Reliability of the Gas-Electric System

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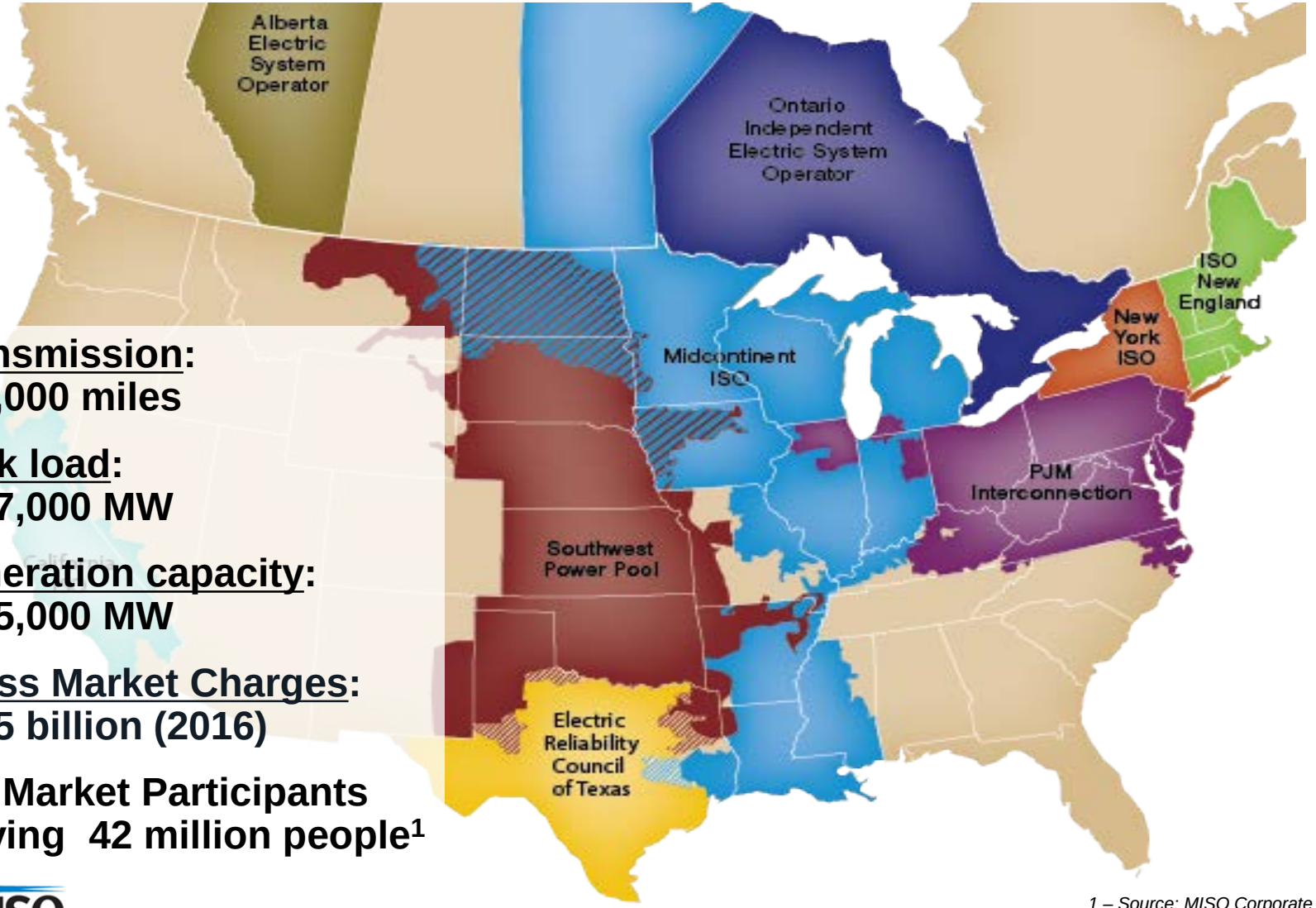
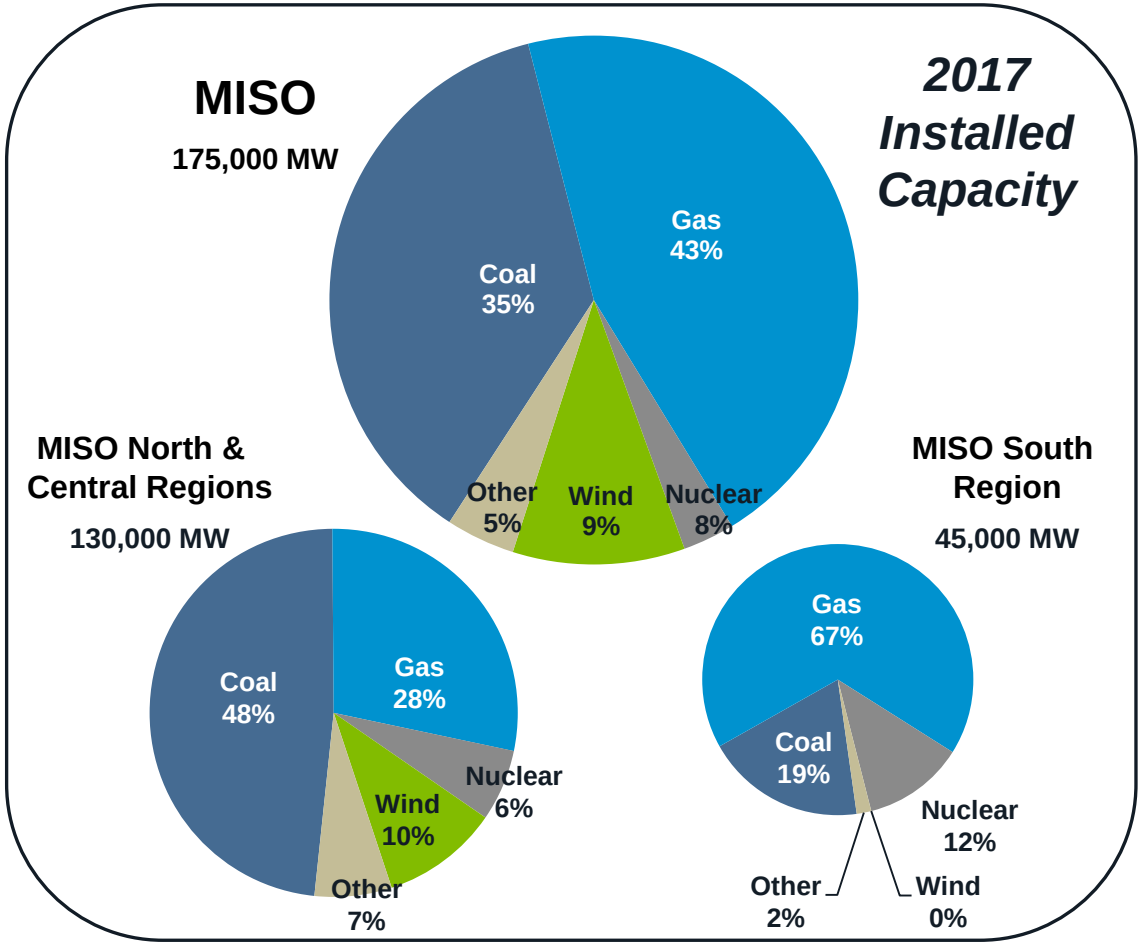
Geographically, MISO is the largest Independent System Operator in North America

