinating market algorithms with reliability applications to quickly reflect and address sub-regional/local operational risks.

The next section will briefly review a history of market evolution in MISO, and from there discuss necessary changes to position MISO markets for the future.



A History of Market Evolution in MISO

When MISO launched the wholesale energy market in 2005 and ancillary services markets in 2009, the grid predominantly relied on dispatchable thermal units, used a centralized generation model, and planned for mostly inelastic load. Nodal energy pricing accounted for congestion and provided a way to meet local needs while optimizing globally. Reserves, co-optimized with energy, efficiently positioned the system to be ready for unforeseeable generation contingencies or small variations between supply and demand. Continually updated load forecasts, ancillary services and staging of the day ahead and real time markets sufficiently addressed load uncertainties. Initial agreements between some of the neighboring ISO/RTOs were developed to help manage seams.

Over the next decade, MISO implemented a capacity market and look-ahead commitment to more efficiently plan near-term commitments. During that period, wind resources grew from 0% to 9% of energy production and natural gas from 7 percent to 31 percent, while 23 GW of mostly thermal units retired. Load Modifying Resources (LMRs), accessible only in emergencies, grew to roughly 11 GW of qualifying planning resources. The footprint also expanded considerably, growing by about 40 GW of generation capacity with the South Region integration. Battery storage and solar resources began to grow within the industry though were still a relatively small share within MISO.

In response to these trends, MISO added new resource models, including Dispatchable Intermittent Resources (DIR) and new energy storage models. These allowed MISO to co-optimize resources and manage congestion related to intermittent generation in market clearing and dispatch while accounting for characteristics that differ from conventional generation.

As part of the South Region integration, MISO defined a sub-regional constraint within the market optimization. MISO also implemented a reserve procurement enhancement (RPE), intended to adjust pricing to acknowledge reserve recovery limitations due to a transmission or sub-regional constraint after reserve deployment. These were co-optimized with energy.

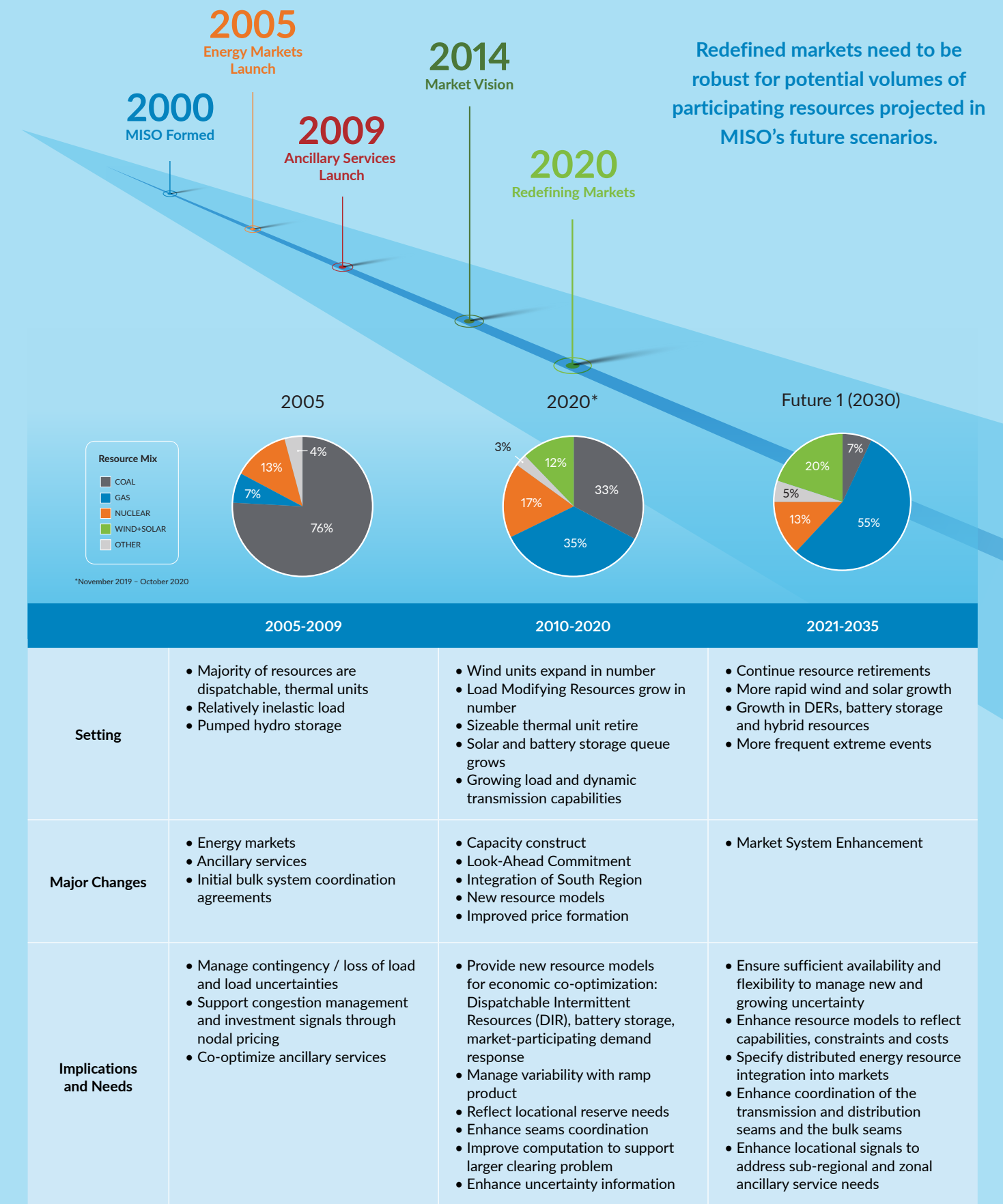
To help address uncertainty and variability, MISO created a new ramp ancillary service in addition to reserves that addresses variability within the 10-minute timeframe. To support stakeholder decision-making under uncertainty, MISO also began compiling a multi-day operating forecast for stakeholders, providing a forward-looking view identical to that used by MISO.

