Agenda

• Review of past Gas-Electric coordination efforts
• Highlights on non-planning Gas-Electric items
  • Operations/Coordination
  • Strategy/External Studies
• Introduction to natural gas modeling tools
• Description of gas modeling enhancements in MTEP18
• Interactive walkthrough of gas price forecasting with GPCM
Review of MISO’s Past Gas-Electric Initiatives
Gas demand has grown and MISO’s evolving fleet will propel gas demand even higher

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

- **Henry Hub $/MMBtu**
  - 2011: $4.00
  - 2012: $2.76
  - 2013: $3.73
  - 2014: $4.37
  - 2015: $2.63
  - 2016: $2.51
  - ... 2030
  - ?

- **Range of scenario outcomes**
  - Gas prices
  - Growth in renewables
  - Impacts of coal retirements

- **High certainty gas burn (across a range of scenarios)**

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

  - MISO North / Central
  - MISO Total (including MISO South)

- **MISO MTEP17 sensitivities with range of gas prices (mid-case +/- 30%)**

- **MISO Interconnection Queue as of March, 2017**
Significant changes on the gas system are driving impacts across the MISO region

- Increased flows to MISO from Marcellus/Utica on new-build pipelines and pipeline reversals are improving MISO supply diversity
- U.S. gas production from non-traditional supply regions continues to be favorable, causing flatter prices
- Perceived sustained long-term abundance is driving Liquefied Natural Gas (LNG) exports from facilities like Sabine Pass in MISO South

Historic Flow Patterns and LNG Imports

Developing “Grid” Flow Patterns & LNG Exports

MISO has been working to understand the impacts of the evolving gas system for the past 6 years.
MISO is supporting a number of external work efforts intended to investigate gas-electric reliability

- **2015 EIPC study investigated gas-electric contingency events**
  - MISO is supporting FERC in reviewing the results of the study and identifying critical areas of pipeline security

- **NERC transmission planning standards (TPL-001-4) came into effect 2015/2016**
  - MISO’s Extreme Events reliability analysis includes “Loss of two [or more] generating stations resulting from…loss of a large gas pipeline into a region”

- **NERC Single Point of Disruption (SPOD) special assessment**
  - MISO is supporting NERC in the study that aims to identify potential risks to BPS as a result of disruptions on major natural gas infrastructure facilities

- **DOE/PHMSA Task Force – *Ensuring Safe and Reliable Underground Natural Gas Storage***
  - MISO is working with Argonne National Labs to identify large gas storage facilities where an outage could have an effect on gas-fired generation reliability
MISO is continuing to integrate our gas understanding into our planning processes

**Stakeholder Meetings**
- Futures Workshop – April 4
- PAC – April 19
- Planning Workshop – Aug 18
- PAC – Oct 18

**MTEP Gas Modeling**
- Develop plant-level burner tip adders for all generators in the economic planning models
- Integrate gas price adders into MTEP models

**Benefit Metrics**
- Support RECB process for identification of additional transmission benefit metrics

**Pipeline Security**
- Support ongoing NERC SPOD, FERC, & Argonne work on gas-electric issues
- Investigate potential impacts from pipeline contingency events

**Ad Hoc Gas Studies**
- Develop scopes for potential studies
- Begin analyses

MISO is continuing to integrate our gas understanding into our planning processes.
On-going Non-Planning Gas-Electric Items
MISO Operator Tools and Coordination with the Gas Industry
Questions to Answer

1. How do MISO system operators ensure reliable operations in regards to fuel availability challenges?

2. What initiatives has MISO Gas-Electric recently taken to promote reliability?

3. How does MISO work with the natural gas industry in order to foster coordination?
MISO Control Room Operations

- Commitments are based off market participant submitted unit parameters
- MISO expects market participants to update unit availability via the Market Portal
- MISO is not a direct customer of pipelines/LDCs and expects gas system operators to communicate directly with generators
MISO has improved communication & situational awareness around pipeline activities and impacts to generators

- Leveraging MISO Pipeline Notification Website
- Monitoring market conditions
  - Intercontinental Exchange (ICE), Platts, and Bentek Subscriptions
- Expanding control room tools & reports to improve visibility & awareness
- Expanding involvement in gas industry events and conferences
MISO’s Gas Pipeline Notifications Website provides regional insight into pipeline operating conditions