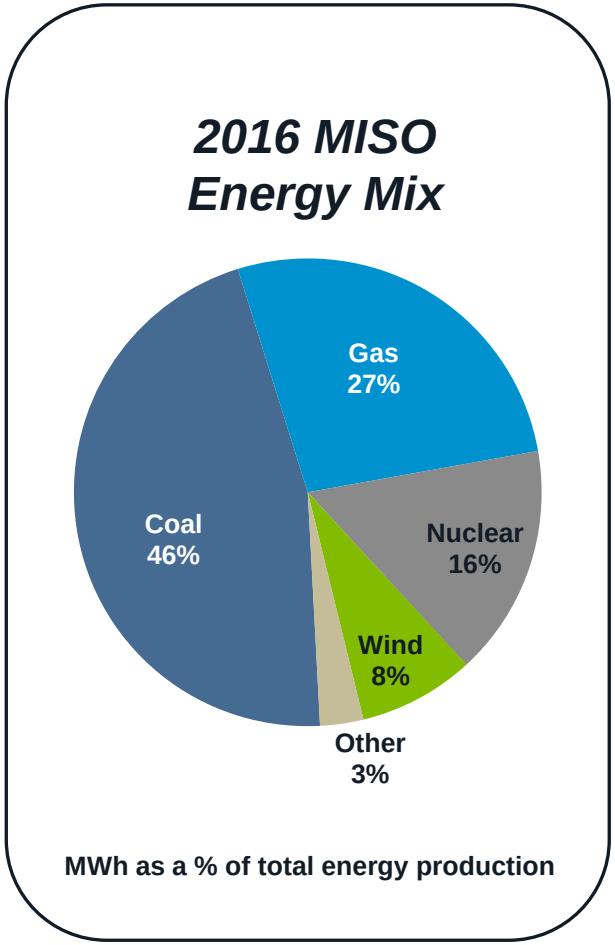


- **Transmission:** ~66,000 miles
- **Peak load:** ~127,000 MW
- **Generation capacity:** ~175,000 MW
- **Gross Market Charges:** ~$25 billion (2016)
- **437 Market Participants serving 42 million people[1]**

1 – Source: MISO Corporate Fact Sheet

The current resource mix in MISO is largely coal and gas, supplemented by nuclear and renewables