MISO and neighbors created additional bulk seams agreements and took further actions to limit inadvertent seams-related power swings.

Additional price formation enhancements helped pricing better reflect the true marginal cost of production and more fully compensate resources for the total cost of service. Extended Locational Marginal Pricing (ELMP) incorporated the commitment costs for fast-start units, a 5-minute settlement better aligned prices with dispatch and emergency pricing rules bolstered pricing emergency resources at shortage levels.

Finally, MISO made improvements to reduce day ahead clearing times to better align with natural gas procurement deadlines, delivering market results faster despite significant growth in the optimization problem.

MISO markets are not static and have continued to evolve to meet changing needs and requirements. Continuing this trend, additional changes are needed, responsive to current changing industry conditions – the changing resource mix, integration of new technologies and customer needs.





Preparing for the Future

Market reforms over the past decade have successfully increased efficiency and adapted markets with industry change. However, further reforms are needed over the next decade. Planning projections suggest that by 2030, an estimated 20% of transmission connected production will likely come from wind and solar, and more thermal units will retire. Additional amounts of solar will deploy on the distribution system and battery storage and hybrid resources will grow. Advanced controls will enable more demand and DER aggregation capability.

With these projected changes, MISO expects system variability and uncertainty to become more pronounced, adding to operational challenges that have already arisen with 15 years of dramatic wind growth. Ramping needs will grow in size and frequency and the largest ramps could occur at different times of day and times of year. The impact of uncertainty will increase, as will the total amount of forecast errors (due to solar and wind growth) and forced outages continuing as existing fleets age. Markets will play an important role in maximizing the efficiency by which the system manages uncertainty.

Transmission line overload and voltage issues could become more pronounced as renewables located far from load centers supply increasing amounts of energy over longer distances. The number of transmission constraints that MISO must plan for and operate around will also likely increase until new transmission is built. Wind capacity additions have fully loaded transmission lines requiring more frequent curtailment of low-cost energy which will continue to grow in time and duration

as more wind and solar generation is added to the grid. Enabling the delivery of resources to support the provision of flexibility services from one area to another will be critical to efficiently leverage flexibility across the system.

