Gas and Electric Coordination and Co-Optimization

Aleksandr Rudkevich

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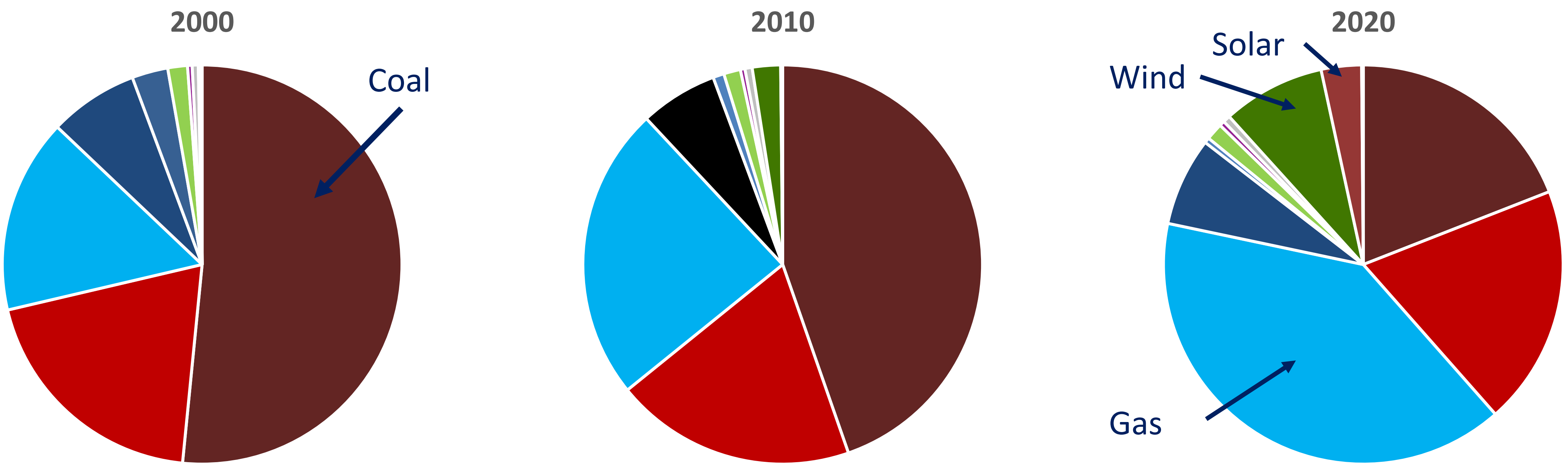
Outline

- Why are we getting increasingly concerned with the impact of natural gas supply on power systems operations, planning, reliability?
- Overview of gas-electric interactions
- How can gas-electric simulations be done for operational and planning (reliability) assessment
- A modeling framework: existing and proposed

Why are we getting increasingly concerned with the impact of natural gas supply on power system reliability?



