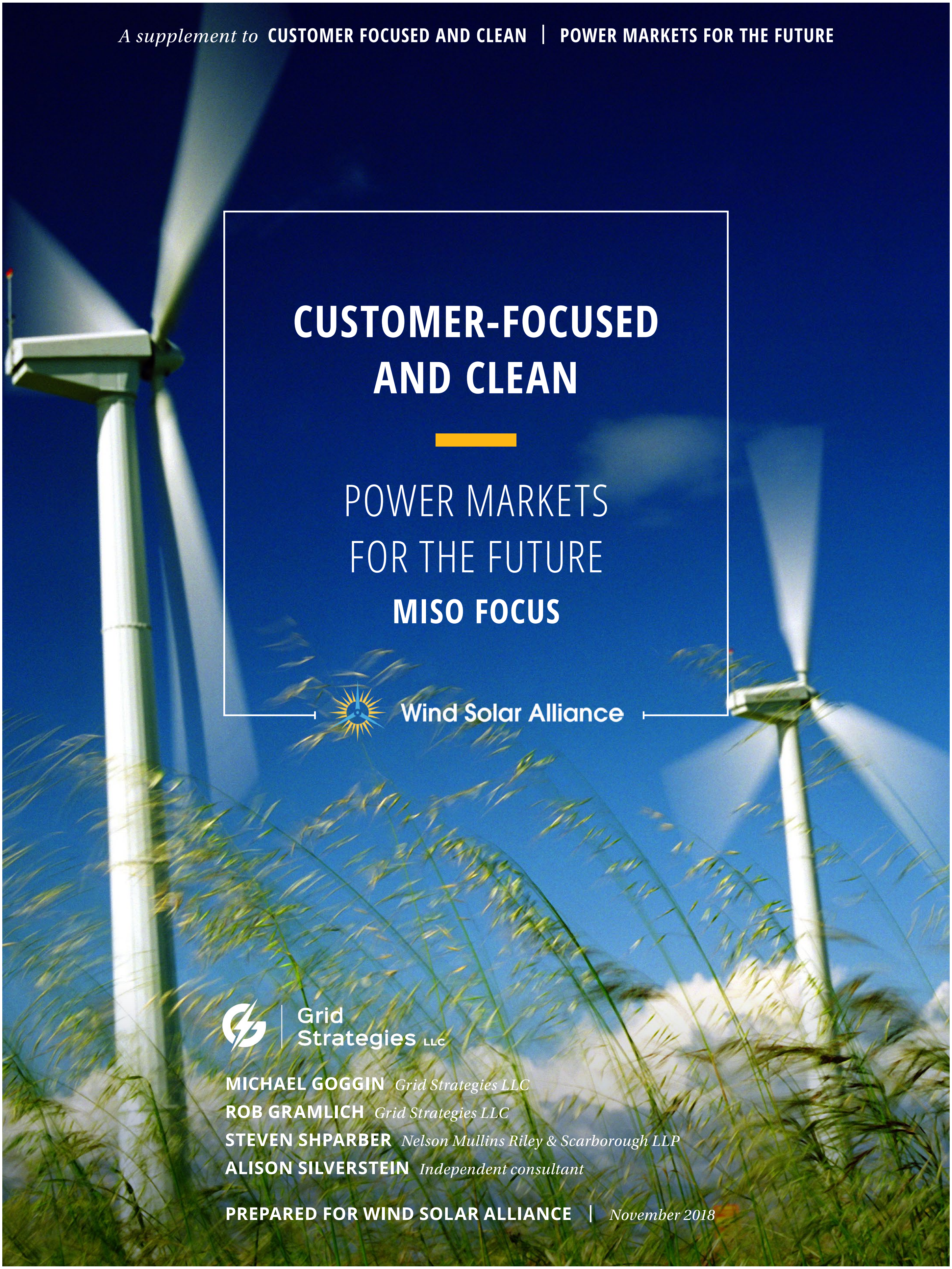


A supplement to **CUSTOMER FOCUSED AND CLEAN | POWER MARKETS FOR THE FUTURE**

CUSTOMER-FOCUSED AND CLEAN

POWER MARKETS FOR THE FUTURE

MISO FOCUS

Wind Solar Alliance

Grid Strategies LLC

MICHAEL GOGGIN *Grid Strategies LLC*
ROB GRAMLICH *Grid Strategies LLC*
STEVEN SHPARBER *Nelson Mullins Riley & Scarborough LLP*
ALISON SILVERSTEIN *Independent consultant*

PREPARED FOR WIND SOLAR ALLIANCE | *November 2018*

I. INTRODUCTION AND EXECUTIVE SUMMARY

This paper offers recommendations for how to update wholesale electric market rules for the Midcontinent Independent System Operator (MISO) to better serve customers' and regulators' desire for clean, affordable electricity. These recommendations seek to align wholesale market rules more closely with several considerations: the continued growth of renewable generation, energy efficiency and distributed generation due to advantageous economics and customer preferences; the need for reliable, secure and resilient energy systems; the need for affordable electricity; and federal and state mandates requiring fair, non-discriminatory opportunities for all providers, technologies and customers.

The Wind Solar Alliance (WSA, formerly the Wind Energy Foundation) is working in partnership with the American Wind Energy Association and Solar Energy Industries Association on a research and educational campaign called A Renewable America (ARA). As part of this effort, WSA hired a team assembled by Grid Strategies LLC (GS) to research and offer recommendations on how wholesale electric power markets can better foster a reliable, affordable and clean electric system given current trends in energy technologies and economics. WSA also asked the GS team to recommend paths toward that improved market design in the MISO region.

The GS team embarked upon an extensive literature review and expert survey to develop key findings and recommendations about changes needed to ensure a reliable and low-cost power system with much higher levels of wind and solar resources. Experts consulted include wind and solar developers, renewable customers, Regional Transmission Organization (RTOs, which operate competitive power markets), stakeholders and staff, and other electric sector experts.

Markets that work for renewable resources must enable success for all resources that support aspects of system reliability, including conventional and renewable generation, demand-side and storage resources. Transmission infrastructure and interconnection issues also have major impacts on markets, affecting resource participation timing and economics; but those issues are not in the scope of this study.