With increasing dynamics and growing supply and demand uncertainty, the ability to respond in a coordinated fashion across both distribution/ transmission and neighboring systems becomes even more important. This coordination will be particularly important to manage efficiently during periods of shortage or scarcity. Bulk electric operators will need to coordinate more closely across the transmission and distribution interface as DERs grow. This will require more robust information exchange to accommodate needs across entities while maintaining data security. With variability and uncertainty growing industry wide, coordination approaches with neighboring systems will need to adapt to new dynamics and less predictability of power flows.

Further clarification or refinement of resource models and products will help markets maximize the use of resources and account for unique characteristics such as ramp rate, energy duration or configuration transition constraints or variable offer capability. Finally, enabling technology will be an important to any market transition, continuing to feed reliable inputs into the clearing engine and ensure that modified market algorithms solve quickly and with high accuracy.

Redefining Markets to Meet Future Needs

MISO works in a perpetually evolving industry and continually anticipates change to maintain reliability and efficiency. Within markets, MISO will focus on upcoming reforms to address (1) growing uncertainty and variability; (2) evolving locational constraints; (3) new resource capabilities and constraints; and (4) increased coordination needs. These changes are a reliability imperative as system risks continue to shift and vital to cultivating an ecosystem of exchange that enables utilities with divergent business models to access the full value of system wide diversity. To address these risks, MISO must continue to mature our markets.

UNCERTAINTY AND VARIABILITY: NEW WAYS TO MANAGE NEW RISKS

While uncertainty and variability are not new to the energy markets, aging infrastructure, greater weather correlation of supply resources and more dynamic loads are changing the nature and amount of uncertainty to manage. MISO must find new ways to manage these burgeoning risks.

Changes currently underway include:

New Short-Term Reserve Products

In 2020, MISO's regulator approved a new short-term reserve product (STR) that specifies and prices a 30-minute response capability in addition to the established 10-minute reserves and ramp products. This will help identify and value 30-minute flexibility on the system, in both the day ahead and real time markets

Emergency Pricing Improvements

In December 2020, MISO filed for emergency pricing with FERC. Emergency pricing reforms will improve price formation for emergency events. This includes incorporating start-up costs into price for the longer-lead units started for emergency purposes and ensuring emergency offers "stack" on top of economic supply.

Enhanced Aggregate Forecasts

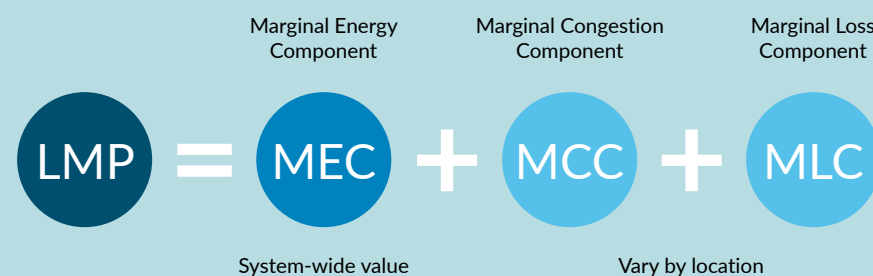
In addition to products and price formation, MISO now provides more information about aggregate forecasts to support stakeholder decision-making. This includes a multi-day operating margin forecast and improvements to information on maintenance margin.

Going forward, MISO has identified potential market enhancements opportunities.

These include:

- MISO will begin working on modifying or adding demand curves for Operating Reserve, Ramp Capability and STR in 2021 to embody aggregate risks at the different timeframes and to differentiate demand curves under typical, tight and emergency conditions
- Identifying how can we efficiently manage growing and new types of uncertainty and variability by continued evaluation across differential time horizons
- Developing new ancillary service products while looking at the potential benefit and feasibility of smaller decision timeframes; continuous decision-making and probabilistic and stochastic approaches

In 2020, MISO began prototyping stochastic commitment approaches and evaluating the computational impacts of a 15-minute market interval. In 2021, MISO will evaluate the need for reserves beyond 10 and 30-minutes and continue evaluating stochastic tool and modified market timing.