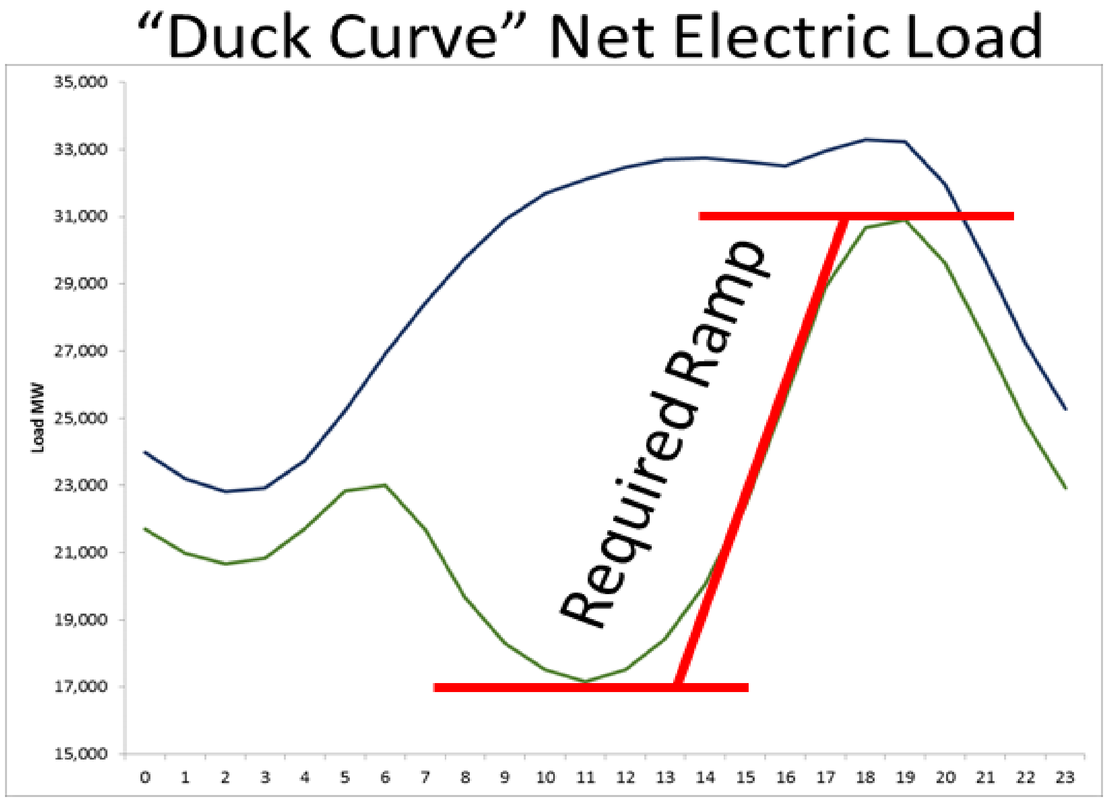
Coal: 52% Gas: 16%
Wind + Solar: 0.16%

Coal: 45% Gas: 24%
Wind + Solar: 2%

Coal: 19% **Gas: 40%**
Wind + Solar: 12%

- Lower costs have driven the growth of gas-fired generation, displacing coal
- Increased gas fired generation → increased flows in natural gas network

Why are we getting increasingly concerned with the impact of natural gas supply on power system reliability?



- Variability of electric generation from wind and solar increases the variability of pipeline deliveries to gas-fired generators used to balance the electric grid.
- Pipelines must be able to support fuel needs of fast ramping generators following the net loads
- The resulting intra-day and even sub-hourly swings in demand for natural gas as a fuel for electric generation create new challenges for pipeline operators that pose reliability risks for both gas pipelines and electric systems

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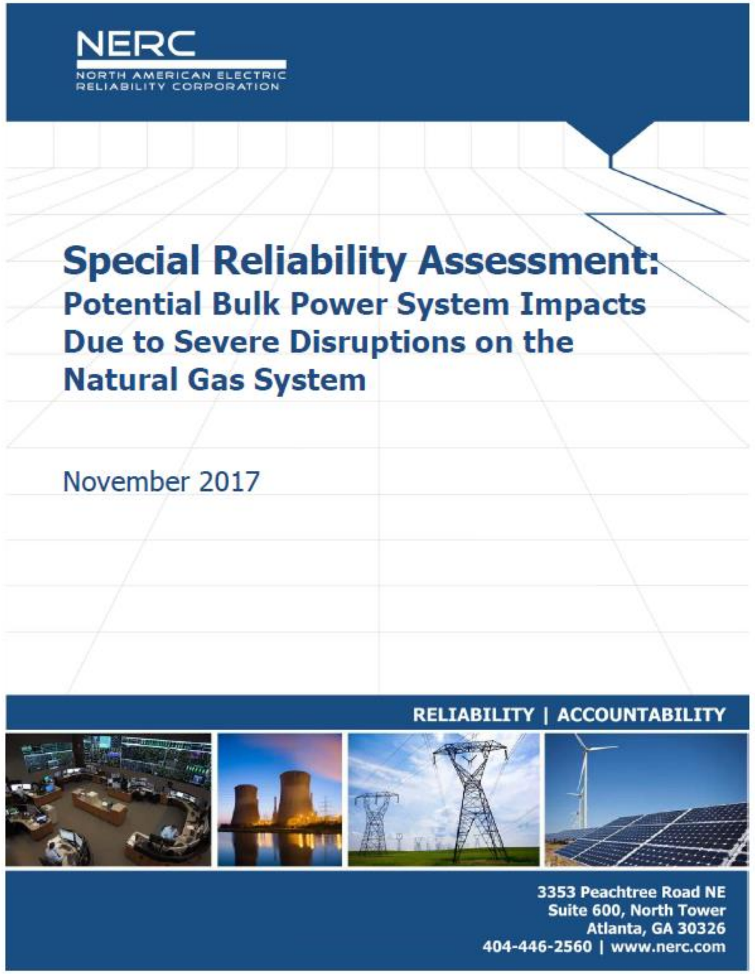
How Reliable is Gas in Stressed Conditions?