The time is ripe for a re-evaluation of MISO's market rules. Along with trends occurring across the country with changes in the resource mix, the RTO has indicated its plan to revamp its market system and software in the near future. MISO initiated a Market Roadmap process with its stakeholders to prioritize changes for short- and long-term system and software redesign.

CONCLUSIONS AND RECOMMENDATIONS

We offer several reform recommendations for MISO markets:

1. **Attract more flexible resources, including demand resources and storage through value-based pricing and open participation**
2. **Allow renewable resources to participate in all product markets**
3. **Improve the efficiency of generator commitment and dispatch**
4. **Update resource adequacy design, including seasonal capacity requirements**

II. THE CORE MISO MARKET DESIGN PROVIDES A SOUND PLATFORM

MISO has been a worldwide leader in integrating renewable resources. When MISO began operation just over 15 years ago, no system operator had meaningful experience integrating over 5 percent of its region's energy from renewable resources. Both the MISO region and MISO's renewable energy penetration have grown over that period. Today, 8% of MISO's annual energy comes from renewable sources,[1] and there are another 40,747MW of wind and 35,204 MW of solar in MISO's interconnection queue.[2] While adding these renewable resources, MISO has delivered consistently reliable and efficient grid performance and market operations and has retained the support of its stakeholders, including state and federal officials.

MISO's fundamental design improves reliability, efficiency, and renewable energy integration compared to the balkanized structure that existed previously. Before MISO consolidated into a single Balancing Authority, its footprint was comprised of 25 Balancing Areas, each keeping supply and demand in balance but doing so without taking advantage of the net surpluses or shortages in neighboring areas. The MISO market acts as a power pool to leverage and net out all of those excesses and shortages, keeping the overall system in balance with less collective effort, cost and physical energy infrastructure.

The MISO market design serves a wide load and resource area with a real-time and day-ahead market for energy and a suite of reliability services: frequency regulation, operating reserves, and ramp capability. This core design (which has become the standard for wholesale power markets internationally) is reliable and efficient, and is particularly well-suited for variable generation sources such as wind and solar energy. Variability and uncertainty in electricity demand and renewable and conventional generation supply mostly cancel out over large geographic areas. MISO's basic market framework of a large regional spot market with rapid dispatch and multiple reliability services, which allows the least-cost resources to provide each product, is a sound platform -- even though that design intent is not always implemented well in the detailed market rules.

MISO relies less on "capacity" markets than PJM, New York, and New England. This benefits renewable energy sources because capacity market product definition and eligibility determinations for renewables have not been fully evidence-based and have discounted renewables' value in those other regions. Recently FERC and those ISO/RTOs have been applying capacity market bid restrictions to any sources eligible to receive state policy support (such as state-created Renewable Energy Certificates); this reduces compensation to renewable and other resources for the capacity value they provide to the system. Fortunately that has not yet been considered seriously within MISO.

The MISO market exhibits the basic criteria for reliable, affordable markets that work effectively for a supply mix that includes high levels of renewable generation. Such markets need to be *flexible*, *fair, far,* and *free*.

- *Flexibility* refers to both the market and the power system. A flexible power system should be able to respond and adapt to changes in uncontrollable or non-dispatchable factors such as consumption (load), wind speed, solar insolation, other generator output deviations, forced generation outages and transmission disruptions.
- A *fair* market will treat all customers and resources evenly and allow all the opportunity to succeed. Such a market will be designed around service requirements and performance capabilities and be fuel-neutral and technology-agnostic, without inappropriately advantaging or penalizing particular customers or resources.
- A *far* market will have a broad geographic span, to maximize the efficiency benefits of supply and demand diversity, reducing variability of resources by netting them out against each other.
- A *free* market facilitates customer choice and does not raise barriers to market entry and exit.

The core market design used in MISO is generally flexible, fair, far, and free, and has the potential to remain so as resource technologies, customer preferences and public policies continue to evolve.

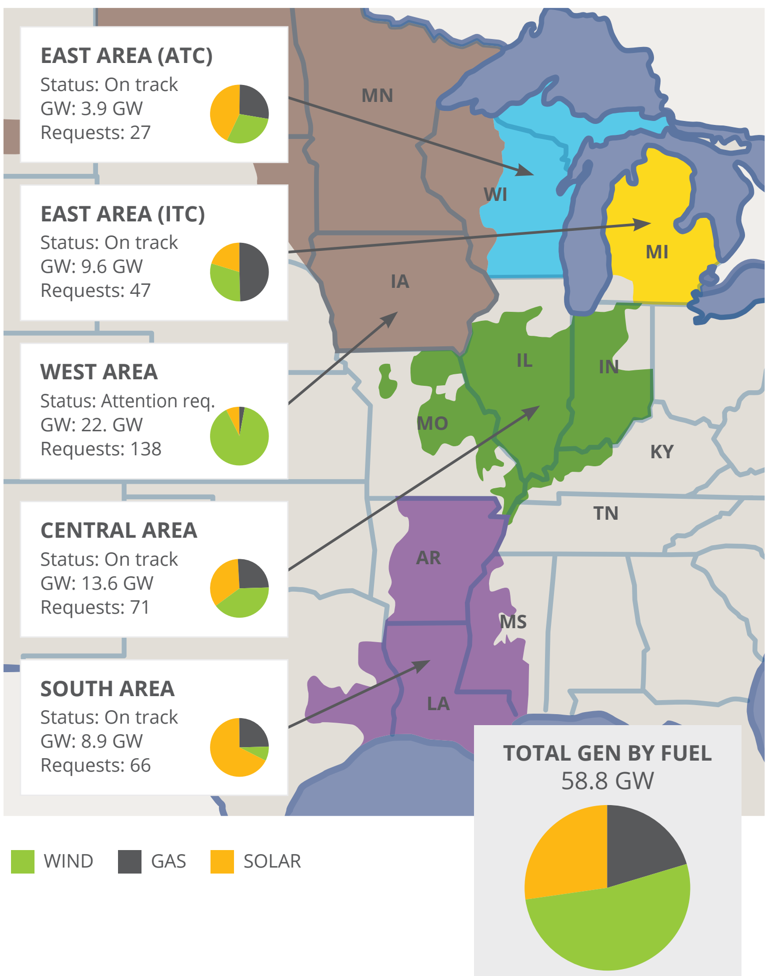
1 MISO (2017), slide 4.
2 MISO (2018a).