Energy and ancillary services markets have many components that are co-optimized to attain prices reflective of marginal cost or value

Market Clearing through Co-optimization	Prices Reflective of Marginal Cost or Value
<p>Energy (Hourly interval day-ahead; 5-minute interval real-time)</p> <p>Regulating reserve (5-minute response time) Capacity held by a frequency responsive resource for the purpose of providing Regulating Reserve Deployment in both up/down direction</p> <p>Spinning reserve (10-minute response time) A specified percentage of Contingency Reserve that must be synchronized to the system and converted to energy within the deployment period</p> <p>Supplemental reserve (10-minute response time) Contingency Reserve not considered spinning</p> <p>Short-term reserve (30-minute response time) Capacity held to meet system, regional, local needs <i>[Under Development]</i></p> <p>Ramp capability product (10-minute response time for t+10 to t+20 ramping service)</p>	<p>Extended Locational Marginal Price MISO extends the LMP and MCP by allowing the cost of committing Fast Start Resources, the Energy cost of Fast Start Resources dispatched at limits, and Emergency Demand Response Resources to set Energy and reserve prices. This process is known as the Extended LMP</p> <p>Locational Marginal Pricing The cost of providing the next MW of electrical energy at a specific location on the transmission grid. This includes a marginal congestion component and marginal loss component in addition to marginal energy component to account for losses and congestion</p> <p>Market Clearing Price The marginal cost to serve market-wide and zonal reserve requirements</p> <p>Operating Reserve Demand Curves Value of expected loss of load; value increases as shortage worsens to reflect the higher reliability risks. The demand curve sets prices during shortage conditions</p> <p>Operating Reserve Substitution A higher quality reserve can serve the requirement of a lower quality reserve; the price of the higher quality reserve is thus higher or at least equal to the lower quality reserve</p>

LOCATION: IDENTIFYING AND PRICING ANCILLARY SERVICE LIMITATIONS

Through the Reserve Procurement Enhancement (RPE) implemented in 2011, MISO adjusts pricing to acknowledge locational reserve needs and reflect the ability to recover reserves. It is important for resources to be available when needed, throughout the system.

Changes currently underway include:

Reserve Procurement Enhancement

MISO reflects the reserve recovery need in prices through a single marginal value limit in the optimization. This year, MISO began evaluating the use of a "demand curve" to broaden its use to more conditions and to more purposefully reflect sub-regional flow uncertainties.

Short-term Reserves

MISO will apply the RPE to the new 30-minute Short-Term Reserve product to make sure 30-minute reserves are procured in the right location and incentivize resource flexibility.

Going forward, MISO has identified potential market enhancements opportunities.

These include:

- Enhancing existing products such as ramping capability to assist with flexibility
- Specifying constraints to meet these new local ancillary services requirements while still maximizing the use of system diversity
- Applying penalties to more transmission constraints within the system, to more broadly incorporate transmission limitations in pricing
- Defining reserve zones more granularly

MISO will begin working on modification to the RPE marginal value limit in early 2021.





RESOURCE MODELS: REFLECTING CAPABILITIES AND CONSTRAINTS

The characteristics, capabilities and constraints of grid resources differ by resource type. Availability of fuel source, minimum run time, start-up time, speed of ramp, ability to respond quickly to signals, foresight needed to optimize operations and other factors can all vary substantially depending on the resource technology. Refining how MISO models resources will allow markets to better leverage their full capabilities and reflect their costs, particularly as the diversity of the fleet increases and demand for flexibility services grows.

Changes currently underway include:

Energy Storage Resource (ESR) Model

MISO developed the ESR product to facilitate storage resource participation across market products.

Multiple Configuration Resource (MSR) Model

MISO developed MCR to better reflect the constraints, costs and capabilities of resources that can transition to multiple different configurations.

Going forward, MISO has identified potential market enhancements opportunities.