- During Texas cold snap, gas generation failed to perform as expected
  - ERCOT: 29.7 GW of gas unit outages & derates for Feb. 15: Equals 53% of ERCOT's Winter gas-fired capacity
    - Includes outages starting on Feb. 15 and on Feb. 14 while carrying into Feb. 15 or later (March 4 letter to legislature, excludes suppliers not authorizing release of their data)
  - Post-mortems should provide data on what happened and contributed to failures
- Not possible to effectively evaluate the reliability of gas supplies
  - Data needed to model gas pipeline operations are not available
    - Requires data on pipe & compressor specifications, flows, topology & interconnections
  - Data needed to understand gas supply shortages are inadequate
    - US DOT incident reports: Have been the most comprehensive public source for data on pipeline outages, capacity constraints, curtailments, & operations
    - Explains <20% of generation lost due to gas supply shortages between 2012 & 2017
  - Inadequate institutional capabilities and divided jurisdiction:
    - Unlike the electric sector, no mandatory Gas Reliability Organizations to gather data, analyze lessons learned, or develop standards
    - FERC regulates interstate transport (71% of gas pipelines); 19 States have significant intrastate pipelines; US DOT regulates operating safety and security

Key Findings of the NERC 2017 Report

- Natural gas facilities' disruptions can have varying impacts depending on geographical location and overall infrastructure dynamics
- At the time of gas contingency, replacing supply of gas-dependent generators often becomes complicated due to electric transmission problems
- Increased demand for natural gas storage is significantly affecting storage operations. Increased demand for fast intra-day storage operation vs. seasonal storage
- Firm transportation and dual fuel capability provide highest level of fuel supply reliability
- Diversity of natural gas supplies (e.g. access to multiple pipelines) improves power system reliability
- FERC Orders 787 and 809 improve gas/electric coordination which positively affects reliability
- Comprehensive planning by Planning Coordinators can significantly increase system resilience



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Most gas contingencies are not physical but operational

- Gas pipeline failures do not account for the majority of fuel shortage power plant failures (under 9% of events and 5% of MWh lost were due to pipeline failures)
- The majority of events of reduced or interrupted gas deliveries to power plants were due to operational or scheduling or market deficiency issues
- Firm contracts are not cure-all. Gas plants were affected by fuel shortages regardless of contract statuses
- Fuel shortages affect peakers, shoulder and baseload units
- At the time of fuel shortages experienced by power plants, relevant gas hubs were often under-utilized. Gas could have been moved.

Primary source: G.M. Freeman, J Apt, J. Moura "What Causes Natural Gas Fuel Shortages at U.S. Power Plants?" Energy Policy, Vol. 147, December 2020