III. THE MISO MARKET DESIGN NEEDS TO ADAPT TO TECHNOLOGICAL CHANGE AND CUSTOMER PREFERENCES

Significant shifts are underway across North America's electric industry. Technology and project installation costs have fallen for wind and solar generation, as have natural gas fuel and generation costs. Technologies and business models for energy storage and customer demand management have also evolved dramatically. Computing power for more sophisticated system operations has grown exponentially, and monitoring and control systems have improved, facilitating more reliable and efficient system operation.

Customer preferences have changed as well. Large corporate electricity users are transforming energy acquisition with purchases of renewable energy. Since 2013, dozens of U.S. corporations have contracted for 13.1 GW of wind and solar capacity[3] across the nation.

MISO PLANNING AREA MAP



These economic changes are transforming MISO's generation mix. The following map illustrates that wind (green) and solar (yellow) generators account for the vast majority of resources that have applied to interconnect to MISO's system.[4]

This shift in the resource mix creates both opportunities and challenges. Wind, solar, and battery resources are inverter-based resources[5] with different operating characteristics from conventional resources. These resources offer new ways to improve system reliability and efficiency, but necessitate different approaches and assumptions about power system design, capability and operation. Market rules, tariff provisions, and NERC and regional reliability standards and guidelines do not yet capitalize on the performance capabilities of wind and solar resources and the inverters that connect them to the grid.[6]

New wind, solar, storage and demand response technologies can only improve grid reliability and efficiency if grid operators and regulators modify reliability and compensation rules to allow these new resources to do so. Table 1 shows the services that can be provided by these new resources as well as conventional resources. Overall, renewable energy sources perform very well relative to other sources in their capability to provide reliability services.

3 RMI Business Renewables Center (2018).

4 MISO (2017), slide 4. More resources have joined the interconnection queue since this map was created.

5 Inverter-based resources are connected to the power system by power electronics that convert Direct Current (DC) to the Alternating Current (AC) used on today's grid; conventional resources such as hydro, nuclear and fossil resources all generate AC power and feed it directly into the grid.

6 The power electronics in the inverters connecting renewables and batteries to the power system can be programmed and controlled to provide reactive power and frequency response, both of which are essential reliability services.

TABLE 1. *Essential Reliability Services Provided by Different Generation Technologies*

RELIABILITY SERVICE	WIND	SOLAR PV	DEMAND RESPONSE	BATTERY STORAGE	GAS	COAL	NUCLEAR
Voltage support: Reactive power and voltage control	Provides, and can provide while not generating by using power electronics.	Provides, and can provide while not generating by using power electronics.	Could provide, though this would require detailed knowledge of distribution system state and dispatch.	Power electronics provide fast and accurate response.	Must be generating to provide.	Must be generating to provide.	Must be generating to provide.
Voltage support: Voltage and frequency disturbance ride-through (also important for frequency support)	Voltage and frequency ride-through capabilities due to power electronics isolating generator from grid disturbances. Wind meets more rigorous ride-through requirement (FERC Order 661A) than other generators.	Can thanks to power electronics, but standards have prevented use of capability.	NA	Power electronics isolate battery from grid disturbances.	Generators often taken offline by grid disturbances.	Generators and essential plant equipment, like pumps and conveyor belts, often taken offline by grid disturbances.	Generators and essential plant equipment, like pumps, often taken offline by grid disturbances.
Frequency support: Frequency stabilization following a disturbance (through primary frequency response and inertial response to disturbances)	Wind regularly provides fast and accurate PFR in ERCOT today. Can be economic to provide upward response if curtailed. Can provide fast power injection (synthetic inertia) if economic to do so.	Can provide downward frequency response today, can provide upward frequency response and fast power injection if curtailed.	Load resources currently provide this in ERCOT through autonomous controls when frequency drops below a certain point.	Power electronics provide very fast and accurate power injection following a disturbance.	Only 10% of conventional generators provide sustained primary frequency response.	Only 10% of conventional generators provide sustained primary frequency response.	Nuclear plants are exempted from providing frequency response, but they do provide inertia.
Ramping and balancing: Frequency regulation	Fast and accurate response. Can provide but often costly, particularly for upward response. Provides on Xcel's system.	Fast and accurate response. Can provide but often costly, particularly for upward response.	Autonomous loads like water heaters can provide, though the cost of disruption may be too great for other DR.	Very fast and accurate response.	Must be generating to provide.	MISO data show a large share of coal plants provide inaccurate regulation response.	Does not provide.
Ramping and balancing: Dispatchability / Flexibility / Ramping	Fast and accurate response. Can but often costly, particularly for upward response. Provides on Xcel's system.	Fast and accurate response. Can provide but often costly, particularly for upward response.	Many forms of DR are likely to be energy limited or too expensive for longer duration deployment.	Many types of batteries will be energy limited for longer-duration events, particularly if state of charge is not optimal going into event.	Most gas generators are operated flexibly.	Many coal plants have limited flexibility, with slow ramp rates, high minimum generation levels, and lengthy start-up and shut down periods.	Almost never provides.
Ramping and balancing: Peak energy, winter (color reflects risk of common mode unavailability reducing fleetwide output below accredited capacity value)	Wind plants typically have high output during periods of extreme cold, as seen in ERCOT in 2011 and much of the country in 2014.	Solar plants have lower output during the winter.	Many DR programs are not currently designed for winter peak demand reduction.	Good, though will be energy limited for longer-duration events.	High gas demand can cause low gas system pressure, fuel shortages. Can be mitigated with dual fuel capability or firm pipeline contracts.	Many coal plants failed due to cold in ERCOT in February 2011, polar vortex event in 2014, and other events.	Some failures due to extreme cold.
Ramping and balancing: Peak energy, summer (color reflects risk of common mode unavailability reducing fleetwide output below accredited capacity value)	In many regions wind output is lower during hot summer days, though that is accounted for when calculating wind's capacity value. In some regions, like coastal areas or mountain passes, wind output is higher on hot summer days.	Solar plants typically have high output on hot summer days, though solar output has typically declined by the early evening peak demand period.	Many forms of DR are used for summer peak load reduction today, including air conditioning curtailment.	Good, though will be energy limited for longer-duration events.	Gas generators experience large output de-rates when air temperatures are high.	Coal plants experience de-rates when cooling water temperatures are high.	Nuclear plants experience de-rates when cooling water temperatures are high.

