ESIG 2020 Meteorology & Market Design for Grid Services Workshop

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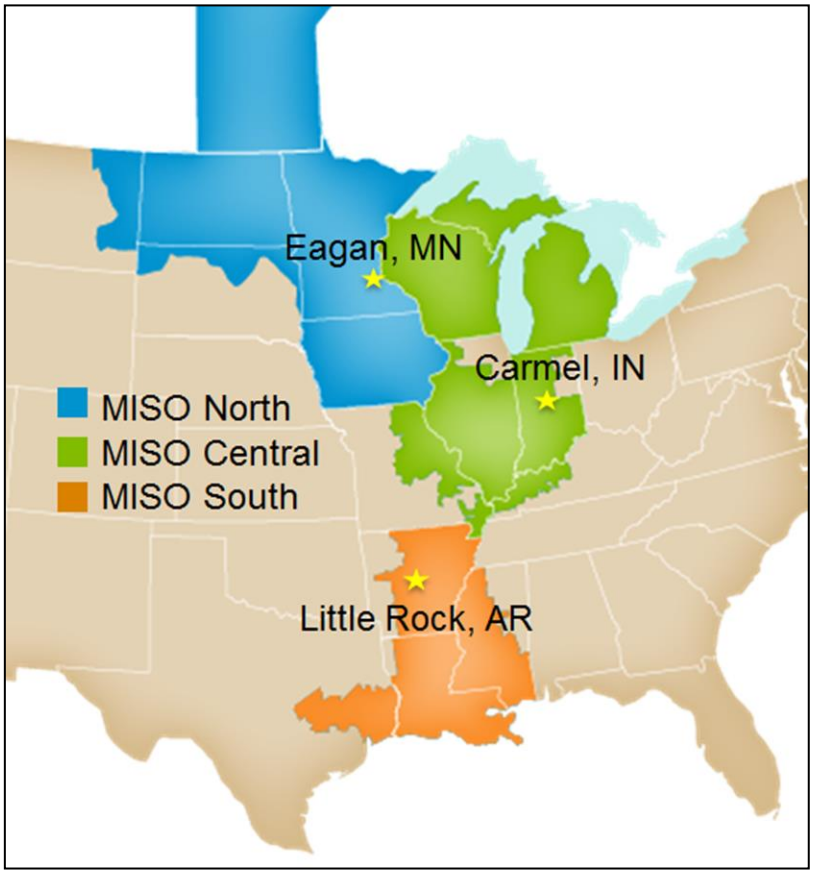
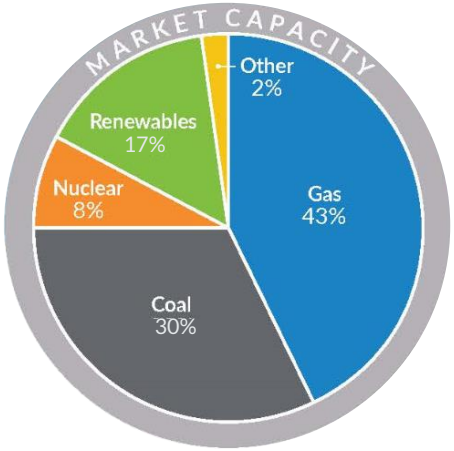
MISO drives value creation through efficient and reliable markets, operations and planning

