Natural Gas/Electric Integration

Questions and Answers

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Overview

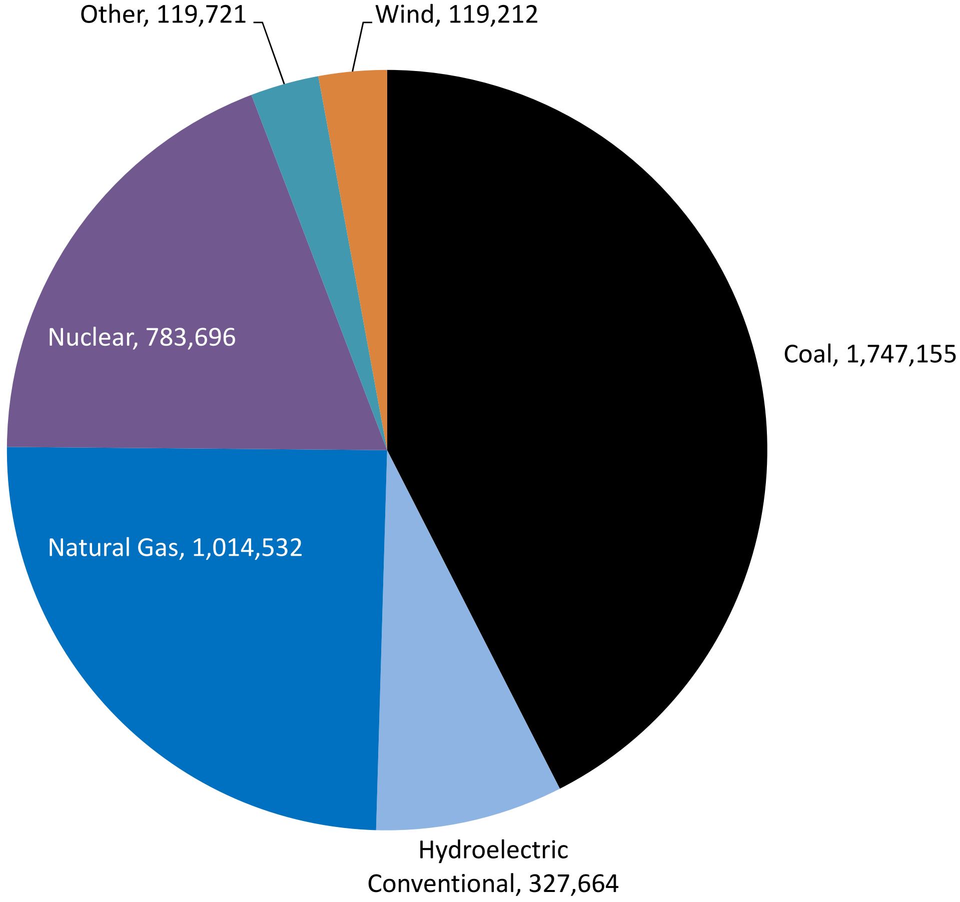
- Why are we interested?
- What are the questions?
- How do we find the answers?

WHY IS NATURAL GAS DIFFERENT?

Of the Major Electricity Generating Energy Sources, Only Natural Gas:

- Is not easily stored onsite – therefore, real-time delivery is critical to support generators.
- Procurement cycle is several times per day – not synchronized with electricity markets.
- Is also widely used outside the power sector – therefore the concurrent demand from other sectors critically affects supply for the power sector.
- Is delivered by a regulated pipeline under standard tariff services that cannot be modified for individual generators.

U.S Electricity Generation by Fuel - 2011 (1000 MWh)



Why Has It Become so Important to Study Gas/Electric Integration Issues?

- Gas generation accounted for 25% of total electric generation in the U.S. in 2011, versus only 17% ten years earlier, and is expected that gas generation will continue to grow.
  - Gas generation reached a high of 32% of total generation in June of this year.
- Natural gas is seen as playing a growing role in "firming" variable generation.
- There have been events in which gas supply/delivery limitations have affected electricity delivery – there is concern that there will be more.
- There is long-term, continuing concern over the operational and contractual differences between gas and electricity systems.