HIGH CAPABILITY TO PROVIDE SERVICES · SOME CAPABILITY TO PROVIDE SERVICES · LITTLE TO NO CAPABILITY TO PROVIDE SERVICES

Current market design and grid operations protocols were written without any of the above changes in mind, nor any recognition of the capabilities of these new technologies. Most of the power system planning, operations and market methods now in use were developed around the operational capabilities of large, utility-owned conventional fossil, nuclear and hydro power plants. Some examples of the historical characteristics and assumptions that underlie current market rules include:

- The timing of the two-settlement market, with day-ahead and real-time clearing, was based on the typical fuel procurement timeline of gas generation as well as the start-up time for coal generators.
- Operating reserves were defined by characteristics of thermal generation supply ("spinning" vs "non-spinning"), rather than by system needs.
- "Inertia" from the rotating masses of synchronous generators was considered a product, when it is actually only one tool to stabilize frequency following a system disturbance (the other primary tool being fast frequency response, which inverter-based resources and some industrial demand response providers can deliver).
- Operating reserve needs were defined based on the loss of large synchronous generators, rather than other sources of variability and uncertainty.
- Transmission and generation were scheduled well in advance of the operating period, because most of the available resources were relatively inflexible, most market transactions were conducted bilaterally, and the system lacked the fast communications and computing power to set schedules closer to the operating period.
- Generation and transmission were operated very conservatively using fixed operating limits and schedules and contingency analysis, because operators and generating resources lacked the ability to monitor and control power system operations and respond to contingency events in real time.
- Many grid services such as "inertia" and voltage support were not compensated through the market because most power plants were owned by vertically integrated utilities that were recovering generation costs in rate base and fuel cost rate cases, not market-based compensation.

Studies and experiences around the world have shown that systems can operate reliably with renewable penetrations over 50 percent, but there are implications for system operations. The National Renewable Energy Laboratory (NREL) performed a comprehensive study of high renewable penetration for the U.S. Eastern Interconnection, of which PJM and MISO are significant parts. The study concluded, "While [the Eastern Renewable Generation Integration Study] shows it is technically possible to balance periods of instantaneous [Variable Generation] penetrations that exceed 50% for the [Eastern Interconnection], the ability of the real system to realize these futures *may depend more on regulatory policy, market design, and operating procedures*."[7] [italics added] NREL also performed a Renewable Energy Futures Study which thoroughly studied the grid implications of an 80 percent renewable scenario.[8] The report finds, "the central conclusion of the analysis is that renewable electricity generation from technologies that are commercially available today, *in combination with a more flexible electric system*, is more than adequate to supply 80% of total U.S. electricity generation in 2050 while meeting electricity demand on an hourly basis in every region of the United States."[9] [italics added] A more recent NREL report found that 70% wind and solar can be reliably accommodated in the Eastern U.S., but that system operating costs would be higher if market rules do not facilitate flexible operation of the generation fleet or among grid operators.[10] The more flexible electric system and changes to market design assumed in these models are the focus of this report.

With rapid changes in MISO and other regions' resource mix and operational capabilities, it is time to consider how to modify MISO's rules and procedures to address and anticipate current and future renewable penetration levels.

7 NREL (2016), p. 154.
8 NREL (2012).
9 *Ibid* p. 5. The 80 percent renewables included approximately 50 percent variable wind and solar resources and 30 percent from other resources including hydroelectric, biomass and geothermal.
10 NREL (2018).

IV. RECOMMENDED MISO REFORMS

The reform proposals below are intended to improve the effectiveness of MISO's market and operations at serving all customers and resources under a range of future resource mixes, technology paths, societal and customer preferences. They are consistent with the principles discussed in Section 2, that wholesale electric markets and systems should be flexible, fair, far and free.

1. ATTRACT MORE FLEXIBLE RESOURCES, INCLUDING DEMAND RESOURCES AND STORAGE THROUGH VALUE-BASED PRICING AND OPEN PARTICIPATION

The new generation patterns introduced by wind and solar plants, as well as their variability and uncertainty, are increasing the value of power system and resource flexibility. The notorious California ISO "duck curve" (in which solar generation has caused net load (total load minus variable renewable generation) to bottom out midday and then ramp up swiftly in the evening as the sun sets) is a good example of the increasing need for fast-responding resources. This pattern drives wholesale electricity prices notably higher during the morning and evening ramps, reflecting the premium for flexible generation during those periods.[11]

Any energy market offer caps should reflect the full value of providing reliable electric service during times that generation is scarce.[12] An Operating Reserve Demand Curve (ORDC) adder to the energy market price can also be used to reflect the value of scarce operating reserves during shortage events.[13] MISO caps energy market prices at levels below the $9,000/MWh cap used in ERCOT. MISO's IMM has written that, "MISO's current ORDC does not reflect reliability value, overstating the reliability risks for small, transient shortages and understating them for deep shortages."[14]

Scarcity pricing attracts needed flexibility both in the operating time frame and in the long term investment time frame. By allowing prices to swing high or low during periods in which flexibility is needed, it is incentivizing resources to become more flexible. In an effective power market, most customers do not actually pay the scarcity-based price, as they have been shielded by advance forward contracting for energy at reasonable costs; it is only those customers that did not plan for their needs that pay the spot price during the scarcity event. Scarcity pricing serves as a penalty or a speeding ticket, that exists to dissuade inefficient behavior (in this case, leaning on the system or free riding during extreme market conditions) but should rarely have to be paid.

To make the power system more flexible and encourage customers to shift electricity consumption to when energy supply is abundant, retail electricity customers should see prices that reflect both energy surplus and energy scarcity, if not real-time wholesale electricity prices. This would enable controllable electricity demand to be dispatched to provide both energy and reliability services. One way to achieve this is to allow load participation in the wholesale energy and reliability services markets (as through demand aggregators). Another option (which is beyond the jurisdiction of RTOs and FERC and therefore the scope of this paper) is for states to implement real-time retail pricing to allow electricity users to respond to price signals. Whether implemented through state or federal jurisdiction, these changes would allow end users with automated loads to see when energy availability is high – as from night-time wind and afternoon solar generation – and consume more of that low-priced electricity, as well as reducing load in times when less generation is available and the grid may be experiencing scarcity or emergency conditions.