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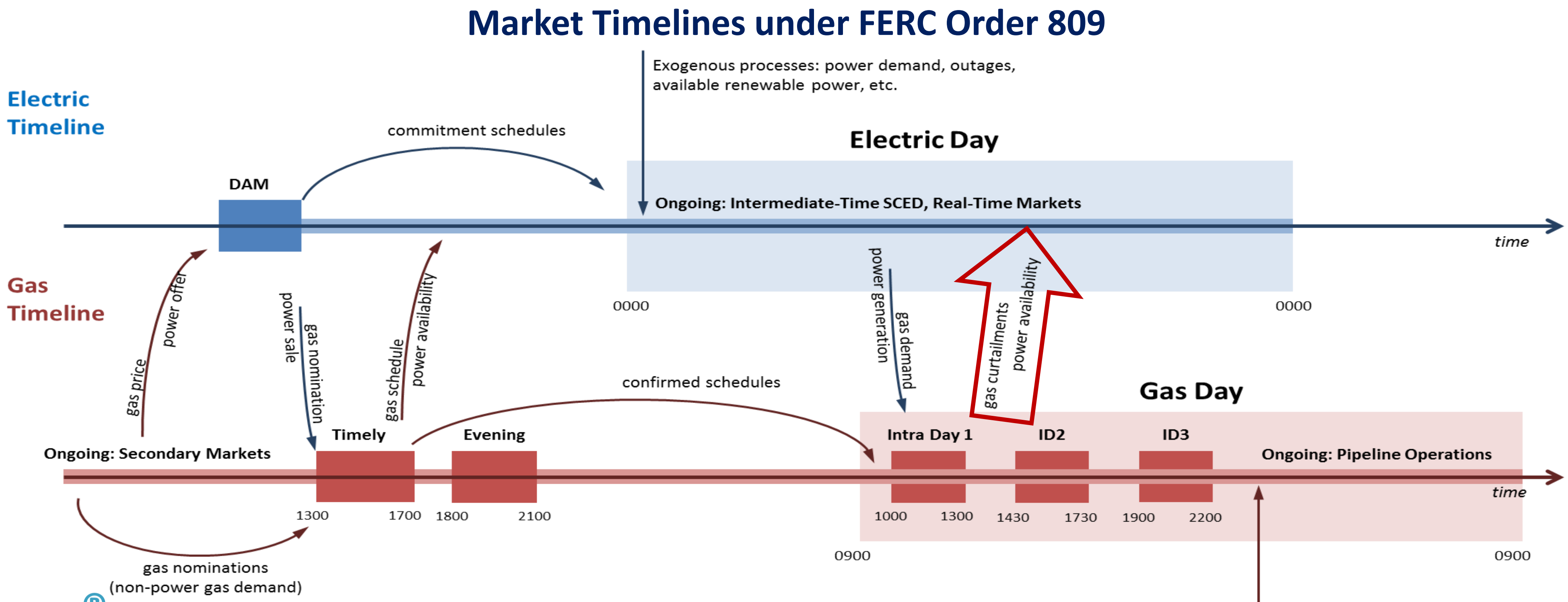
How Reliable is Gas in Stressed Conditions?

- Electric power accounted for 42% gas deliveries in 2020, double 2001 volumes
- Gas markets are not tightly integrated with pipeline and electric system operations
- Lack of near real-time integration of exposes generators to fuel supply risks and limits their operating flexibility in tight market conditions



Notes:
- All times are in Central prevailing time.
- The gas cycles depicted are the standard cycles required by FERC. Each pipeline may offer additional cycles. Under emergency conditions scheduling could be done outside of these cycles.

Challenges of the Quantitative Assessment of Gas-Electric Interactions

- Operational models of natural gas pipelines
- Resource adequacy electric models that capture transmission details
- Gas-electric coordination models
- Incorporating weather into analysis
- Data availability challenges

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Available Pipeline Modeling Tools

- **There are two types of models**
  - Very detailed physical flow models that represent engineering relationships between changes in pressure, flow, temperature within the natural gas pipeline network
  - Capacity allocation models that match supply and demand across a pipeline system, subject to pipeline capacity

- **There are two modeling techniques**
  - Simulation models compute dynamics for transient, or statics for steady-state, changes in gas flow and pressure with given receipts, deliveries and compressor settings
  - Optimization models determine receipt and delivery schedules and/or compressor operations to optimize certain objective functions to assess feasibility of natural gas delivery needed for electric reliability
- **Operational modeling of gas and electric systems simulations** require optimization tools based on physical flow transient models which until very recently were mathematically intractable