- Scrapes 35 MISO Pipeline EBB’s for Critical Postings
- Useful for Market Participants and MISO Staff
- One Location, Regional Insight
- Critical Postings are issued if supply, capacity, or operational flexibility is impacted
- [www.misoenergy.org](http://www.misoenergy.org) > Markets and Operations > Gas Pipelines
  - [https://www.misoenergy.org/MarketsOperations/Pages/GasPipeline.aspx](https://www.misoenergy.org/MarketsOperations/Pages/GasPipeline.aspx)
Fuel Impact Report: At Risk Units

- Internally, MISO will be monitoring the Pipeline Notification Website daily and will be translating relevant Critical Notices.
- MISO will attempt to identify units that may be impacted and classify them as “At Risk” based on available information.
  - *Internal classification will not impact unit status or Market Participant’s portal submissions.*

![Pipeline Notice - Unit Impact Report](image-url)
Control Room Electric/Gas Pipeline Real Time Display

• Further interpretation and leveraging of Pipeline Notification Website and Fuel Impact Report
• Pipeline Map Display with additional generator data included
• Daily interpretation of pipeline conditions
  • Pipeline Critical Notices will be translated and visually interpreted on display
  • Serves as quick reference for Operators
  • Provides visuals of restrictions
  • Improves situational awareness
Gas Usage Profiles Project

- Gas system operators will receive customized daily summaries of usage forecasts based on the MISO day-ahead clearings of interconnected generators
  - Forecasted daily totals and hourly profiles
- MISO will coordinate with gas pipelines/Local Distribution Companies (LDCs) to develop the most effective gas usage aggregations for each system
MISO 2017-2018 Winter Generator Survey

- October’s survey will be MISO’s 4th annual implementation
- Last year, MISO had its highest ever participation rate, with 87% (63,600 MW) of capacity reporting
- More user friendly for 2017, no significant changes to questions
Responsive to EOP-011, requested fuel characteristics for all MISO natural gas generators

MISO now has complete database of pipeline connections and dual fuel capability for all gas generators

- Further optimization of situational awareness tools

---

## Generator-Pipeline Database Upgrade

<table>
<thead>
<tr>
<th>Asset Name</th>
<th>Power Plant Interconnect</th>
<th>Pipeline Interconnect (Inter/Intrastate)</th>
<th>Pipeline Meter</th>
<th>Secondary Fuel Capability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name of the Combined Cycle [CC_XXXXXXX]. This should be same as Combined Cycle Aggregate Name for Generator asset of each resource.</td>
<td>Is your combined-cycle plant connected directly to a pipeline, LDC (local distribution company), or both Pipeline and LDC? Select the Interstate or Intrastate pipeline(s) that connect to the generator (primary pipeline first, then subsequent pipelines). If not applicable, or source is not listed, select “Not Applicable” or “Not Listed” and review subsequent fields.</td>
<td>Pipeline Interconnect (Inter/Intrastate)</td>
<td>Pipeline Meter Number (Used for nomination purposes) for each Interconnect selected. List meter number for first pipeline selected, meter number for second pipeline selected, and so on. Separate with a comma.</td>
<td>Does the unit have Secondary (backup) fuel (YES/NO)? Secondary fuel capability refers to ability to produce meaningful MW's, not just heating or auxiliary services.</td>
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<tr>
<td>Unit 1</td>
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<td>111111</td>
<td>No</td>
</tr>
<tr>
<td>Unit 2</td>
<td>Pipeline</td>
<td>NGPL</td>
<td>222222</td>
<td>No</td>
</tr>
<tr>
<td>Unit 3</td>
<td>Pipeline</td>
<td>Acadian Gas Pipeline, NNG</td>
<td>333333</td>
<td>Yes</td>
</tr>
<tr>
<td>Unit 4</td>
<td>Pipeline</td>
<td>ANR</td>
<td>444444</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*Pipelines and services in this example are random and do not represent any actual MISO units*
Gas Industry Outreach

- North American Energy Standards Board (NAESB)
  - Wholesale Gas Quadrant (WGQ) End User Segment
- Member of IRC Gas-Electric Task Force
- Monthly calls with G-E Operations Coordinators at other ISOs
- Monthly pipeline calls
- Pipeline/LDC visits and presentations
  - NGPL, NNG Pipeline, DTE Gas
- Presentations/workshops with state regulators (NARUC, OMS)
- Discussions with gas trade associations – INGAA (interstate pipelines), AGA (gas utilities), API (gas producers)
- Participation in various gas industry events and conferences
Questions?