Flexibility can be increased by reducing operational "seams" between MISO and its neighbors, since it is often the case that flexibility can come from outside the region. MISO, PJM, and SPP should work together to reduce wheeling costs and other "friction" for transactions across RTO/ISO market seams, including implementation of coordination

11 DOE EIA (2017).

12 FERC acted in Order No. 831 to ensure offer caps reflect the value of reliable electricity, although that order limits offers to $2,000/MWh. See FERC (2016).

13 ERCOT has set an energy market price cap and an ORDC that reflects a Value of Lost Load of $9,000/MWh. See ERCOT (undated).

14 Potomac Economics (2018), p. 86

transaction scheduling.[15] RTOs should further reduce "pancaked" transmission rates that increase the cost of transmitting electricity across multiple balancing areas.

MISO should consider additional flexibility products. Market operators have tried several different approaches to procuring flexibility. MISO has reported success from its implementation of a 10-minute ahead Ramp Capability Product.[16] MISO assesses likely variability and uncertainty over the next 10 minutes and then procures enough flexibility to meet that need. MISO allows renewables and demand response resources -- but not storage -- to provide the service and has seen 95-97% of eligible supply-side resources participating. Pricing is based on a resource's opportunity cost, a ramp capability demand curve, and incentives for performance in following dispatch.

STORAGE INTEGRATION

Storage resources could provide a lot of new flexibility to the system if the rules appropriately accommodate them. MISO and other FERC-jurisdictional RTOs are in the process of implementating Order No. 841 providing for participation of storage resources in energy, capacity, and reliability services markets. That process should clarify rules such as whether separate operating (charge and discharge) modes are needed, and the ability to update a resource's State of Charge when coming back on line from an off-line state. Those are key parameters for storage resources, for the owner and the system, that are unlike the parameters of other resources.

Storage participation in capacity markets is important in MISO as much for the way states incorporate MISO-determined capacity values in their resource planning as for the actual MISO market. Storage resources should be allowed to participate in capacity markets to increase overall system operating flexibility. If a storage resource can be sufficiently charged to help meet a system peak (which likely means not providing other reliability services at that time), it should receive credit for doing so. Duration requirements should be re-examined because shorter operational increments provide greater flexibility and thus better support system reliability than longer increments.[17]

Flexibility price signals should not be diluted by misapplication of market power mitigation rules. The market power mitigation rules applied by market monitors were designed for conventional generators. These rules generally limit resources' bids to their marginal operating costs (heat rate times fuel cost for a typical fossil plant). That method, while justified for conventional resources to achieve competitive prices where true supply and demand intersect, does not translate well for storage or demand resources for which the marginal cost of production is based on opportunity cost rather than the cost of fuel. The opportunity cost of storage fluctuates widely over time and is not known to market monitors. Market power mitigation rules also prevent physical withholding. The rules should clarify that storage resources de-rating in order to satisfy minimum run-time requirements are not engaging in physical withholding. Given that most storage and demand resources are small and are owned by smaller market participants, the risk of market manipulation from these resources is low.

MISO has a "Use Limited Resource" capacity product that allows a resource to be a capacity resource if it is capable of providing the energy equivalent of its claimed Capacity for a minimum of at least four continuous hours each day across MISO's peak, and meets other requirements specified in MISO Manual No. 011. However, MISO also has rules in Manual 011 stating that battery storage resources are eligible to qualify as Planning Resources only if they are behind the meter. This is an unwarranted restriction; any storage or hybrid storage-renewable resource that can meet the minimum 4-hour performance requirements should be considered as a capacity resource. Changes to these rules will require revisions to MISO's tariff and MISO Manual No. 011.

"Hybrid" resources, such as generators paired with storage or demand response, should be allowed to provide all services, including capacity and reliability services. Discussions on allowing hybrid resources in the interconnection process have been taking place since 2015, yet despite FERC rules on storage (Order No. 841) and interconnection (Order No. 845), there has been little change in the interconnection process to allow hybrid resources timely interconnection. While the benefits of pairing specific storage and renewable plants usually result from design flaws

15 This also includes reforms to pricing methods across the RTO interface. Initial attempts have not worked well but proposals to improve it are being discussed. See, e.g., MISO (2018b).

16 MISO Market Subcommitee (2016).

17 Shorter requirements result in a much larger population of qualified resources, and thus more capability at lower cost. If long-duration ramp needs occur, they can still be met by combining shorter-duration blocks of flexibility, such as a fleet of one-hour batteries.

that could be fixed, if RTOs fail to fix those flaws, it is important that market participants have the opportunity for resource aggregation and pairing. Ideally the bulk power system will inherently aggregate all resources and achieves a higher capacity value and less variability than the sum of its parts because output deviations among generators are not perfectly correlated, such that formal resource pairing is not needed. But under current market rules the synergistic capabilities offered from pairing can create more revenue for both resources than operation alone. Pairing makes sense if resources are being denied credit for their actual contributions to system capacity needs, as due to the lack of seasonal markets and the asymmetric penalty structure in PJM, if they are overly penalized for their operational deviations, or if the two resources can achieve interconnection at a lower total cost than interconnecting separately. While the best solution is fixing market design flaws, if that is not feasible then formal resource pairing can add value to the system.

2. ALLOW RENEWABLE RESOURCES TO PARTICIPATE IN ALL PRODUCT MARKETS

As the speed and variability of North America's grids increase, the faster and more precise reliability services offered by inverter-based resources can be part of the solution to assure grid reliability, security and resilience. To maximize fairness and efficiency in reliability services markets, every resource that can provide a reliability service should be able to compete to do so. This would allow the market to choose the mix of least cost supply and demand resources that can best deliver needed services over time, and benefit customers through higher reliability at lower costs.

MISO bars dispatchable renewables from providing frequency regulation, spinning reserves, and supplemental (non-spinning) reserves, though renewables can provide MISO's new ramping service.[18] Energy storage is now allowed to provide frequency regulation but not the other reserves.