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The GECO Project

- 2016 – 2019. Project funded by ARPA-E. Participating entities – Los Alamos Laboratory (LANL), Newton Energy Group, Polaris Systems Optimization, Boston University, Tabors Caramanis Rudkevich
- Project objective is to develop methods, model, algorithms and an associated market design for a dramatically improved coordination and / or co-optimization of wholesale natural gas and electric physical systems and economic markets on a day-ahead and intra-day basis
- Modeling tools developed:
  - Gas System Optimizer (GSO) based on Gas Reliability Analysis Integrated Library (GRAIL) by LANL
  - Power System Optimizer (PSO) by Polaris
  - GECO ENELYTIX – Newton integrating both GSO and PSO into a GECO Machine and setting parallel computations of multiple GECO machines within ENELYTIX cloud platform

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Gas System Optimizer (GSO)

Transient and steady state pipeline optimization solver

Inputs and models

- Fixed and price sensitive demand
- Fixed and price sensitive supply
- Pipeline topology and pipe characteristics
- Compressor stations

Algorithms

Steady state and transient optimization of:

- Market surplus (social welfare)
- Throughput
- Compression energy or cost
- User defined objective function

Rolling horizon modeling

Outputs

Physical:

- Gas flow and pressure dynamics
- Compressor details
- Delivery and curtailments

Dual/Financial:

- Shadow values of binding constraints
- Locational value of gas
- Energy costs

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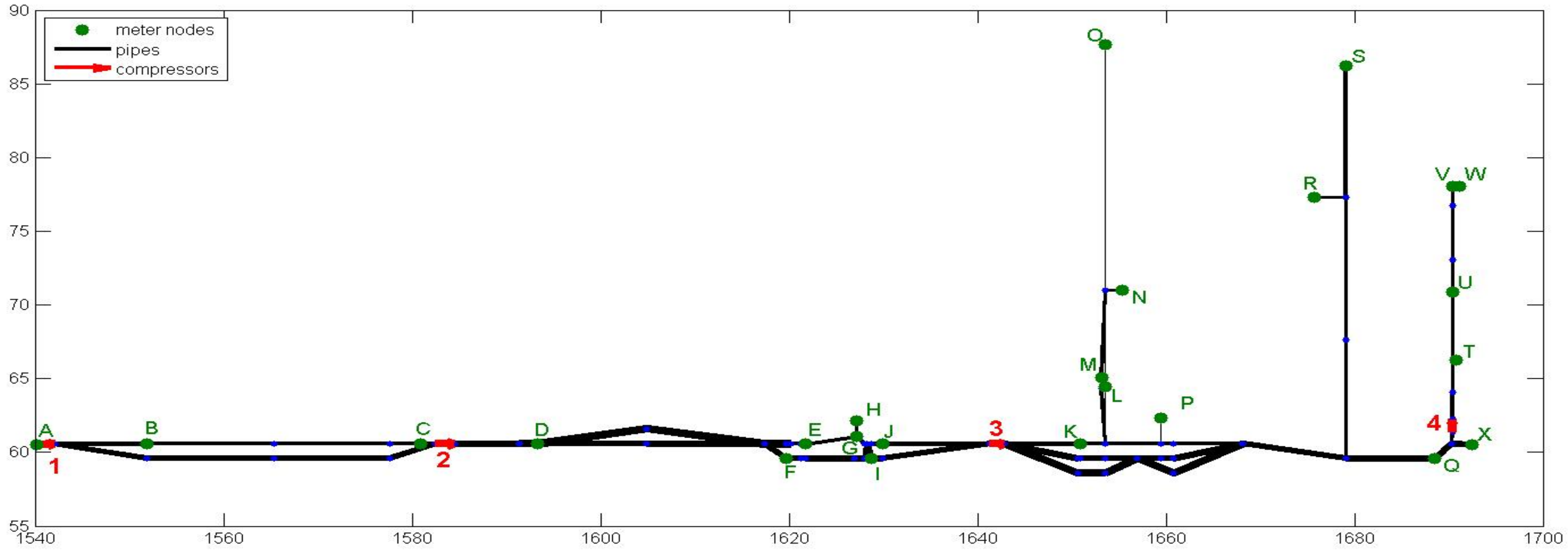
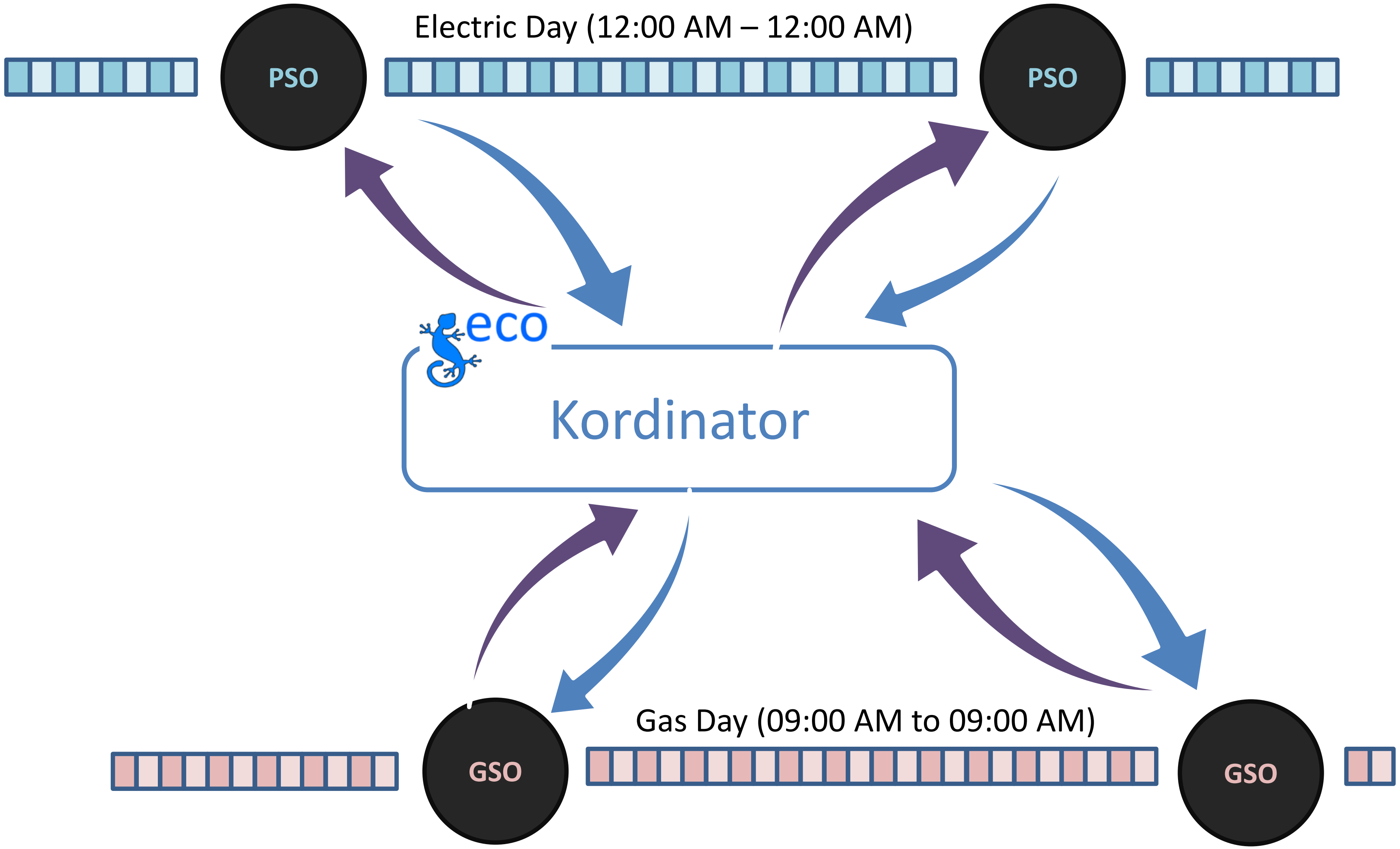
Testing and Benchmarking GSO

- GECO project team tested the precision and computational performance of GSO using SCADA data for a specific pipeline system provided by Kinder Morgan provided for February and March 2014 – the Polar Vortex period
- The system serves three CCGT power plants
- Simulated hourly flows and pressure dynamics across the system demonstrated high accuracy (within 1% - 3% of SCADA measurement) while taking seconds of compute time