Mark Thomas
Electric-Gas Operations Coordinator
mmthomas@misoenergy.org
317-249-4898
MISO Strategy and External Studies
Executive Summary

- Dependence on natural gas has implications for resilience and reliability
- MISO has made a number of preparations to minimize the impact of external events
- A changing fleet will stress the grid, but we will remain resilient and adapt
Events around the globe highlight the need to prepare for worst-case contingency events.
The gas industry operates to an entirely different reliability standard than the electric power industry

1) FERC reviews applications for construction and operation of natural gas pipelines – they have no jurisdiction over pipeline safety and security - TSA's responsibility
Gas-Electric interdependencies impact grid reliability and resilience

### Installed Capacity (MW) vs. Pipelines

<table>
<thead>
<tr>
<th>Installed Capacity (MW)</th>
<th>Single</th>
<th>Multiple</th>
<th>LDC</th>
</tr>
</thead>
<tbody>
<tr>
<td>NNG</td>
<td>1,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NGPL</td>
<td>2,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ANR</td>
<td>3,000</td>
<td></td>
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</tr>
<tr>
<td>CG</td>
<td>6,000</td>
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<td></td>
</tr>
<tr>
<td>PEP</td>
<td>7,000</td>
<td></td>
<td></td>
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<tr>
<td>GS</td>
<td>8,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>KTEJ</td>
<td>1,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GLGT</td>
<td>2,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AGP</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>TG</td>
<td>4,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>KTEX</td>
<td>5,000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) LDCs may contain multiple interconnects

### Compressor Failure Scenario

Source: NERC MRC Update on SPOD
MISO’s current process gathers gas pipeline events from a variety of sources, but does not capture all potential issues.
MISO is leading a multi-year effort to improve risk awareness and increase resilience with increased gas-dependence

The first phase (2018-2019) involves identification of potential system events
  - Where is the system at risk of an N-1 pipeline event becoming an N-x electric system event?
  - What are the time-domain impacts of these events?

Later phases (2019 and beyond) will involve collaboration with stakeholders and the industry to understand and address any credible system risks
  - Are solutions needed on the electric system, the gas system, or both?
  - How can the electric industry ensure that the gas system is capable of meeting its needs?
Next Steps

• Continue revising scope and deliverables
• Update stakeholders and continue conversations at applicable forums (PAC, etc.)

Questions?

• How can MISO enhance bulk electric system reliability and resilience with increased gas dependence?

Contact:
Mike Nygaard – mnygaard@misoenergy.org
Kyle Abell - kabell@misoenergy.org
Jordan Bakke – jbakke@misoenergy.org
Introduction to GPCM
MISO is continuing to expand its ability to assess 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
About the GPCM model

RBAC Inc.’s Gas Pipeline Competition Model (GPCM) is a network flow model of the gas pipeline system in North America

- Models over 1,000 pipeline nodes on 200+ interstate & intrastate pipelines
- Includes all supply, demand, and storage information for the continent
- Used to investigate the impacts of changes in supply, demand, and pipeline/storage infrastructure on prices and flow patterns
- Includes historic data back to mid-2000s, and base forecasts through 2040
- Used by a wide variety of gas & power industry organizations (midstream/upstream/downstream, consultants, national labs, banks)
What can MISO do with GPCM?

• Incorporate assumptions from MTEP Futures on top of forecasts provided by RBAC (GPCM vendor)

• Adjust assumptions (supply, demand) to match gas price forecasts included in the MTEP Futures

• Output data provides a glimpse into flow patterns, basis differentials in various areas of the country, and potential infrastructure needs
  • Output data can also serve as an input to the PLEXOS model

• Quickly investigate the effects of major gas system changes on gas prices, flow patterns, and infrastructure needs.
  • Results of these quick-hit studies can be distilled into one-page reports for easy consumption
Sample of GPCM inputs and outputs

GPCM calculates gas prices at Market Points and Pipeline Zones around the continent.