UNIVERSAL PARTICIPATION MODEL

RTO market operators currently use a model of each type of resource participating in the market to calculate how each resource will interact with others and the system as a whole. FERC recently issued Order No. 841, which requires all RTOs and ISOs to create a storage "participation model" and allow storage resources to participate in any energy, reliability services and capacity markets for services they are capable of providing. While some parties asked for these changes to generically apply to all resources, FERC ruled that Order No. 841 was focused on storage only. FERC has not to date directed comparable treatment for wind and solar resources.

Rather than adding more technology-specific participation models for each new technology on top of the generator, load, demand response, and now storage participation models now used, FERC (or an individual RTO such as MISO) could replace all of these with a "Universal Participation Model." A Universal Participation Model is a technology-neutral set of bid parameters that reflect all of the operational characteristics and capabilities that matter to grid operators.[19] FERC could propose a universal model for Order No. 841 compliance, as allowed in the Order (although compliance is due in the very near term and significant work would be needed at each RTO), or MISO could adopt the Universal Participation Model in the near future as a step beyond Order No. 841 compliance.

With modern computing power and optimization methods, and the similar capabilities among all inverter-based resources, there is reason to believe that all resources could submit energy and ancillary services offers to the market using the same set of parameters, which the system could then optimize.[20] This would have to be accompanied by technology-neutral reliability service definitions. If every resource participating in a competitive market had to submit accurate, verified performance parameters annually to the RTO for modeling and dispatch based on a common Universal Participation Model, that would enable better comparison of asset and technology capabilities and facilitate more accurate, up-to-date market and operational forecasts.

FREQUENCY REGULATION

Beyond letting renewables provide frequency regulation services, there is potential value in establishing separate

18 MISO Market Subcommitee (2016), p. 4.
19 Ahlstrom (2018).
20 Ahlstrom (2018).

markets for up- and down-frequency regulation, because wind and solar typically face a greater opportunity cost for providing up-regulation than down-regulation.[21] Providing up-regulation ("reg-up") requires holding a plant below its maximum output at all times while it is offering the service so that it can increase output when needed to provide the reg-up service. In contrast, reducing the output of a plant to provide frequency down-regulation ("reg-down") only requires withholding the amount of output that is necessary to bring the system back into balance. Renewable resources that have already been curtailed can provide very low cost reg-up service. Separate reg-up and reg-down markets would also enable greater regulation provision by storage resources (which at high or low levels of charge may be able to provide one service but not the other) and demand response resources (which typically only provide reg-up service by dropping load).

Wind and solar plants, with wholly electronic controls, are able to provide regulation services with greater speed and accuracy than conventional power plants. CAISO has found that frequency regulation from solar PV inverters is around 90% accurate at meeting specific regulation demands quickly, which is almost twice as accurate as conventional generators and some energy storage technologies.[22] Even though wind and solar resources typically face higher opportunity costs than other resources for providing frequency regulation, their ability to deliver fast and accurate frequency regulation under FERC Order No. 755 could make inverter-connected resources more economic for this premium service than conventional resources.[23] This change could significantly improve grid operational reliability without significant cost.

MISO does not operate a "fast regulation" market at present, but only a slower market that does not reflect the full value of the faster service that renewables energy and renewables plus storage could provide. Any changes to MISO's regulation services will require revisions to the MISO Tariff and associated manuals.

FREQUENCY RESPONSE

RTOs should not require renewable resources to curtail production to reserve headroom to provide upward primary frequency response, as has been discussed in some stakeholder meetings. FERC was clear in Order No. 842 that it was not imposing a headroom requirement (although that does not prevent an ISO from attempting to do so). Such a requirement would keep low-marginal cost resources like wind and solar from earning revenues on their full operational output and could be viewed by FERC as unjust, unreasonable, and unduly discriminatory. Rather than imposing a flat operational requirement, RTOs can use market mechanism as a more efficient way to procure frequency response service, since the cost of that service varies considerably across resources, time, and operational conditions. RTOs should also create premium markets for fast frequency response to reflect its greater value to the power system, similar to the premium markets for fast and accurate frequency regulaton under FERC Order No. 755.[24]

During a frequency disturbance requiring upward primary frequency response, resources should be allowed to increase their output above interconnection limits or dispatch limits imposed by thermal constraints on the transmission system. This would allow resources that are curtailed due to transmission thermal limits to offer valuable upward primary frequency response at essentially zero opportunity cost, and there is no significant harm to the transmission system from exceeding thermal limits over the seconds-to-minutes time frame for which primary frequency response is deployed.

Changes to primary frequency response rules would affect the MISO Tariff and MISO Manual 018 (among others).

PRICE-SETTING FOR RELIABILITY SERVICES

Renewables, demand and storage resources should be able to provide and set prices for all reliability services. One reason this change has not been implemented to date is that many current RTO stakeholders do not understand or

21 Up-regulation ("reg-up") entails quickly increasing generation to restore frequency to safe operating levels when load on the grid exceeds available generation (as when a large generator fails or transmission drops, cutting delivery from one or more power plants). Down-regulation ("reg-down") involves a fast drop in generation to restore frequency to safe operating levels when generation on the grid exceeds load (as when an extensive transmission or distribution event drops a large amount of load).

22 Loutan & Gevorgian (undated), p. 30.

23 FERC (2011).

24 In FERC Order No. 755 the Commission sought to remedy undue discrimination in frequency response service, to make sure resources that respond faster are compensated accordingly. FERC (2011).

trust renewable generators' ability to provide reliability services, are not yet comfortable with the statistical reliability of many diverse resources aggregated across a wide range of geography and ownership, or assume that renewable resources will always produce the maximum output they can based on the solar or wind resource available at that time. Some operators may not feel comfortable with meteorological or forecast-based estimates of wind and solar plants' available capacity for operating reserve or ramping headroom.[25] Such discomfort is understandable, but it would be worthwhile to begin doing shadow forecasting and managed dispatch to demonstrate and gain familiarity with these new resource capabilities and performance characteristics.