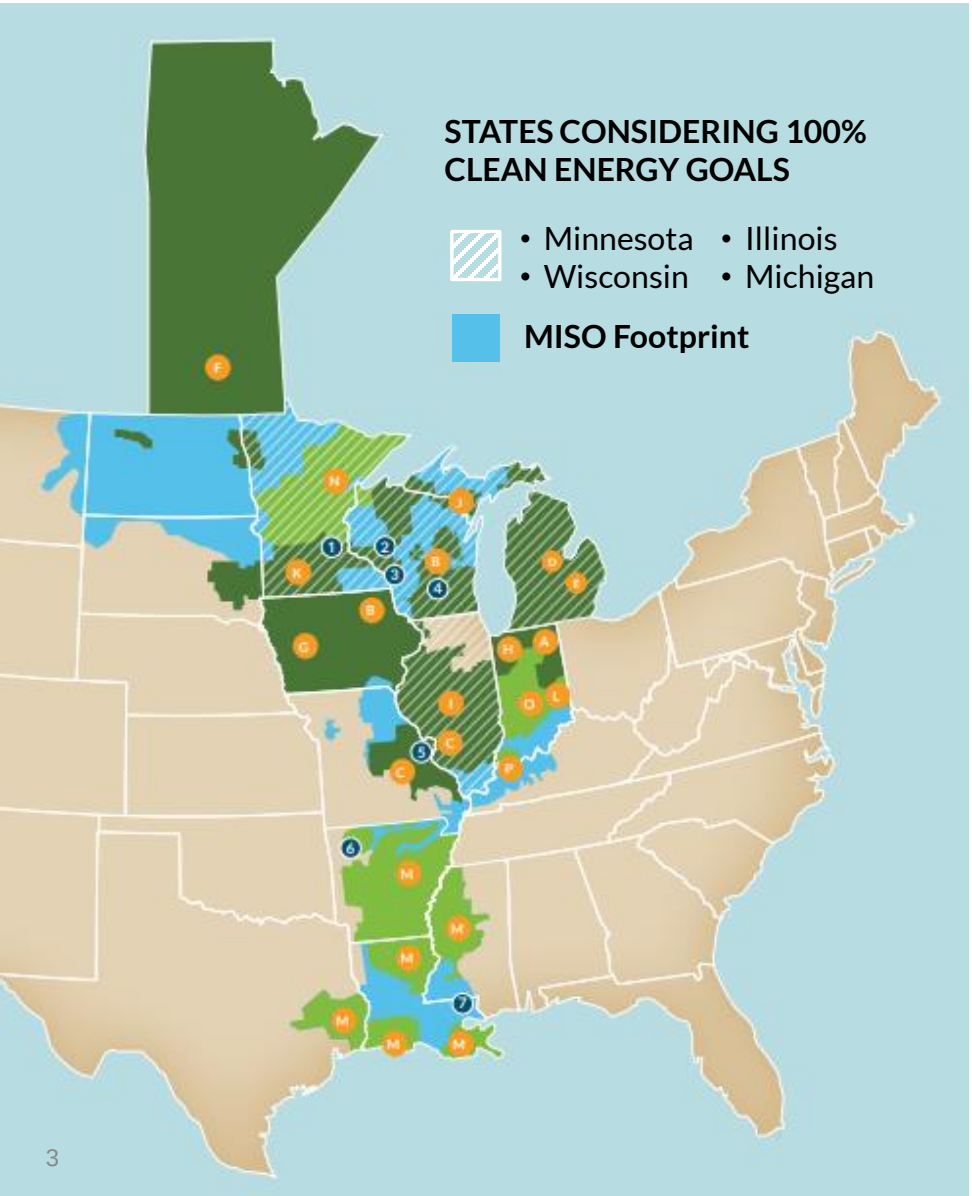
MISO's vision: Be the most reliable, value-creating RTO



MISO by-the-numbers	
Transmission	71,800 miles
Generation Capacity	177,760 MW
Peak Summer System Demand	127,125 MW
Customers Served	42 Million



Large portions of the MISO footprint have set high decarbonization or clean energy goals



MISO States, Cities and Utilities with Decarbonization or Clean Energy Goals

CITIES WITH 100% CLEAN ENERGY GOALS

1. Minneapolis, Minn.
   St. Paul, Minn.
2. Eau Claire, Wis.
3. La Crosse, Wis.
4. Madison, Wis.
5. St. Louis, Mo.
6. Fayetteville, Ark.
7. Abita Springs, La.