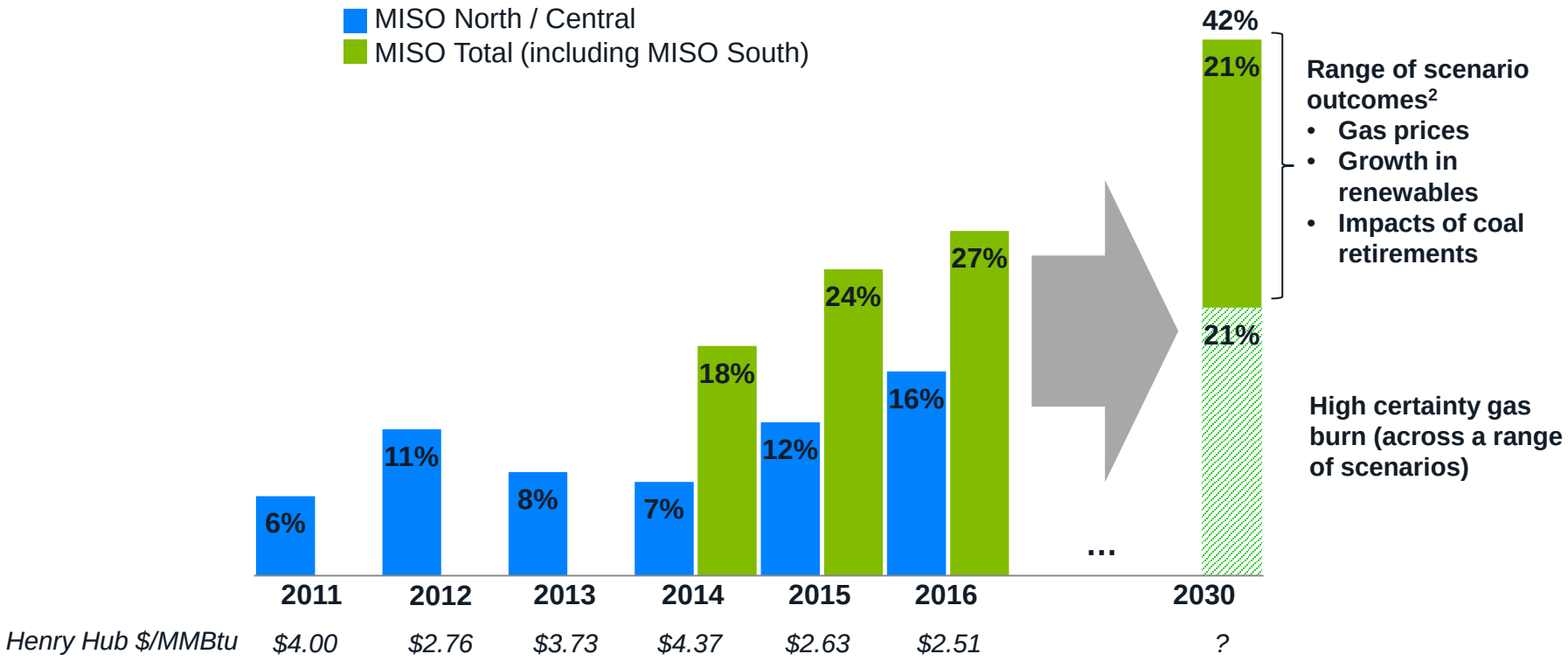




"Other" category includes hydro, pumped hydro, oil, solar, and others

Gas demand has grown and MISO's evolving fleet will propel gas demand even higher

Gas Share (%) of MISO Electric Generation (MWh)



Installed gas capacity is projected to increase 8,000 MW in the queue through 2020[3]

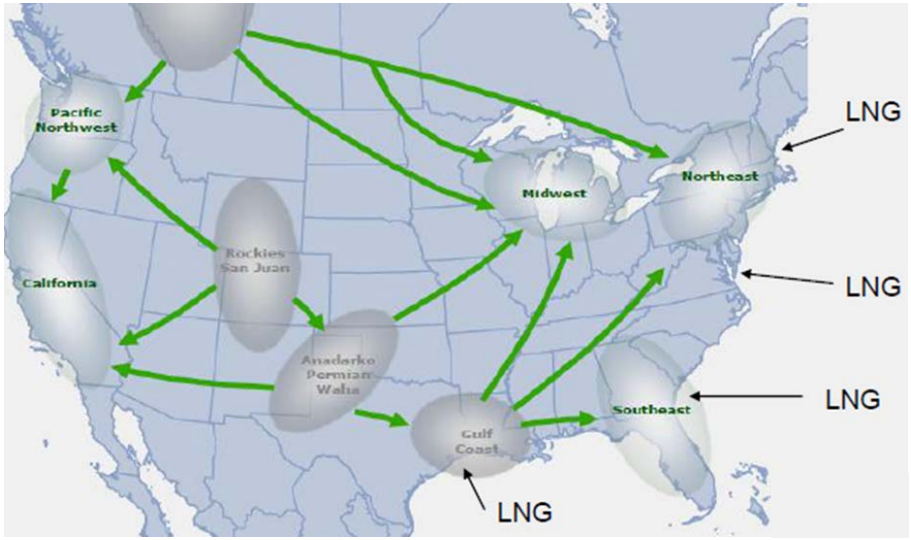
(Signed interconnection agreements 3,700 MW; final definitive studies 4,300 MW)

2 – MISO MTEP17 sensitivities with range of gas prices (mid-case +/- 30%)
3 - MISO Interconnection Queue as of Dec, 2016

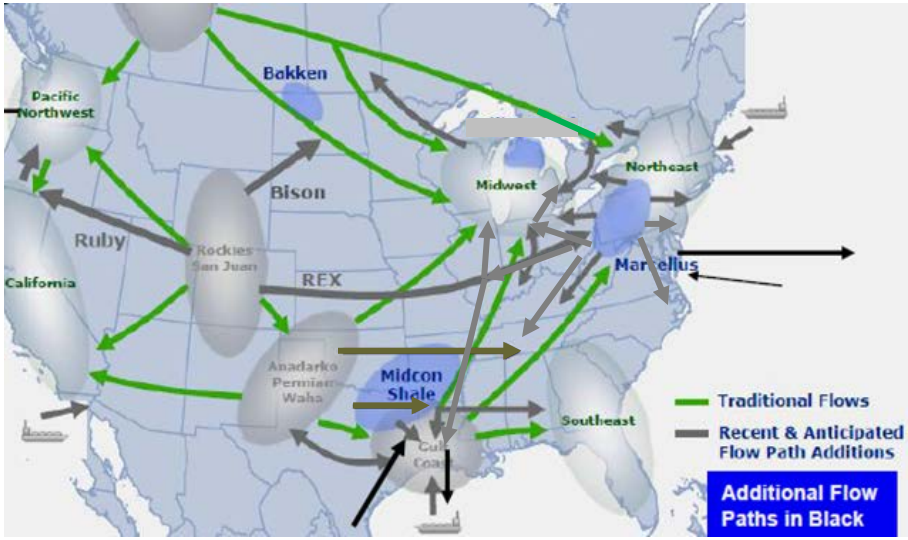
Significant changes in the gas industry are driving impacts in both MISO and the Southeast