Demand (and supply) inputs are elastic curves, where total demand depends on price.

Each interstate pipeline is represented as a series of distinct prizing zones.
Introduction to PLEXOS
What is PLEXOS and why does MISO use it?

• A power market modeling and simulation software tool
• A flexible optimization platform with production cost modeling functionality
• Able to represent a variety of generation constraints, including rate-based emissions targets
• Able to simultaneously dispatch gas and electric systems

What is the PLEXOS integrated gas-electric model?

• It is the PLEXOS (electric) production cost model with built-in gas infrastructure
• It can simultaneously optimize gas and electric system operations in an hourly chronological dispatch
• It is an approximation of real-world gas and electric markets clearing in the same timeframe
The tie between the gas and electric systems in PLEXOS is gas-fired electric generation.
Representation of gas system topology parallels the electric system in PLEXOS

<table>
<thead>
<tr>
<th>GAS INFRASTRUCTURE</th>
<th>In PLEXOS</th>
<th>ELECTRIC INFRASTRUCTURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas pipelines (incl. interstate, intrastate, laterals, headers, gathering)</td>
<td>Lines</td>
<td>Electric transmission lines (≥ 34.5 kV)</td>
</tr>
<tr>
<td>Min/max volume (MMcf), max flow (MMcf/d)</td>
<td></td>
<td>Min/max/overload ratings (MW), reactance (p.u.), resistance (p.u.)</td>
</tr>
<tr>
<td>Pipeline/pipeline or pipeline/load interconnects</td>
<td>Nodes</td>
<td>Electric buses</td>
</tr>
<tr>
<td>Gas basins/plays; gas storage fields</td>
<td>Production/Source</td>
<td>Electric generators, demand-side management (DSM)</td>
</tr>
<tr>
<td>Min/max production (MMcf); production price ($/MMBtu)</td>
<td></td>
<td>Min/max capacity (MW); O&amp;M ($/MWh) and fuel price ($/MMBtu)</td>
</tr>
<tr>
<td>Residential (R), commercial (C), industrial (I), power (gas-fired electric gen) loads; LNG exports</td>
<td>Demand/Sink</td>
<td>Residential, commercial, industrial loads</td>
</tr>
<tr>
<td>Hourly profile per state for RCI; separate hourly profile for LNG; power load determined via PLEXOS (MMcf)</td>
<td></td>
<td>Hourly profile per company (MWh)</td>
</tr>
</tbody>
</table>

Note: This list is not exhaustive; additional characteristics are modeled for both the gas and electric systems.
GPCM to PLEXOS – Data hand-offs

**Inputs:**
- Pipeline topology
- Pipeline flow limits
- Storage parameters

**Outputs:**
- Demand volumes (monthly)
- Demand distribution factors (monthly)
- Production prices (monthly)
- Production volumes (monthly)
- Pipeline flow charges (monthly)

**GPCM**

**PLEXOS**

**Global Inputs:**
- Pipeline topology
- Pipeline flow limits
- Storage parameters

**Scenario-Specific Inputs:**
- Demand profiles (hourly)
- Demand distribution factors (monthly)
- Production prices (monthly)
- Production volumes (monthly)
- Pipeline flow charges (monthly)

Once

Each Future
The PLEXOS integrated gas-electric model allows us to answer very complex questions

• Examples of potential study areas:
  • How would a major natural gas supply disruption (fracking ban?) affect the electric system?
  • How much additional generation can the existing gas pipeline system support before we see widespread congestion and price spikes?
  • How are ramping requirements affected by increased reliance on natural gas and renewables?
  • What new gas infrastructure will be needed in a future with more natural gas generation?
These models can tell stories about micro- and macro-effects of increased reliance on gas-fired generation.