These include:

- Enhancing models to better reflect constraints, costs and capabilities, including changing energy duration limitations, elasticities or configuration
- Providing additional information for distribution-connected resource to estimate powerflow effects
- Clarifying hybrid resources
- Clarifying distributed energy resource aggregations
- Developing additional storage optimization services

COORDINATION: ADVANCEMENTS AT SEAMS OF BULK POWER SYSTEMS AND TRANSMISSION-DISTRIBUTION INTERFACE

MISO is responsible for ensuring Bulk Electric System reliability. It is important that MISO have an accurately modeled system and understanding of the changing power flow across the transmission and distribution interface.

Changes currently underway include:

Coordination

MISO continues to enhance coordination with neighboring entities and has several initiatives underway, including:

- Enhancing market-to-market relief request calculation
- Enhancing parallel flow visualization

Stakeholder Involvement

MISO holds regular conversations with stakeholders about coordination at the transmission and distribution (T&D) interface

FERC Order 2222

Work is underway to define visibility needs, which was the subject of the recent MISO and DER: Ensuring Grid Reliability Through Visibility and Communication whitepaper (November 2020).

Going forward, MISO has identified potential market enhancements opportunities.

These include:

- Assessing the uncertainty associated with a changing resource portfolio and identify seams strategies to support this transition
- Identifying additional ways to leverage modern computation, algorithmic techniques and data analytics to support enhanced coordination and market mechanisms

MISO will begin working with stakeholders in 2021 to develop a FERC Order 2222 compliance plan.

		Explore	Decide	Do	Done
Flexibility	Uncertainty and Variability Management	<ul style="list-style-type: none"> • How can MISO efficiently manage growing and new types of uncertainty and variability? What ancillary services are needed? How can look-ahead or clearing intervals and probabilistic or stochastic approaches help? • Stochastic and probabilistic tools or clearing • Need and design for new reserve product(s) • Need and design for modified market timing or intervals 	<ul style="list-style-type: none"> • Scarcity Pricing: Demand curves for reserves and ramp including aggregate uncertainty 	<ul style="list-style-type: none"> • Emergency pricing reforms: Extend qualification of units for ELMP and raise offer floor 	<ul style="list-style-type: none"> • Multi-day Operating Margin forecast (MOM) • Maintenance Margin enhancements • Extended Locational Marginal Pricing (ELMP)
	Resource Models	<ul style="list-style-type: none"> • How might MISO specify resource models to account for changing capabilities and cost components? • Hybrid resource participation models • Enhanced demand response integration • Storage optimization offering (pumped hydro prototype) • Other advanced models addressing capabilities, constraints and cost structures 	<ul style="list-style-type: none"> • FERC Order 2222: market integration • Multi-configuration Resources (Enhanced Combined Cycle) 	<ul style="list-style-type: none"> • Energy Storage Resource (ESR) 	<ul style="list-style-type: none"> • Dispatchable Intermittent Resources (DIR) for wind and solar
Availability	Location	<ul style="list-style-type: none"> • What is the best way to specify constraints for meeting these new local ancillary services requirements while still maximizing the use of system diversity? • Extending Sub-regional and zonal (nodal reserves need and application) • Regional resource assessments 	<ul style="list-style-type: none"> • Scarcity Pricing • Enhancements for long lead units and self commitments 	<ul style="list-style-type: none"> • Short-Term Reserve (STR) 	<ul style="list-style-type: none"> • Reserve Procurement Enhancement (RPE)
Visibility	Coordination	<ul style="list-style-type: none"> • With increasing dynamics and uncertainty, how can MISO bolster coordination across seams? • Seams uncertainty characterization and forecasting • Changing seams needs • Advanced T&D coordination and situational awareness • Utilize efficient market mechanisms to manage seams coordination and market transactions 	<ul style="list-style-type: none"> • FERC Order 2222: Distributed Energy Resource (DER) market integration • Enhance market-to-market coordination processes 	<ul style="list-style-type: none"> • Continue stakeholder engagement • Enhance market-to-market relief request calculation • Implement parallel flow visualization 	<ul style="list-style-type: none"> • Improve MISO-SPP and MISO-PJM market-to-market process • MISO and DER: Ensuring Grid Reliability Through Visibility and Communication whitepaper