- Increased flows from Marcellus/Utica on new-build pipelines and pipeline reversals are improving supply diversity
- U.S. gas production gains continue to be favorable, causing lower (and flatter) prices
- Perceived long-term abundance is driving LNG exports from facilities like Sabine Pass in MISO South (and soon Elba Island in Georgia)

Historic Flow Patterns and LNG Imports

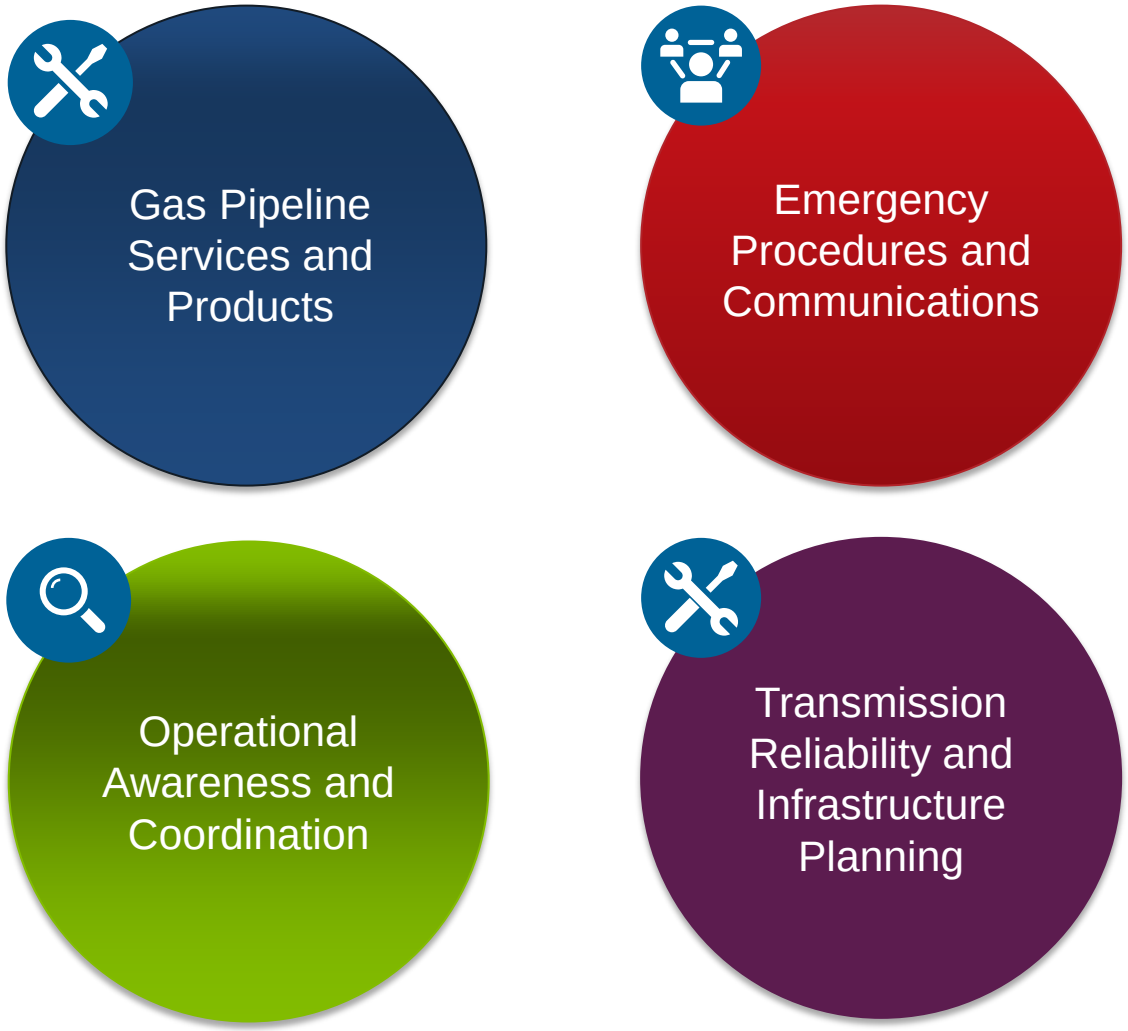


Developing "Grid" Flow Patterns & LNG Exports



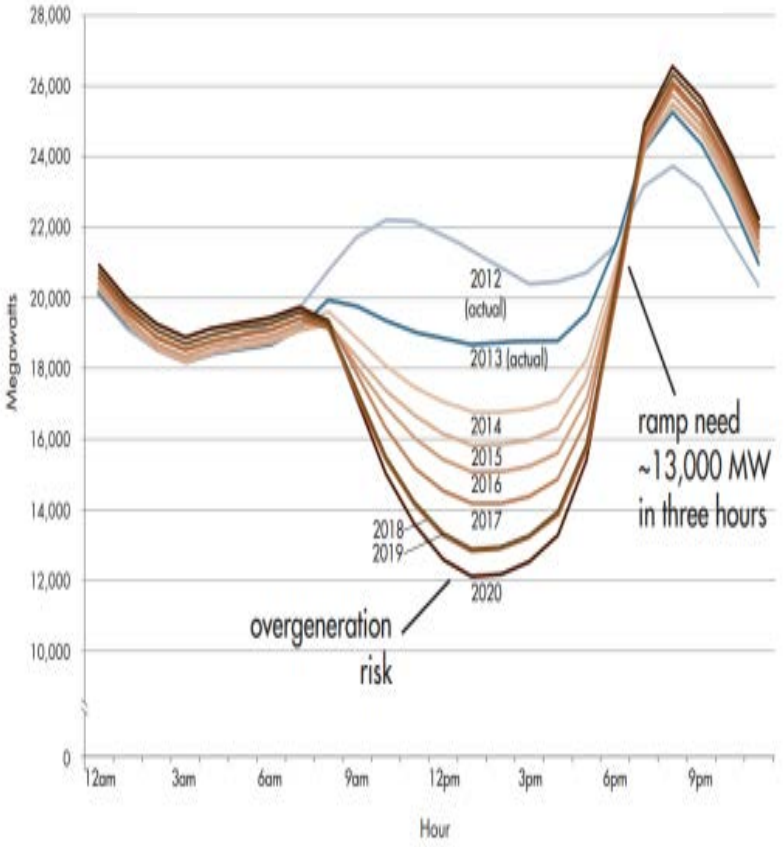
Graphics per MISO Phase I: Gas and Electric Infrastructure Interdependency Analysis, February, 2012. Updated flow changes 2015