**GPCM results highlight** *long-term financial* impacts of increased gas usage.

**PLEXOS results highlight** *operational and reliability* impacts of increased gas usage.

*Charts are for illustrative purposes only*
Gas Modeling in MTEP18
MISO’s reliance on gas-fired generation continues to grow

- Natural gas generation has risen from 18% of MISO’s energy in 2014 to 27% in 2016

- Nearly 8,000 MW of gas-fired generation projects in advanced stages of the GI queue\(^1\)

- MTEP17 futures built between 20,000 and 28,000 MW of additional gas-fired generation by 2031

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\(^1\) - Generator projects in the DPP phase or with a signed GIA as of March, 2017
U.S. gas production from non-traditional supply regions is causing flatter national prices

- Increased flows to MISO from areas like Marcellus/Utica on new-build pipelines and pipeline reversals are improving MISO supply diversity
Powerbase’s current representation of natural gas transportation is simplified

- Henry Hub gas price is developed through MTEP Futures process
- Fixed cost to transport gas from Henry Hub to one of a few dozen Market Points (Ventura, Carthage, Chicago, etc.)
  - Bases vary by month and year, **but not by Future scenario**
- Fixed cost to transport gas from Market Points to Natural Gas Pools (NG Indiana, NG Louisiana, NG Minnesota, etc.)
  - Intended to represent cost to get gas to a unit’s “burner tip”
  - All generators in a pool see the same gas price
MISO has developed more granular gas prices for use in the MTEP study process

**Plant’s Gas Price = (Locational Price) + (Burner Tip Price Adder)**

- DOES NOT replace the Henry Hub price forecasting done as part of the MTEP18 Futures Development process
- Enables locational fuel prices to vary based on MTEP Futures assumptions (“Locational Prices”)
  - For example, increased industrial production along the Gulf Coast in the Limited Fleet Change future will cause higher relative gas prices in this region compared to the rest of MISO
- Allows for a more accurate representation of differences in fuel contracting costs (“Burner Tip Costs”)
  - Captures differences in costs for firm vs interruptible service, LDC connection vs direct pipeline connection
- Feedback on these changes was solicited through the MTEP18 Futures Development Workshop¹

¹ – See: [https://www.misoenergy.org/Events/Pages/FuturesDevelopmentMTEP1820170404.aspx](https://www.misoenergy.org/Events/Pages/FuturesDevelopmentMTEP1820170404.aspx)
How are we doing Locational Prices? GPCM

- RBAC Inc.'s GPCM is a network flow model of the gas pipeline system in North America. Gas prices are an output of GPCM.
- We can model MTEP futures assumptions (supply/demand trends) in GPCM to develop gas price basis for each pipeline node in each future.
- Units from the PROMOD model can be tagged to specific nodes on their supply pipeline.

How are we doing Burner Tip Costs? EIA-923

- EIA-923 Power Plant Operations Report collects information on fuel cost for power plants.
  - Monthly data includes total delivered volume of natural gas, and price in average $/MMBTU.
  - Price reflects all-in cost for generators to procure fuel (e.g. fixed service charges, variable commodity charges).
- We plot the delivered volume against the cost difference between the burner tip and the GPCM node. Linear regression gives an approximation of the variable cost component.
- RRF units (and any other missing units) will be given a burner tip cost consistent with units of the same type in the same county (or state, where county is not available).
- Burner tip costs are assumed to not change considerably over the course of the study period or by future scenario.
The process for developing individual burner tip adders requires data from multiple sources.

1. Map Generator to GPCM Pipeline Zone
2. Pull GPCM Zone Price Data 2012-2016
3. Pull Generator Fuel Delivery Data from EIA-923 2012-2016
4. Calculate Monthly Cost of Gas at GPCM Node and Burner Tip
5. Perform linear regression \((Ax+B)\) on GPCM vs EIA cost difference

Burner Tip Adder
In the MISO Commercial Model, Angus Anson lists a connection to Northern Natural pipeline. Anson is in Northern Natural’s “Market ABC” Zone.
Step 2 - Pull GPCM Zone Price Data 2012-2016

GPCM’s historic data gives wholesale gas prices for each pipeline zone dating back to the mid-2000s.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Period</th>
<th>Fct Zone Use</th>
<th>Fct Rplt Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>NNG Mkt ABC</td>
<td>Jan-2012</td>
<td>960</td>
<td>$2.937</td>
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<tr>
<td>NNG Mkt ABC</td>
<td>Feb-2012</td>
<td>881</td>
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<tr>
<td>NNG Mkt ABC</td>
<td>Mar-2012</td>
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<tr>
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<td>Nov-2012</td>
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<tr>
<td>NNG Mkt ABC</td>
<td>Dec-2012</td>
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<td>$3.451</td>
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</table>
Step 3 - Pull Generator Fuel Delivery Data from EIA-923 2012-2016