Firm Pipeline Capacity

- Gas pipelines must show firm transportation contracts for their capacity to receive FERC certification for construction.
- Holders of firm pipeline capacity have first call but can release unused capacity at times of low demand, but only during pipeline nomination windows.
- Electric generators may use this capacity without paying for firm capacity.
- However, at peak gas demand periods, unused capacity may not be available so generators may not be able to receive fuel.
- In organized electricity markets, generators cannot recover firm pipeline charges through market payments and therefore rely on interruptible or released capacity, even when bidding “firm” electricity.

Operational Differences

- Gas load for electricity can change frequently and unpredictably during one day. Gas is nominated (bid) only four times per day.
- Electricity is delivered essentially instantaneously but actual gas delivery moves at only tens of miles per hour, so pipelines must plan well ahead for delivery.
- Gas generators may take gas that they have not contracted for in order to meet electricity demand.
- While these gas volumes are ultimately replaced through balancing provisions, the timing of the replacement does not prevent pressure transients that threaten delivery pressures along the pipeline.

Reliability Assessment

- Electric assets are often either ”on” or “off,” while gas assets usually maintain substantial capacity after component failures
- Critical electric assets, when inoperable singularly or in small groups, can lead to rapid, widespread service outage. Cascading failures are unlikely in a gas system.
- Electric system resiliency is most usefully analyzed using N-1 or N-2 analyses. These are also useful for gas systems, but weather variability and its effects on interruptible capacity are the more practical concern
- Redundancy and interconnects make both electricity and gas systems more reliable.

Key Questions to Address

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- Is there sufficient gas supply (i.e., overall gas resources) from producers to satisfy peak demand in a given market? Will this outlook be affected by more stringent upstream environmental rules?
- Is there sufficient physical delivery capability to deliver gas to power plants at a time of peak demand?
- Do power plants have contractual call on supply and delivery capacity at a time of peak demand, and can the power plants be considered firm if they don't have firm gas supply? If not, what is the probability that interruptible gas service will be available?

Key Questions to Address

- How can utilities, transmission organizations, and gas pipelines better coordinate the different scheduling and contracting practices to ensure reliable and efficient operation of the gas and electric systems?
- How and why might gas supply be limited under certain circumstances (e.g., well freeze offs and LNG disruption), and how would this impact gas and electric system reliability?
- How and why might delivery capacity be limited under certain circumstances (e.g., compressor or pipeline failure), and how would this impact gas and electric system reliability?
- What are the costs and feasibility of on-site storage (e.g., LNG storage) and dual fuel capability as solutions to these problems?

How Do We Organize These Questions?

- Area 1 – Policies – Broad policy topics that address national policies or industry-wide concerns.
- Area 2 – Fuel Supply Alternatives – Technology and feasibility analysis of generic on-site fuel alternatives. May provide options for planning exercises in Area 3.
- Area 3 – Assessments for Specific Markets – Analysis of local or regional supply, infrastructure and integration issues. May be informed by policy conclusions from Area 1 and technology options from Area 2.
- Areas 1 and 2 in particular should be addressed consistently across regions.

Area 1 – Policies

- Differences in Scheduling and Contracting in Gas and Electric Markets – Identify differences in scheduling and contracting practices and identify possible changes to ensure reliable and efficient operation of the gas and electric systems.

- Contracting for Gas Supply and Delivery – Assess the challenges and implications of the current approach to contracting for gas supply and delivery – i.e., firm vs interruptible gas for electricity generators – and identify alternatives that could reduce uncertainty while providing appropriate returns to all parties.

- Defining and Assessing Resource Adequacy and Reliability – Establish appropriate definitions of adequacy and reliability for fuel supply and consistent methodologies for evaluating fuel supply reliability and impacts on electricity reliability.

Area 1 – Policies

- Study real time operating issues, and attempt to develop regulatory and contract policies and procedures that address potential problem areas.
- Analyze the system planning and infrastructure development processes for gas and electric systems and how those processes should be coordinated (e.g., firm gas service vis-a-vis firm electric capacity).
- Develop a common understanding of what constitutes reliability in the gas and electric sectors and formulate policies that ensure this reliability in both sectors.
- Develop reliability criteria and indicators for the combined gas/electric system and develop planning procedures to ensure that future system development satisfies certain criteria for system reliability.