Gas/Electric reliability comes in many flavors, and requires coordination with a variety of stakeholders



Gas-fired capacity is important during ramping periods, especially as renewable generation drives ramp requirements even higher

CAISO Load – March 31



MISO Load – Feb 12, 2015

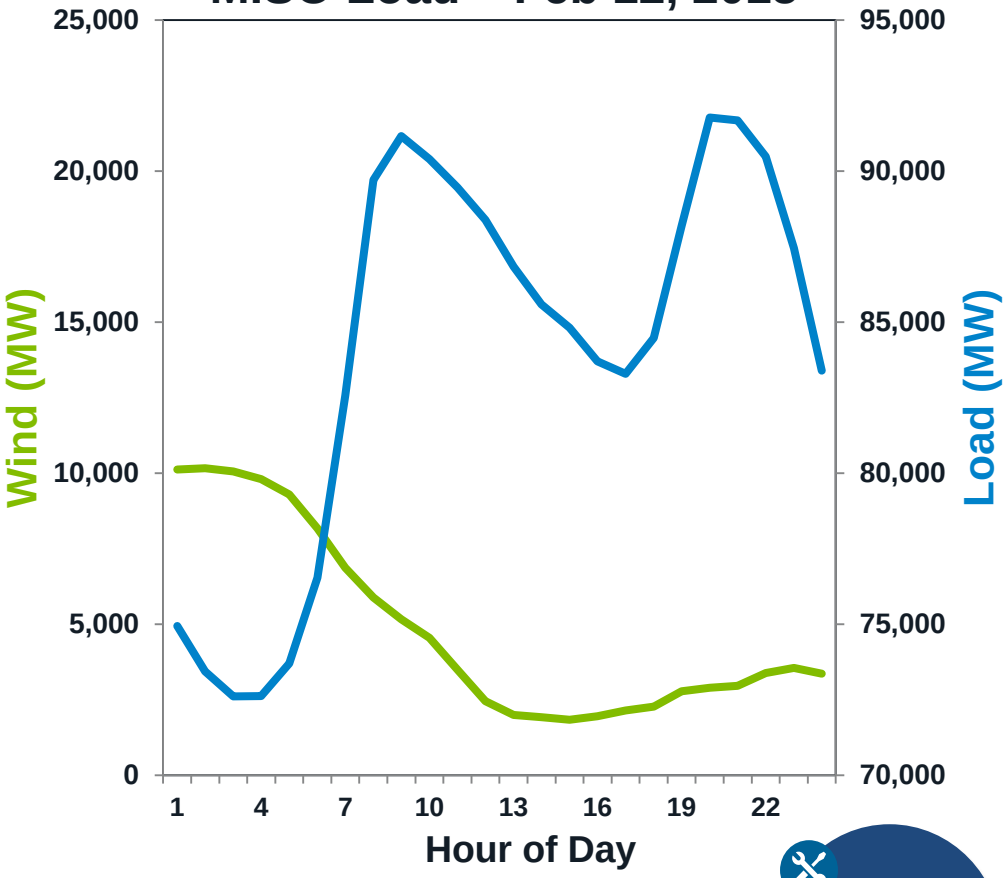
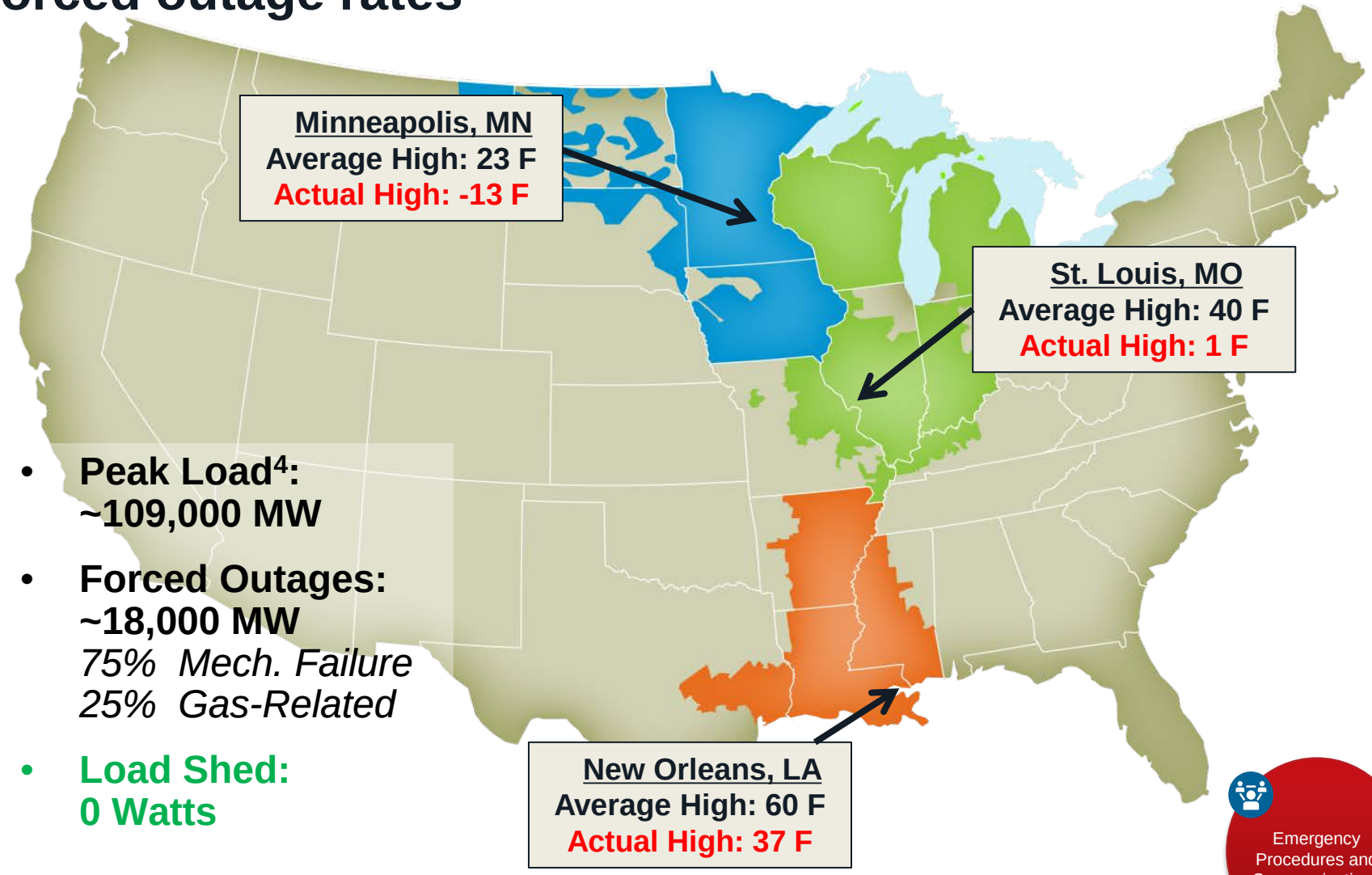