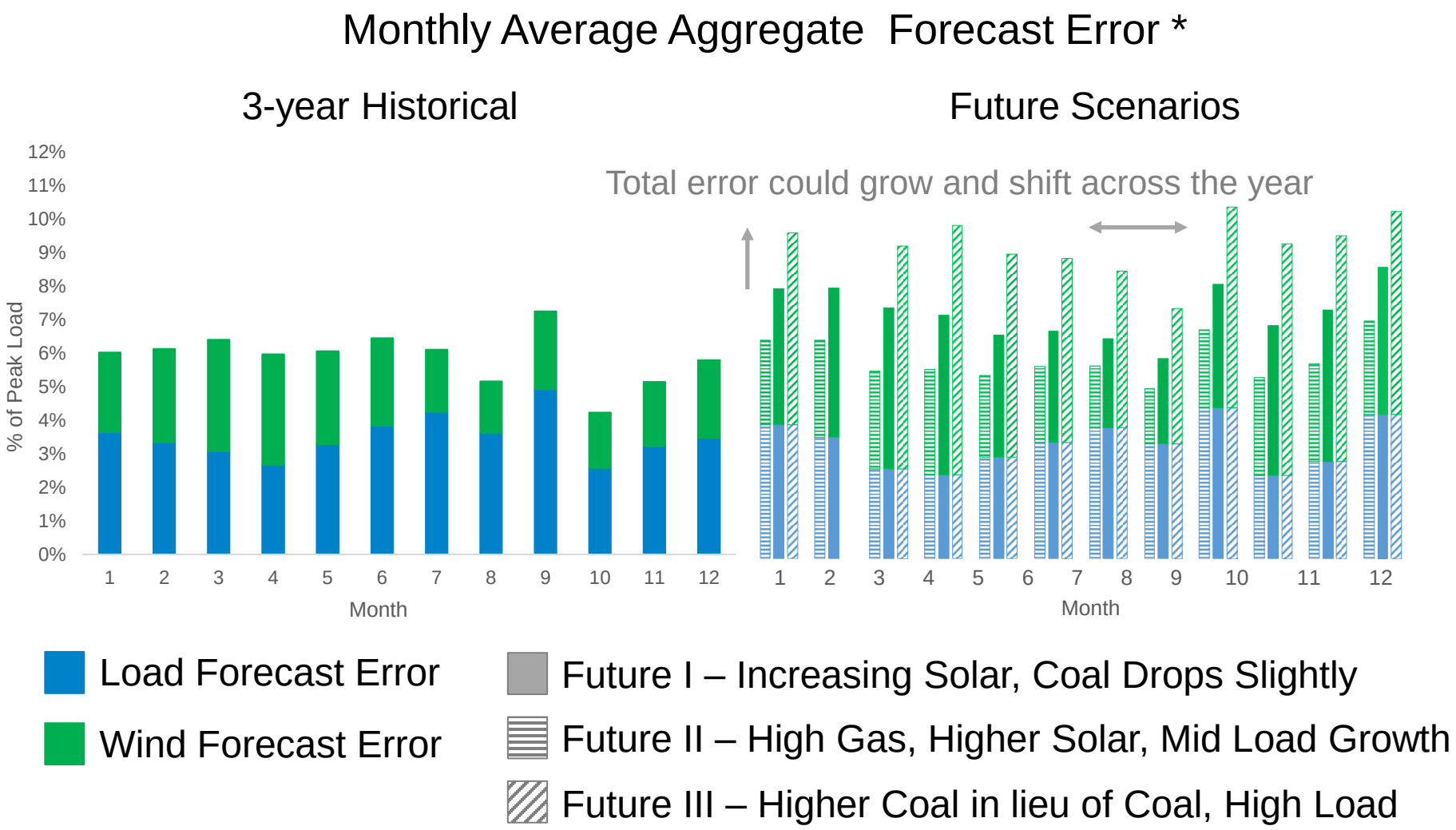
UTILITIES WITH 80%+ TARGETS

A. AEP
B. Alliant
C. Ameren
D. Consumers
E. DTE
F. Manitoba Hydro (achieved, not a target)
G. MidAmerican
H. Northern Indiana Public Service
I. Vistra
J. WEC Energy Group
K. Xcel

UTILITIES WITH 50%+ TARGETS

L. Duke
M. Entergy
N. Great River Energy
O. Indianapolis Power and Light
P. Vectren/SIGE

Uncertainty profiles are likely to change, growing in magnitude and shifting across the year



*Forecast error reflects DA to RT differences. Reflects worst case scenario of additive errors.

Grid operators manage margins to ensure reliability

- The margin between supply resources and obligations is an indicator of how close the system is to emergency or loss of load.*
- It is influenced by a number of factors, some of which are highly variable and uncertain
  - Outages
  - Intermittent generation
  - Net scheduled interchange

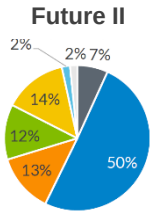
Margin = Available non-intermittent generation + intermittent generation + RDT limit + Net Scheduled Interchange + Load Resources (BTMG + LMR + EDR) **-** Load - Operating Reserve