<table>
<thead>
<tr>
<th>YEAR</th>
<th>MONTH</th>
<th>Id</th>
<th>Plant Name</th>
<th>State</th>
<th>FUEL_GROUP</th>
<th>SUPPLIER</th>
<th>QUANTITY</th>
<th>FUEL_COST</th>
<th>Operator Name</th>
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<tbody>
<tr>
<td>2012</td>
<td>1</td>
<td>7237</td>
<td>Angus Anson</td>
<td>SD</td>
<td>Natural Gas</td>
<td>VARDUS (NATURAL GAS SPOT PURCHASES ONLY)</td>
<td>1,148.0</td>
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<td>$2.98</td>
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<td>SD</td>
<td>Natural Gas</td>
<td>VARDUS (NATURAL GAS SPOT PURCHASES ONLY)</td>
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<td>$3.30</td>
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<td>Angus Anson</td>
<td>SD</td>
<td>Natural Gas</td>
<td>VARDUS (NATURAL GAS SPOT PURCHASES ONLY)</td>
<td>881,596.0</td>
<td>$3.23</td>
<td>Northern States Power Co - Minnesota</td>
</tr>
<tr>
<td>2012</td>
<td>8</td>
<td>7237</td>
<td>Angus Anson</td>
<td>SD</td>
<td>Natural Gas</td>
<td>VARDUS (NATURAL GAS SPOT PURCHASES ONLY)</td>
<td>186,318.0</td>
<td>$3.79</td>
<td>Northern States Power Co - Minnesota</td>
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<tr>
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<td>9</td>
<td>7237</td>
<td>Angus Anson</td>
<td>SD</td>
<td>Natural Gas</td>
<td>VARDUS (NATURAL GAS SPOT PURCHASES ONLY)</td>
<td>34,940.0</td>
<td>$4.86</td>
<td>Northern States Power Co - Minnesota</td>
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<td>2012</td>
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<td>Angus Anson</td>
<td>SD</td>
<td>Natural Gas</td>
<td>VARDUS (NATURAL GAS SPOT PURCHASES ONLY)</td>
<td>37,210.0</td>
<td>$6.01</td>
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<td>11</td>
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<td>Natural Gas</td>
<td>VARDUS (NATURAL GAS SPOT PURCHASES ONLY)</td>
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<tr>
<td>2012</td>
<td>12</td>
<td>7237</td>
<td>Angus Anson</td>
<td>SD</td>
<td>Natural Gas</td>
<td>VARDUS (NATURAL GAS SPOT PURCHASES ONLY)</td>
<td>188.0</td>
<td>$3.93</td>
<td>Northern States Power Co - Minnesota</td>
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</table>

Step 4 - Calculate Monthly Cost of Gas at GPCM Node and Burner Tip

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Total Delivery (Mcf)</th>
<th>EIA Avg Price</th>
<th>EIA Total Cost (EIA Price x EIA Volume)</th>
<th>GPCM Avg Price</th>
<th>GPCM Total Cost (GPCM Price x EIA Volume)</th>
<th>Total Cost Difference (EIA Cost - GPCM Cost)</th>
</tr>
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<td>2012</td>
<td>1</td>
<td>1,148</td>
<td>$ 5.60</td>
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<tr>
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<tr>
<td>2012</td>
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<td>188</td>
<td>$ 3.93</td>
<td>$ 738.46</td>
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<td>$ 648.60</td>
<td>$ 89.86</td>
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</table>
Step 5 - Perform linear regression (Ax+B) on GPCM vs EIA cost difference

Three data points are very obvious outliers, more than two standard deviations away from the median delivered volume.
Removing these outliers creates a much closer trend line. The variable component of this line is the burner tip adder, $0.8146/MMBTU
The result is a unit-specific gas price that reflects market data better than that generated by PROMOD.
MISO’s enhanced gas modeling provides more granularity, accuracy, and flexibility to locational gas prices

**Price adders vary over time AND by Future**

Price adders vary ONLY over time

*Henry Hub gas price is set through the MTEP Futures Development Process*
PROMOD 2013 Market Benchmark Testing