Area 2 – Fuel Supply Alternatives

- Alternatives for On-Site/Local Fuel Supply for Gas Generators – Investigate costs and benefits of alternatives for on-site/alternative local fuel supply for gas-fueled generators.
- Identify impacts of related policies such environmental regulations.

Area 3 – Assessments for Specific Markets

- Gas Resource Adequacy – Assess the gas supply (i.e., overall resources) from producers to satisfy demand (including peak).
- Adequacy of Gas Delivery Capability – Assess the physical gas delivery capability to individual power plants at a time of peak demand and the contractual ability to assess that capacity.
- Gas System Contingency Analysis – Assess the reliability and capabilities of gas resources and infrastructure with respect to electricity demand under various contingency conditions.
- Integrated Reliability Analysis – Assess the reliability of the integrated fuel supply/generation/transmission and distribution system under defined contingency conditions to identify critical links and failure modes.

Area 3 – Regional Supply Assessments

- Provide a detailed characterization of the current gas supply and infrastructure as it relates to all gas consumers and specifically to power plants.
  - Assess the gas resource base and its costs and availability.
  - Identify and risks for supply development (e.g., regulatory restrictions on supply development), and their potential impacts on gas supply.
  - Assess gas pipeline and storage capacity under contract to various types of shippers, especially capacity contracted directly to power plants.
- Identify total gas needs and assess how those needs are likely to be satisfied over time so as to identify when and where potential shortages in gas supply and gas infrastructure are likely to occur.
  - Different electric load growth scenarios should be considered.
  - Winter and summer peak daily and hourly needs should be investigated.

Area 3 – Regional Supply Assessments

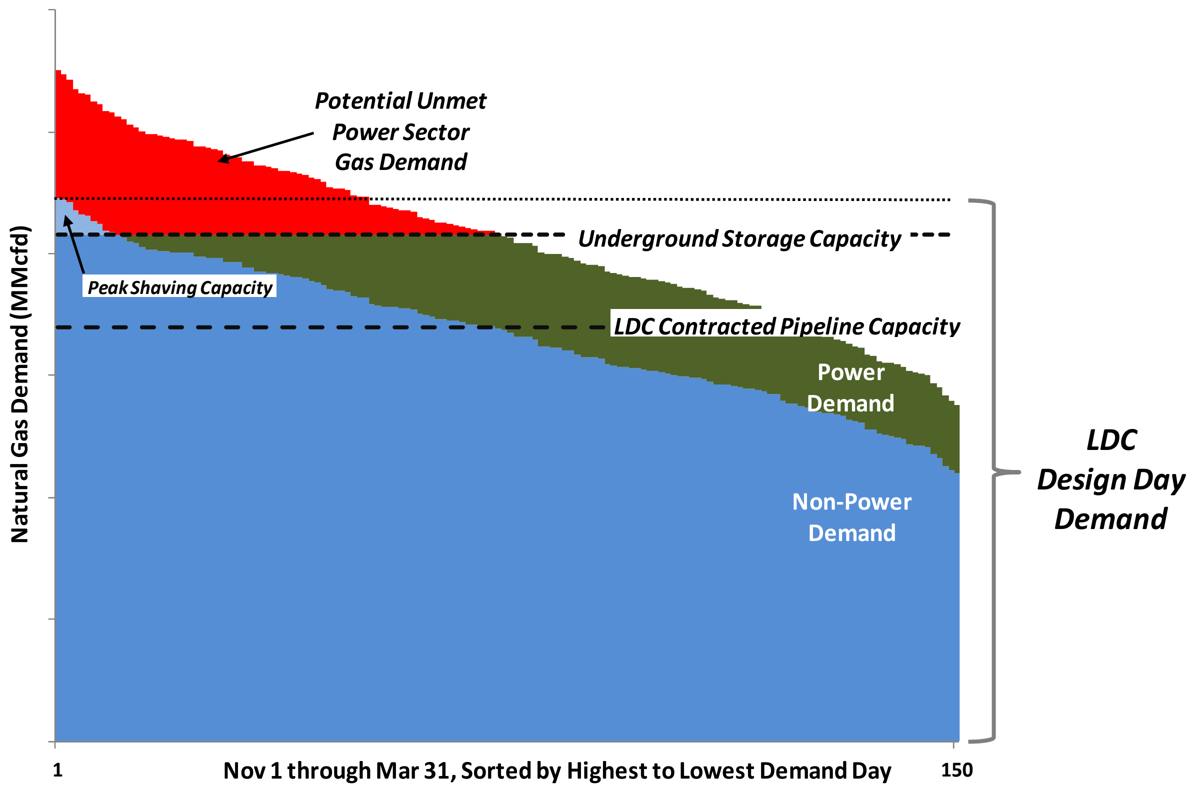
- Broad regional analysis followed by analysis of finer geographic areas.
- Assess how gas supply and infrastructure are likely to change over time, and assess how changes are likely to affect the electric system with modeling and scenario analysis.
- Alternative scenarios should consider different levels of supply and pipeline capacity development over time.
- The implications of power plants not having contractual call on supply and pipeline capacity should be investigated.