* Emergencies include alerts through to load shed

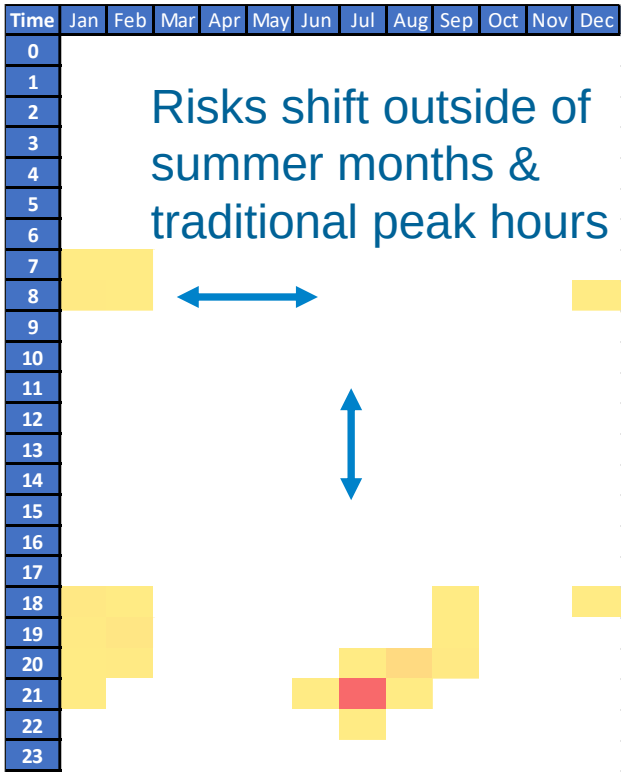
RDT = Regional Dispatch Transfer Limit | BTMG = Behind the Meter Generation
LMR = Load Modifying Resources | EDR = Emergency Demand Response