Chart source: CAISO

Gas Pipeline Services and Products

The Polar Vortex event on January 6-7, 2014 stressed MISO's system with record peak demands and high forced outage rates



- **Peak Load[4]: ~109,000 MW**
- **Forced Outages: ~18,000 MW**
  75% Mech. Failure
  25% Gas-Related
- **Load Shed: 0 Watts**

Emergency Procedures and Communications

4 –All data is for January 6, 2014

MISO's Winter Fuel Survey provides a regional view on winterization and fuel supply practices

- **2016 survey included responses from ~87% of MISO's gas-fired generators (representing 63,500 MW of capacity)**
- **Responses further the optimization of operational tools: pipeline notification website, fuel impact report, and electric/gas pipeline control room display**
- **Key Results**
  - Survey participants reported an increased utilization of flexible gas services, such as no-notice (42%) and non-ratable subscriptions (66%)
  - 83% of Combined Cycle units in MISO North/Central and 100% in MISO South utilize Firm Transportation or a blend of Firm/Interruptible, but only 23% of MISO capacity has dual fuel capability
  - 70% of MISO North/Central generation is connected to one of 5 pipelines, either directly or via LDC/Gas Utility

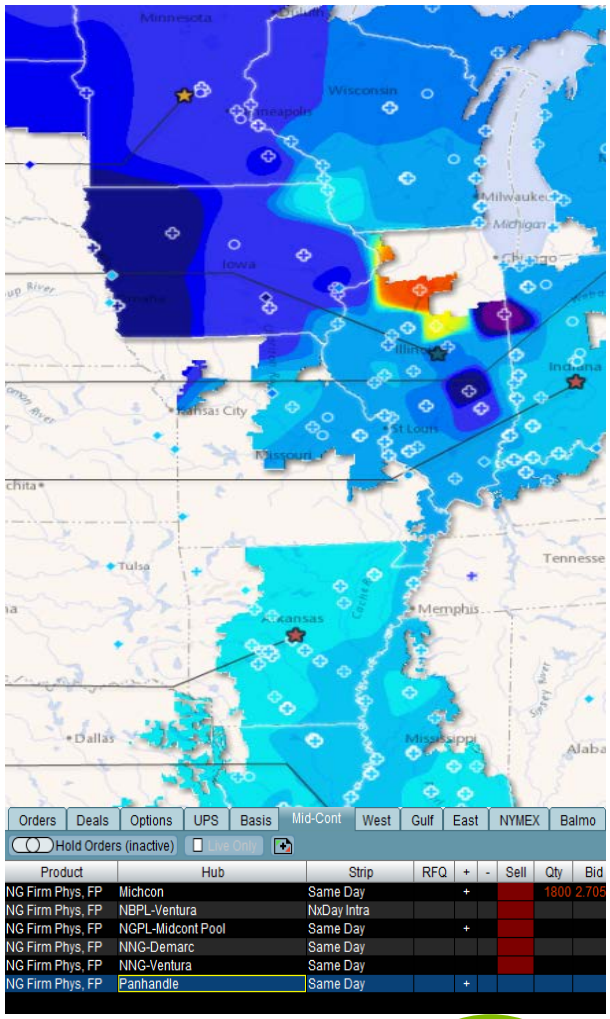
It is critical for MISO's operators to know what is happening on the gas system

Communication Coordination

- Operational contact list established with all pipelines in the MISO footprint
- Monthly—and as-needed—operational calls with major pipelines
- Sharing of MISO public data with pipelines
  - DA Wind Forecast & RT Wind Generation
  - LMP Contour Map