Area 3 – Regional Reliability Assessments

- Assess how gas supply may be limited under certain circumstances (e.g., well freeze offs or LNG disruption).
- Assess how gas delivery capacity may be limited under certain circumstances (e.g., compressor or pipeline failure).
- Perform scenario disruption analysis to quantify shortfall in gas generation versus required levels of generation.
- Perform probabilistic modeling to optimize reliability of gas and electric systems considering a wide range of scenarios and a wide range of potential market solutions (alternatives).
  - Could also consider gas contingency events.
- Perform hydraulic modeling of specific geographic areas that are determined to have the most potential for congestion in the gas transportation and distribution systems to assess the criticality of specific gas assets.

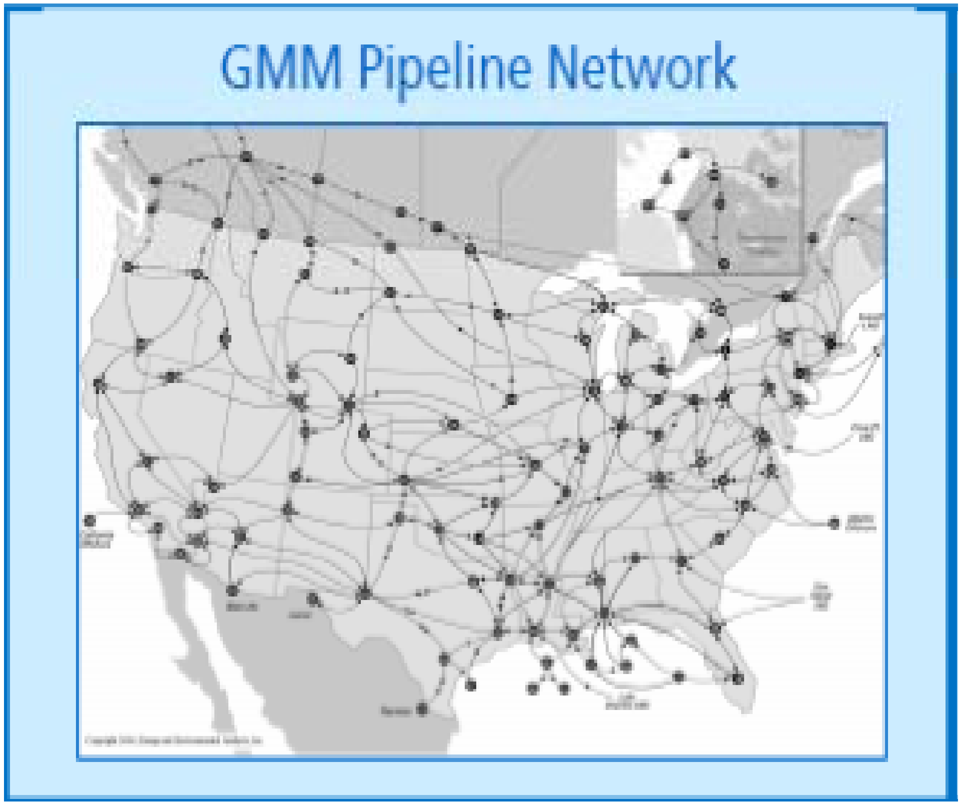
Analytics of Pipeline Capacity Adequacy

- Where LDCs hold nearly all pipeline capacity, power generator access depends on time of year and weather.
- Analysis of resource adequacy requires the ability to project available gas capacity as a function of economic/load growth and weather for non-power sectors.
- Must also be able to assess the interactions with regions upstream and downstream of the target region.