Future resource evolution and total capacity shape patterns of need

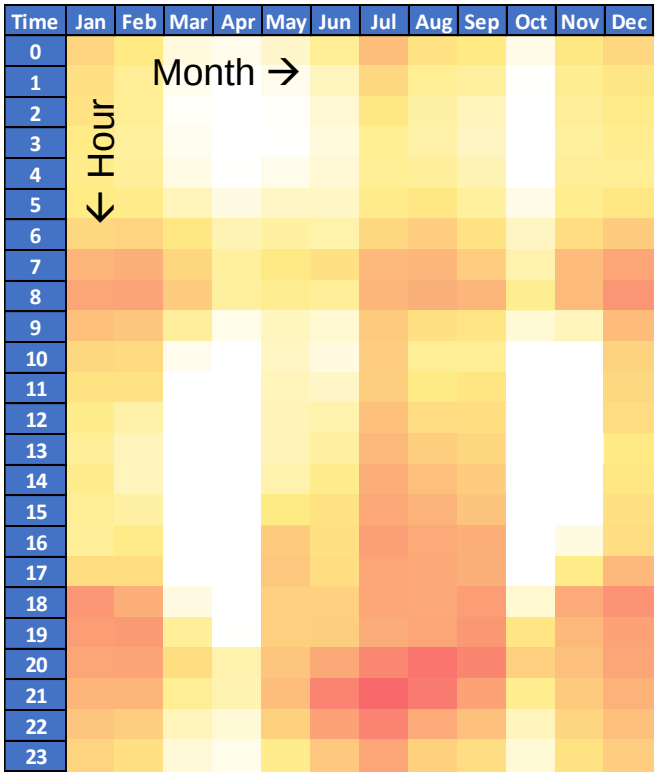
Draft results



0.1 Loss of Load Expectation



Proxy Operator Experience*

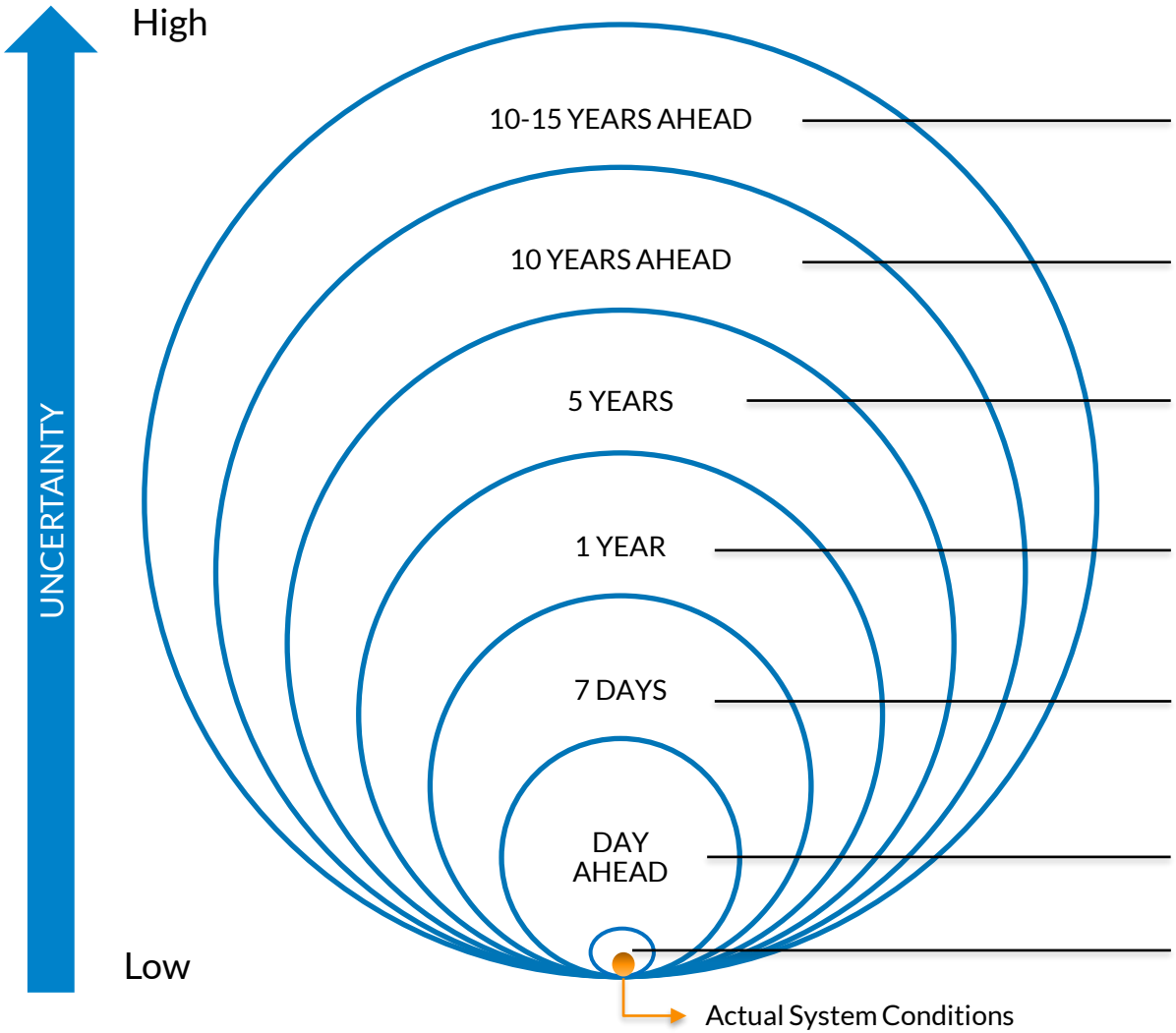


* 0.6 LOLE Target

No risk | Moderate Risk | High Risk

* Work by MISO R&D lead by Long Zhao and Armando Figueroa-Acevedo

MISO and its members prepare from years to minutes ahead to be ready to balance supply and obligations



Member and State Resource Planning Horizon

OMS-MISO Survey data collection horizon…

… OMS-MISO Survey focus and report-out

MISO's Resource Adequacy Planning and Auction Horizon

Multi-day Operating Margin Forecast and FRAC

Day-Ahead Market
Intra Day Assessment (IRAC)
Look Ahead Commitment (LAC)

Real-Time Operations

OMS = Organization of MISO States FRAC = Multi-day Forward Reliability Assessment Commitment IRAC = Intra Day Assessment Commitment

The 2020 focus is on near-term steps that will address both current and longer-term needs

	Identify Reliability Needs	Planning Horizon	Operating Horizon
Needs	Develop analytic methods to define reliability criteria Identify system reliability needs in addition to peak hour MWs	Define planning constructs that complement state and member roles in Resource Adequacy	Improve pricing for existing products Develop necessary new processes, tools and products
Importance	Current analysis (LOLE) does not address 24/7 risk with portfolio evolution	Stakeholders require better information to inform planning and investment decisions	Market prices must better reflect underlying system conditions
2020 Focus	Define system reliability needs and capabilities	Develop sub-annual planning + PRA reform Enhance resource accreditation	Propose scarcity pricing reforms

LOLE = Loss of Load Expectation *PRA = Planning Resource Auction*

MISO has already taken some actions to date and is also planning further work

Uncertainty and Risk Management

- Forecasting Enhancements
- Net Scheduled Interchange (researching needs)
- Research Stochastic Approaches
  - ARPA-E PERFORM Risk Adjusted Market Clearing (Georgia Tech et al)
  - ARPA-E PERFORM Stochastic Nodal Adequacy Pricing (Tabors Caramanis Rudkevich et al)
  - ARPA-E Stochastic Look-Ahead Commitment (University of Arizona et al)

Additional Market Products and Pricing

- Short Term Reserves
- Enhanced Price Formation (e.g., ELMP)
- Additional Product Enhancements

Resource Models

- Enhanced Combined Cycle
- Energy Storage Resource
- Pumped Hydro (prototyping)
- Hybrid Plants (researching)
- Distributed Energy Resource Aggregations (researching needs)