Gas Market/Situational Awareness

- MISO pipeline notification website
- Monitoring market condition
  - Intercontinental Exchange subscription
- Gas industry internal training
- Daily gas outage report tracking – CROW monitoring

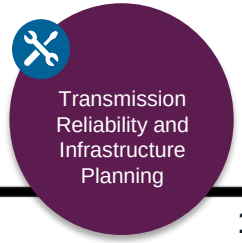


Operational Awareness and Coordination

Reliability of the integrated gas-electric system is a hot topic, with interest from a wide array of groups

- **2015 EIPC study[5] investigated gas-electric contingency events**
- **NERC transmission planning standards (TPL-001-4) came into effect 2015/2016**
  - Extreme Events analysis includes "Loss of two generating stations resulting from…loss of a large gas pipeline into a region"
- **NERC Single Point of Disruption (SPOD) special assessment**
  - Aims to identify potential risks to BPS as a result of disruptions on major natural gas infrastructure facilities
- **Federal Task Force – *Ensuring Safe and Reliable Underground Natural Gas Storage***
  - Established in the wake of Aliso Canyon incident, identifies large gas storage facilities where an outage could affect on gas-fired generation reliability

5- http://www.eipconline.com/gas-electric-documents.html



New modeling tools allow for a view into the interactions between the gas and electric systems

GPCM

About:

- Standalone natural gas model, built on MS Access database foundation
- Used for long-term look into pricing and pipeline flow trends

Pros:

- Well-regarded in gas industry
- Benchmarked against historical data
- Forecast dataset (included) is accurate and easily modified

Cons:

- Monthly data granularity
- No integrated electric model

PLEXOS

About:

- Co-optimized Gas/Electric production cost modeling platform
- Electric model has been used for many MISO studies, including CPP analysis

Pros:

- Capable of very granular detail
- Integrated gas/electric co-optimization
- Familiar tool for MISO

Cons:

- Minimal support for gas model
- No gas model dataset included

Transmission Reliability and Infrastructure Planning

As gas-fired generation continues to grow in MISO, we're considering the following with our stakeholders:

- **Understanding changes in gas flows patterns and infrastructure utilization**
- **Future infrastructure requirements**
- **Implications of gas generation in winter**
- **Gas supply flexibility**
  - Hourly variations (including gas takes during short or specific portions of the day)
  - Load following and ability to ramp up/down for varying load or renewable energy changes
  - Short-notice ability to make changes
- **Capabilities/limitations of pipeline/LDC services and terms**
- **Regulators' role as we move forward**

Thank you!

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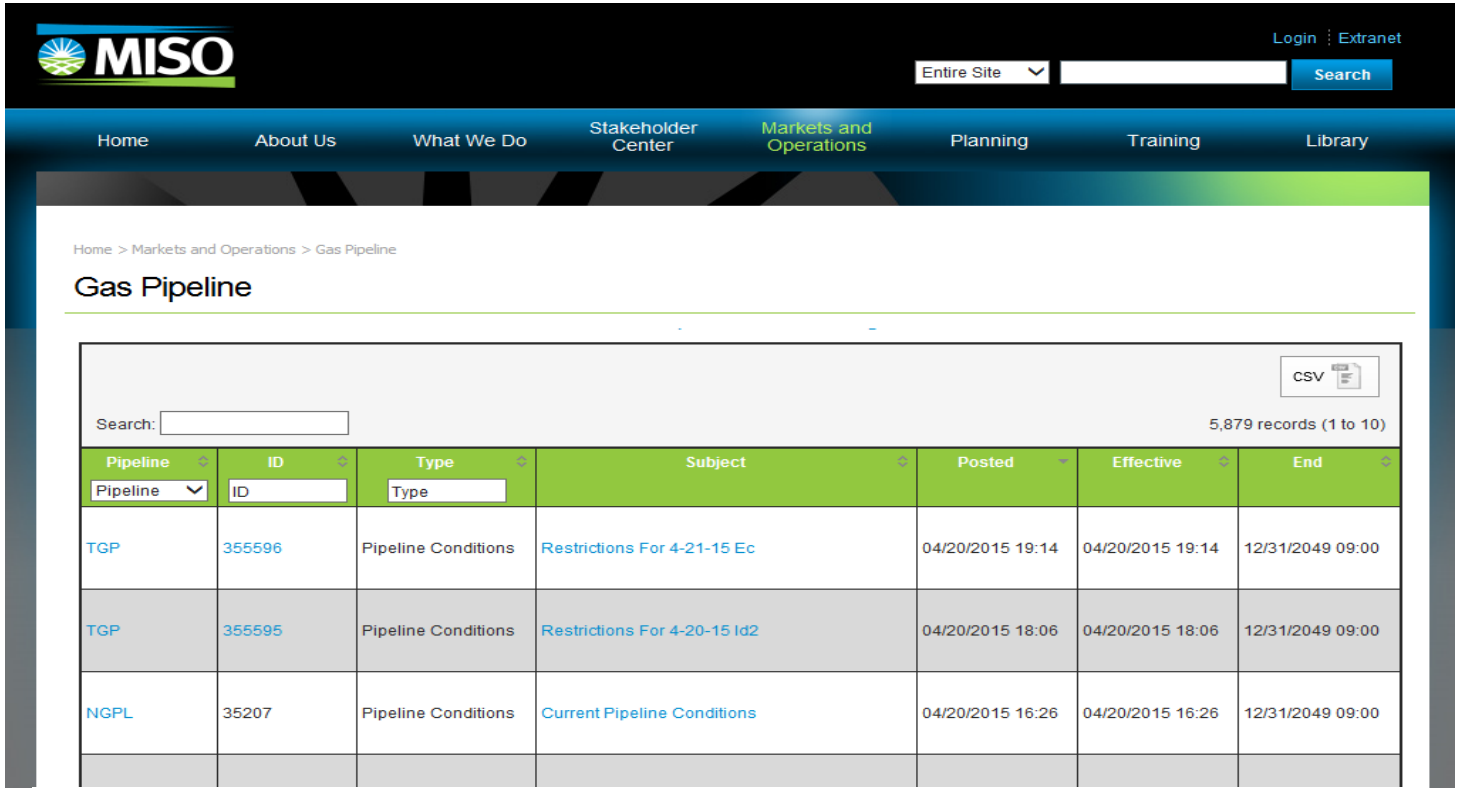
Appendix