3. IMPROVE THE EFFICIENCY OF GENERATOR COMMITMENT AND DISPATCH

Many conventional generators in MISO are self-committed or self-scheduled by their owners. Self-commitment is when the owner commits to starting up to place the resource on-line, and self-scheduling is when the owner unilaterally sets the unit's output level while taking the market-determined prevailing price, rather than being dispatched by the RTO through the centralized unit commitment and scheduling process.[26] Many of these generators are owned by regulated utilities that are under the jurisdiction of state regulators, which may encourage self-commitment and self-scheduling in order to maximize production from the unit. Regulated generators pass through operating costs to utility customers so the plant owner is indifferent to higher operating costs, and the utility may have an incentive to operate the plant to demonstrate its continued usefulness to justify keeping the plant in ratebase, where it earns a rate of return for the utility. Analysts have identified regulated coal plants that incur an average of about $500 million in operating losses per year in MISO.[27]

Both self-commitment and self-scheduling tend to increase overall system costs because the self-scheduled unit is not necessarily the least-cost unit and its operation may force other plants to cycle or curtail output.[28] A plant that is self-committed and self-scheduled typically produces more energy over more hours than that plant would produce if it were to compete with other resources in the RTO's security-constrained unit commitment and dispatch process. For that reason, plants that self-commit effectively reduce the level of load to be served by plants selected through the RTO's competitive market process, and thus the amount of energy that is priced at the lowest competitive level through the RTO's centralized market. This inefficiently suppresses the energy market prices paid to all of the resources serving loads through the centralized RTO market because the lower demand level served through full energy market competition pushes the market-clearing price lower on the supply curve. Over the long-term, however, this tends to raise power system costs because load is being met by higher cost resources operating outside of the market and more economic resources are driven from the market due to artificially low prices. Approximately 75% of operating capacity in MISO (78% of the capacity in the day-ahead market) is self-committed.[29]

Potential solutions to the self-scheduling problem face a jurisdictional obstacle, because most self-scheduled resources are owned by utilities that are providing bundled retail service under state jurisdiction. At the same time, however, self-commitment and self-scheduling plants pose a potential discrimination problem under the Federal Power Act because newer resources are generally required to be dispatchable (as under MISO's Dispatchable Intermittent Renewables program), regardless whether or not those new resources are in utility ratebase. If FERC chose to address this fairness problem, it could develop a rule to address and limit self-scheduled and self-committed resources for consistent application to all resources within RTOs.

25 Members of the renewable community commit to work with RTOs, the research community and others to explore and document the effectiveness and validity of these performance capabilities and successes.

26 Unit commitment is the process that selects, a day in advance, which generators (and other resources) will operate the next day; scheduling and dispatch refer to hourly output levels and instructions for each resource.

27 Daniel (2018).

28 This is particularly true for inflexible nuclear and coal plants, that cannot cycle or ramp inexpensively and have higher marginal and average operating costs than newer natural gas-fired or renewable plants.

29 See Hansen, Xu, Gisin & David (2018). Because the MISO stakeholder process is dominated by vertically integrated utility generation and transmission owners, it is unlikely that MISO will change its self-commitment and self-scheduling rules without FERC or statutory direction. However, given the rapid pace at which utilities have been initiating retirements of conventional plants across the MISO territory, the adverse operational and cost impacts of self-scheduling problem may be shrinking over time.

MISO could use Multi-Day Unit Forecasts[30] to provide better information that reduces the incentive for generator self-scheduling. When market participants with inflexible resources are unsure of near-term (multiple days ahead) supply and demand levels, utility owners tend to over-commit generation to assure they will have sufficient generation to meet load when needed. Those over-committed units are typically inflexible fossil units that displace renewable energy and suppress energy market prices. But if an RTO creates a centralized multi-day-ahead market (extending beyond the current day-ahead market) for voluntary resource and loads transactions, this would create price signals that reflect expected electricity supply and demand, allow participants to create financial hedges against uncertainty, and yield more efficient resource commitment. With better resource commitment, there would be fewer instances when generators would have to operate at a loss over a multi-day or multi-hour period for reliability purposes, so there would be less need to pay generators "make-whole payments" (which perversely insulate a generator from the costs of its inflexibility). The financial opportunity in such a market would also encourage better forecasting of renewable output and electricity demand. If implemented well, multi-day unit commitment could reduce over-commitment and over-generation that suppresses energy market prices. Importantly, participation in this market would be voluntary, and would not entitle a committed resource to any type of make-whole payment if they ended up not being needed. This ensures inflexible resources are not insulated from the system costs of their inflexibility.

RTO operators also act conservatively to protect grid security. They tend to commit more conventional units within the operating day than official schedules say are needed, to ensure that sufficient resources will be available to meet later contingencies.[31] This excess supply decreases market-clearing prices — which underpays all power producers — and keeps more inefficient, inflexible units online. Experts interviewed suggest that MISO operators also commit additional flexible resources they know they will need. Committing flexible units is beneficial for system reliability, but it should be done based on transparent market signals to attract and retain flexible supply sources rather than implemented administratively outside the market.

Grid operators could also offer a shorter commitment window for resources that need less than a day to start up, purchase fuel, etc. One possibility is "rolling unit commitment" based on the actual start-up time for each resource, or two-hour-ahead commitment. This would improve market efficiency and reduce over-commitment by reducing near-term supply and demand forecast error.

Changes to MISO self-scheduling practices will require changes to energy market rules, as well as planning and operating procedures, and revisions to MISO's Tariff and Manual 002. Changing operational practices does not require any changes to RTO tariff or manuals per se.

4. UPDATE RESOURCE ADEQUACY DESIGN, INCLUDING SEASONAL CAPACITY REQUIREMENTS

Current MISO capacity requirements are aimed at assuring that sufficient resources are deployed to meet system peak load, and specify that qualifying resources must be able to perform at a maximum output level year-round. This requirement for capacity to perform year-round should be relaxed, and MISO should instead create seasonal rather than annual capacity products. Broadly speaking, the power system is most reliable and economic when all resources are encouraged and rewarded for contributing to the maximum extent they are capable given their diverse characteristics, so a seasonal capacity requirement would respect the diverse capabilities of seasonally-constrained resources and facilitate a diverse resource portfolio. The MISO IMM has recommended this change for the MISO market, asserting the following benefits from this change:

- Capacity revenues would be better aligned with the value of the capacity;
- Relatively high-cost resources would have an opportunity to achieve savings by taking seasonal outages during shoulder seasons;
- Resources retiring in mid-year would have more flexibility to retire then without having to procure significant replacement capacity to satisfy post-retirement capacity obligations in the remainder of the year;

30 Multi-Day Unit Commitment extends the process of committing generation resources (which has traditionally been done one day in advance through the Day-Ahead market) out several days in advance. For more information, see MISO (2018c).