Example Natural Gas Daily Load Duration Curve

Gas Market Model (GMM™) is ICF's Tool for Evaluating Gas Supply Adequacy



- The GMM™ projects:
  - Integrated power and non-power gas demand under different economic and weather scenarios.
  - Supply and demand Interactions between regions.
  - Seasonal gas supply and storage interactions (by month).
  - Implications of new gas infrastructure projects.
- Provides inputs for ICF daily gas load modeling.

Other valuation models: Energy Asset Decision Support System (EADSS) for probability analysis; RIAMS for detailed infrastructure analyses.

Importance of Weather in ICF Gas Supply Adequacy Analysis

- The gas utility load will include a winter design day during a few select years and a number of other cold days to reflect relatively cold temperatures consistent with a 90/10 winter.(i.e., 90% probability that weather will be warmer)
- Weather cases that approach these LDC design day conditions will be more constrained from a gas supply perspective than an average weather reference case.
- Within each region, ICF utilizes our database of weather data (derived from NOAA data), which includes 80 years of monthly heating and cooling degree day by census region, as well as over 30 years of daily temperature data for weather stations throughout North America.

Gas Supply Contingency Analysis

- Identify and prioritize potential gas system contingencies, such as compressor outages, gas pipeline ruptures, upstream supply disruptions (e.g., hurricane disruptions or well freeze-offs) that could have significant impacts on the Study Region's gas supplies.
- Assess the impacts for each of the identified contingencies, and rank order the contingencies by level of impact (greatest to least) on the electric system for selected years or each year.
- Assess potential for further impacts on pipeline supplies (e.g. electric compressor outages) due to the loss of gas-fired generation.
- Studies may also estimate the probability of these events and social costs incurred.