Midcontinent Independent System Operator (MISO) Facts & Functions

- **MISO:**
  - Is an independent, not-for-profit entity
  - Does not own any electric transmission or generation assets
  - Manages one of the world's largest energy and operating reserves markets using security-constrained economic dispatch of generation
  - Ensures reliable operation of the bulk electric transmission system
  - Coordinates long-term regional planning of the transmission system
- **MISO's mission:**
  - Work collaboratively and transparently with our stakeholders to enable reliable delivery of low-cost energy through efficient, innovative operations and planning

The Gas Pipeline Notifications Page on MISO's website compiles notices from our region's pipeline EBBs



Generators with Potential Fuel Limitations

Condition	Generator	Operator	Pipeline	Potential Impacts
	Unit X	XXXX	ABC	Extended Run's may be limited
				Early morning dispatch may be limited -- Give advanced notice

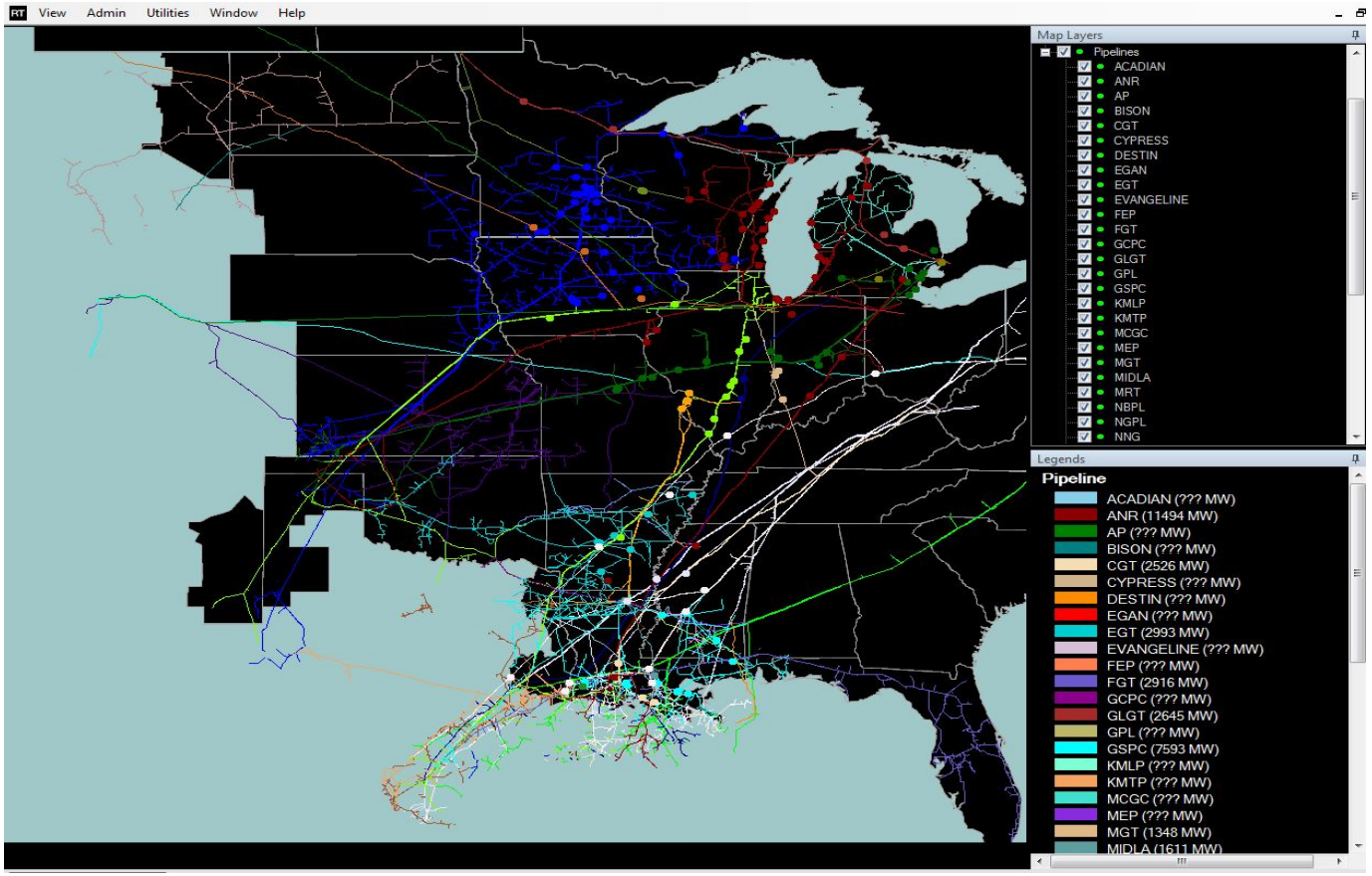
Pipeline Condition
Moderate
Caution
Critical

Operational Awareness and Coordination

Pipeline maps in our control rooms give operators a sightline into the gas system

MISO Control Rooms / Real Time Display

Internal Tool for Real Time Operations



Operational Awareness and Coordination