31 This dispatch of excess units occurs even though the extra units called up are not required under the official dispatch plan for the day or hour.

- The qualification of resources with extended outages can better match their availability; and
- The duration of [System Support Resource] contracts can be matched with planning seasons, which removes a barrier for SSR Units to serve as Planning Resources.[32]

V. CONCLUSION

MISO's operational and market systems have vastly improved the regional grid's reliability, efficiency and ability to integrate clean energy resources compared to the more balkanized 20th century system. MISO has been a leader in integrating renewable generation, reaching relatively high penetrations, despite some growing pains over the years. Continued market evolution will be required going forward. The market should remain technology-neutral and avoid any preferences for or discrimination against any resource. Since many of the market and operating protocols were designed with other resources in mind, there are a number of changes needed to remove implicit preferences for conventional sources. These changes, as described above, would enable MISO to better utilize the capabilities of modern renewables, storage and demand-side resources and improve system economics and reliability on an environmentally cleaner grid.

These and other changes can enable the MISO market to better attract and retain flexible energy resources. Two key changes needed are to allow all sources of flexibility (demand response, storage, ramping from conventional sources, ramping from renewables, and others) to compete to offer their flexibility to the market operator, and to accurately price each flexibility-related service such that the price captures the true value to load at a given time and place.

The changes we recommend include:

1. **Attract more flexible resources, including demand resources and storage through value-based pricing and open participation**
2. **Allow renewable resources to participate in all product markets**
3. **Improve the efficiency of generator commitment and dispatch**
4. **Update resource adequacy design, including seasonal capacity requirements**

MISO, its stakeholders and state regulators in the region have a good opportunity to consider these reforms as the MISO community undertakes a review of its markets and plans for a software overhaul in coming years.

BIBLIOGRAPHY

Ahlstrom, Mark (2018), "Why Storage Might Solve Really Big Problems – But Different Ones Than You Think," May 4, 2018 https://www.esig.energy/why-storage-might-solve-really-big-problems-but-different-ones-than-you-think/.

Daniel, J. (2018), "Out of Merit Generation of Regulated Coal Plants in Organized Energy Markets," September 23-26, 2018, http://www.usaee.org/usaee2018/submissions/Presentations/Out-of-Merit%20Dispatch%20In%20organized%20Energy%20Markets%20Final.pdf.

ERCOT (undated), "ORDC Workshop, ERCOT Market Training," http://www.ercot.com/content/wcm/training_courses/109606/ordc_workshop.pdf

FERC (2011), "Frequency Regulation Compensation in the Organized Wholesale Power Markets," Order No. 755, Docket Nos. RM11-7-

32 Potomac Economics (2018), pp. 101-102.

000 and AD10-11-000, October 20, 2011, https://www.ferc.gov/whats-new/comm-meet/2011/102011/E-28.pdf.

FERC (2016), Order 831, "Offer Caps in Markets Operated by Regional Transmission Organizations and Independent System Operators," Docket No. RM16-5-000, November 17, 2016, https://www.ferc.gov/whats-new/comm-meet/2016/111716/E-2.pdf.

Hansen, C., S. Xu, B. Gisin & J. David (2018), "Using Market Optimization Software to Develop a MISO Multi-Day Market Forecast," FERC Technical Conference AD10-12-000, June 26, 2018, https://www.ferc.gov/CalendarFiles/20180626080726-T2%20-%202%20-%20Hansen%20-%20MISO_PowerGEM_MultiDay_FINAL.pdf.

Loutan, Clyde & Vahan Gevorgian (undated), "Using Renewables to Operate a Low Carbon Grid: Demonstration of Advanced Reliability Services from a Utility-Scale Solar PV Plant," https://www.caiso.com/Documents/UsingRenewablesToOperateLow-CarbonGrid.pdf.

MISO (2017), "Evolution of the Grid in MISO Region," November 2017, slide 4, https://ccaps.umn.edu/documents/CPE-Conferences/MIPSYCON-PowerPoints/2017/GenTheEvolutionoftheGridintheMidcontinentIndependentSystemOperator(MISO)Region.pdf

MISO (2018a), Generator Interconnection Queue, accessed October 10, 2018, https://www.misoenergy.org/planning/generator-interconnection/GI_Queue/

MISO (2018b), "MISO-PJM Coordinated Transaction Scheduling (CTS) (MU043)," https://www.misoenergy.org/stakeholder-engagement/issue-tracking/miso-pjm-coordinated-transaction-scheduling-cts/

MISO (2018c), "Multi-Day Market Forecast (MR031)," https://www.misoenergy.org/stakeholder-engagement/issue-tracking/introduce-multi-day-financial-commitments/

MISO Market Subcommittee (2016), "Ramp Capability Product Performance Update," presentation to Market Subcommittee, November 29, 2016, at https://cdn.misoenergy.org/20161129%20MSC%20Item%2005f%20Ramp%20Capability%20Post%20Implementation%20Analysis74816.pdf.

NREL (2012), Renewable Energy Futures Study, https://www.nrel.gov/analysis/re-futures.html.

NREL (2016), Eastern Renewable Generation Integration Study at 154, https://www.nrel.gov/docs/fy16osti/64472.pdf.

NREL (2018), "Operational Analysis of the Eastern Interconnection at Very High Renewable Penetrations," September 2018, https://www.nrel.gov/docs/fy18osti/71465.pdf

Potomac Economics (2018), "2017 State of the Market Report for the MISO Electricity Markets," June 2018, pp. 101-102.

RMI Business Renewables Center (2018), "Deal Tracker," accessed October 4, 2018, http://businessrenewables.org/corporate-transactions/.

U.S. Department of Energy (DOE) Energy Information Administration (EIA) (2017), "Today in Energy,"July 24, 2017, https://www.eia.gov/todayinenergy/detail.php?id=32172.

Grid Strategies LLC

www.gridstrategiesllc.com

Wind Solar Alliance

1501 M Street, NW, Suite 900
Washington, DC 20005

202 383 2525
info@windsolaralliance.org
www.windsolaralliance.org