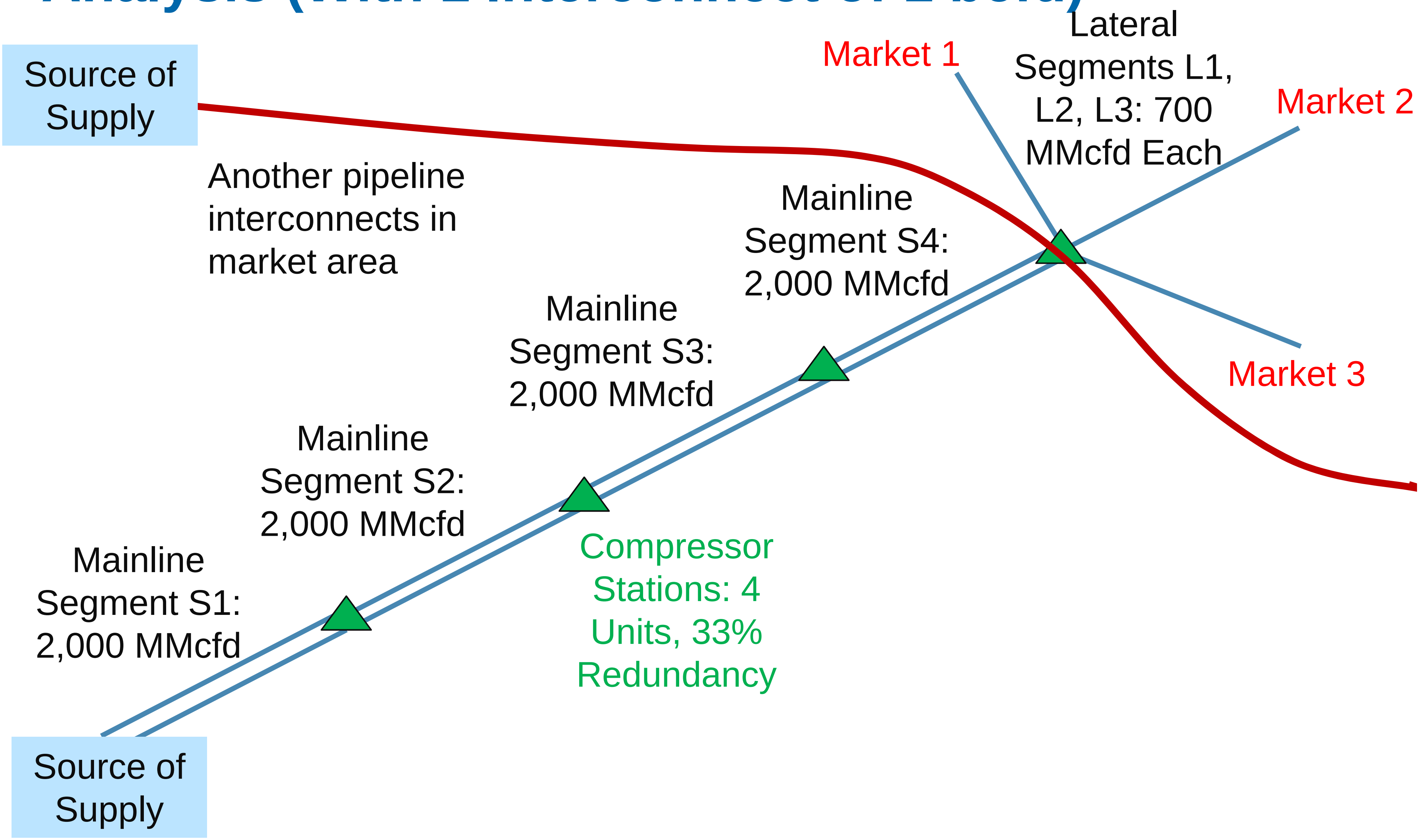
Gas Supply Contingency Events

- *Physical/Operational*
  - Mechanical or Operational Malfunction of a Specific Gas System Component, such as a compressor station
  - Pipeline Leakage or Burst Due to Stress/Corrosion Cracking
  - Storage Well Degradation or Failure due to Scaling, Water Penetration, or Other Factors
  - Pipeline Capacity Outages Due to Scheduled Construction, Maintenance, and Testing
- *Technical/Cyber*
  - SCADA System Malfunction
  - Electrical Failure of Supporting Computer and Control Systems
  - Database Corruption
  - Hacking/Tampering with Supporting Software and Information for Control Systems
  - Failure or Malfunction of Operational Flow Control Systems
- *Natural*
  - Damage to Compressor Stations from Flooding
  - Damage to Pipelines Due to Flooding, Erosion, River Scouring
  - Damage to Facilities Due to Hurricanes or High Winds
  - Well Freeze Offs in Production and Storage Systems
  - Earthquake damage
- *Man-Made*
  - Damage Resulting from Terrorist Activities
  - Pipeline Damage Due to Excavation
  - Damage Due to Negligence