- Utilized new gas transportation system on the 2013 PROMOD Market Benchmark model
- Monthly burner-tip gas prices from this method were on average 1-3% higher than prices in the original PROMOD Benchmark model
- Gas-fired dispatch decreased slightly, to a level that more closely matches actual 2013 market trends
- LMPs in Illinois, Indiana, and Minnesota increased very slightly, to a level that more closely matches actual 2013 market trends

MISO released a Whitepaper in May 2017 that detailed this process, along with the benchmark results

https://www.misoenergy.org/Events/Pages/PAC20170517.aspx
MISO’s new process models the impacts of our study assumptions on the gas pipeline system.
Why is this better than what we had?

- Instead of 24 natural gas market points and 33 state-wide natural gas pools, we can use hundreds of pipeline nodes with each plant possessing its own burner tip price adder.
- More accurately reflects the nuances in different generators’ fuel supply arrangements.
- Allows for variation in regional gas prices as a result of MTEP futures assumptions.
  - For example, increased industrial production along the Gulf Coast in the Limited Fleet Change future will cause higher relative gas prices in this region compared to the rest of MISO.
Next Steps

• Support inclusion of these plant-specific gas prices in MTEP18 EGEAS & PROMOD models

Questions?

Contact:

Mike Nygaard – mnygaard@misoenergy.org

Temujin Roach – troach@misoenergy.org

Jordan Bakke – jbakke@misoenergy.org
Walkthrough of Gas Price Forecasting with GPCM
Developments in hydraulic fracturing and horizontal drilling have led to a wave of natural gas production from non-traditional regions of the US.

North Dakota’s oil fields are rich in natural gas, which makes for a low-cost gas supply to much of MISO’s North/Central region.

Due to a lack of outlet capacity, North Dakota’s gas flaring rate peaked at 36% in January 2014.

- Thanks to new gathering and processing capacity—and drops in production—flaring is currently down to around 12%.

Oil production in the region peaked in 2014 amid falling global oil prices. However, production can ramp up quickly if oil prices rebound.

What happens if we cut Bakken production in half from 2027-2028?
Questions? Comments?

What else would you like to see come from this gas-electric modeling work? Ideas for interesting study topics? Other comments on approach?

General Questions:
  Jordan Bakke – jbakke@misoenergy.org

Modeling Questions:
  Mike Nygaard – mnygaard@misoenergy.org
  Temujin Roach – troach@misoenergy.org
Appendix: Example results from GPCM run
Testing the sensitivity of gas prices to demand shifts

• The US is expected to become a net exporter of natural gas this year\(^1\)
• Sabine Pass is the first major Liquefied Natural Gas (LNG) export facility in the Lower 48 States, and is the single largest gas user in the country
• Three trains are currently online, with three more permitted. Two of which are currently under construction
• The expected export capacity of the facility upon completion of all trains is 27 million metric tons per annum (MTPA)
• An additional 50 MTPA of export capacity is under construction in the Gulf, with 35 MTPA more permitted\(^2\)

What happens if we double Sabine Pass exports from 2018-2020?

\(^1\) [https://www.eia.gov/todayinenergy/detail.php?id=32412](https://www.eia.gov/todayinenergy/detail.php?id=32412)
Isograms represent the demand from a customer given a fixed price of natural gas. In this example, demand saturates after $4 (capacity of the facility is reached).
Total demand from a customer is a function of the price that the customer receives in the model.
Actual demand does not follow the isogram levels, as gas prices are constantly fluctuating due to supply and demand trends from other customers and suppliers.
The Henry Hub price is strongly affected by an increase in LNG exports from Sabine Pass, given its proximity in the region. Prices increase by 40 cents in the summer of 2019.
Even areas far removed from the Gulf South—like Northern Natural’s Market ABC Zone in the Upper Midwest—are affected to some degree by a change in exports from the Gulf.
While not affected to the magnitude that Henry Hub is, prices in the Upper Midwest still increase as a result of demand increases in the South.
Increased demand from LNG Exports in the Gulf South lead to relatively higher prices in that region, including at Henry Hub. This means a lower basis for areas around the country.
LNG exports affect consumption from generators across the country. A doubling of Sabine Pass exports could lead to a decrease in gas generation equivalent to approximately 4.4 GW.