Glossary of Terms

Ancillary Services: The services necessary to support the transmission of electric power from generators to consumers given the obligations of control areas and transmitting utilities within those control areas to maintain reliable operations of the interconnected transmission system

Availability: The ability of transmission and energy resources to meet requirements at all hours

Binding Constraint: A constraint is considered binding if changing its limit can result in changing the optimal solution

Capacity Market: Ensures long-term grid reliability by procuring the appropriate amount of power supply resources needed to meet predicted energy demand one year in the future

Co-optimization: Process of procuring energy and ancillary services simultaneously in the market clearing processes

Day-Ahead Market: Bid-based day-ahead market using security constrained unit commitment and security constrained economic dispatch (SCUC and SCED)

Decentralization: Involves the shift away from large, central-station power plants to smaller, often variable resources that are located on local, low-voltage electricity distribution networks, or “behind the meter” at homes and businesses

Demarginalization: Refers to the modified set of resources that can provide the next needed, or “marginal,” increment of energy at zero additional costs (e.g., renewables), or very low additional costs (e.g., highly efficient gas-fired generation)

Digitalization: Refers to the revolution in information and communication technologies and platforms that will continue to disrupt nearly everything in the U.S. economy, including energy services

Extended Locational Marginal Price (ELMP): MISO extends the LMP and MCP by allowing the cost of committing Fast Start Resources, the Energy cost of Fast Start Resources dispatched at limits, and Emergency Demand Response Resources to set Energy and reserve prices. This process is known as the Extended LMP

Emergency Operations Resource: An online Generation Resource that is started, synchronized and injects Energy, or a Demand Response Resource that reduces its Energy consumption, within two hundred forty (240) minutes but over sixty (60) minutes of being notified and that has a minimum run time of over one hour but less than four hours and that will participate in setting price as described in the process in Schedule 29A of this Tariff.

Fast Start Resource: An online Generation Resource that is started, synchronized and injects Energy, or a Demand Response Resource that reduces its Energy consumption, within sixty (60) minutes of being notified and that has a minimum run time of one hour or less and that will participate in setting price as described in the process in Schedule 29A of this Tariff; or, an offline Generation Resource that can be started, synchronized and inject Energy, or a Demand Response Resource that can reduce its Energy consumption, within ten (10) minutes of being notified and that has a minimum run time of one hour or less, and that will participate in setting price as described in the process in Schedule 29A of this Tariff. A Fast Start Resource does not include fuel-limited resources such as pumped storage, run-of-river hydro, and wind resources.

Financial Transmission Rights: A financial instrument that entitles the holder to receive compensation for Congestion Costs that arise when the transmission grid is congested in the Day-Ahead Energy Market, and differences in Day-Ahead Locational Marginal Prices (LMPs) result from the dispatch of generators to relieve the congestion

Flexibility: The ability to anticipate and adapt to frequent, significant changes in generation output and demand; and enable new sources of flexibility

Locational Marginal Pricing (LMP): The cost of providing the next MW of electrical energy at a specific location on the transmission grid. This includes a marginal congestion component and marginal loss component in addition to marginal energy component to account for losses and congestion

Market Clearing Price (MCP): The marginal cost to serve market-wide and zonal reserve requirements

Real-Time Market: Bid-based real-time market solved with security constrained economic dispatch

Reliability Commitments: SCUC-based reliability commitment processes to ensure that sufficient generation will be online to meet forecast real-time requirements

Reliability Imperative: The shared responsibility of utilities, states and MISO to address the host of complex and urgent challenges to electric system reliability in the MISO region

Resource Models: A set of mathematic models to represent resource physical or business constraints

Security Constrained Unit Commitment (SCUC): Security Constrained Unit Commitment

Transmission Constraint: A limitation on one or more transmission elements that may be reached during normal or contingency system operations

Visibility: The ability to see and coordinate relevant resource, demand and powerflow attributes in operations and planning horizons

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