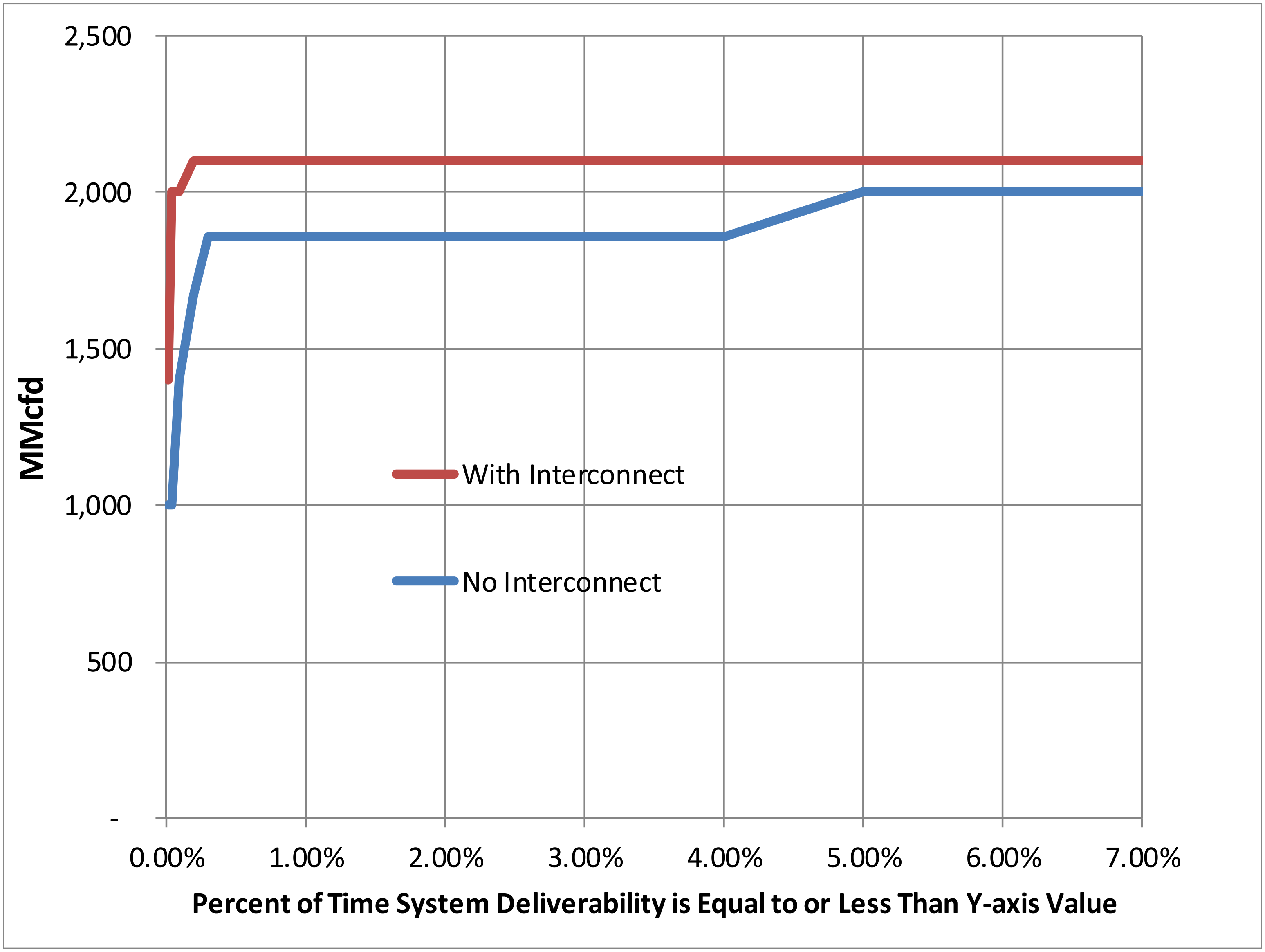
Gas Supply Contingency Event Impact

- Convert an event to an estimate of immediate consequences using hydraulic modeling/calculations (e.g., loss of typical compressor may reduce capacity on pipeline 1 Bcfd segment by 250 MMcfd or 75 percent for 72 hours)
- For each of the identified contingency, evaluate the ability to serve gas requirements (with and without gas fuel switching) performed assuming and "expected" and "90/10" load conditions.
- The calculated impact should be evaluated recognizing FERC established approved tariffs including:
  - Pipeline nomination, confirmation, and scheduling procedures;
  - Service priorities and "bumping" rules.

Example Gas Pipeline System for Reliability Analysis (With 1 Interconnect of 1 bcfd)



System Reliability Chart
(cumulative probability of total deliverability to 3 market areas)



Conclusions

- Gas/electric integration is a critical issue for both systems and becoming more important over time.
- There are a wide range of questions to be addressed. Some are national policy questions that should be addressed in a coordinated way. Others need to be addressed separately for each region.
- Regional analysis needs to address gas and electricity, power and non-power loads, weather and economic growth in an integrated way.
- Broader probabilistic models may be required for reliability analysis.

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