The GECO Machine



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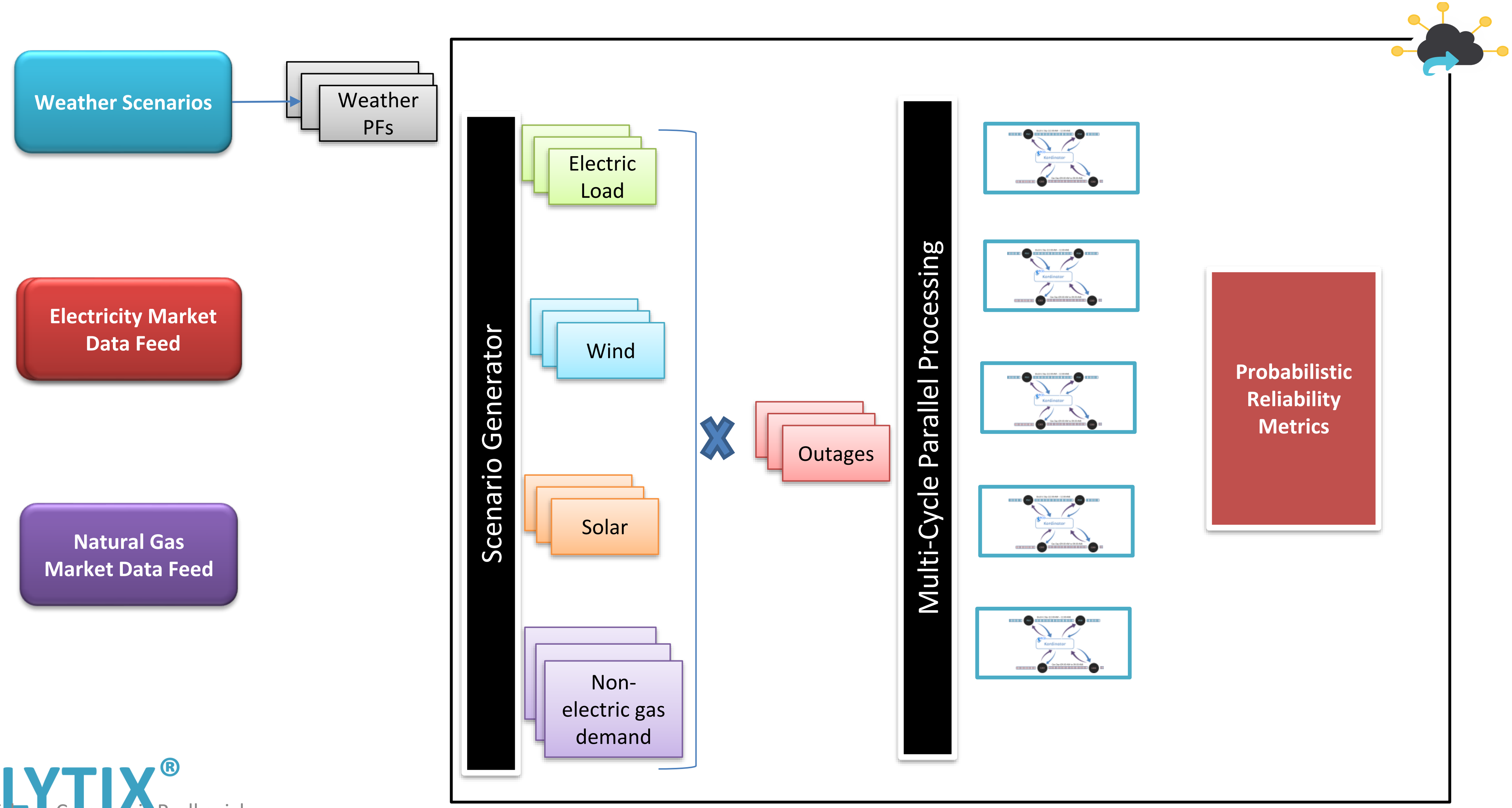
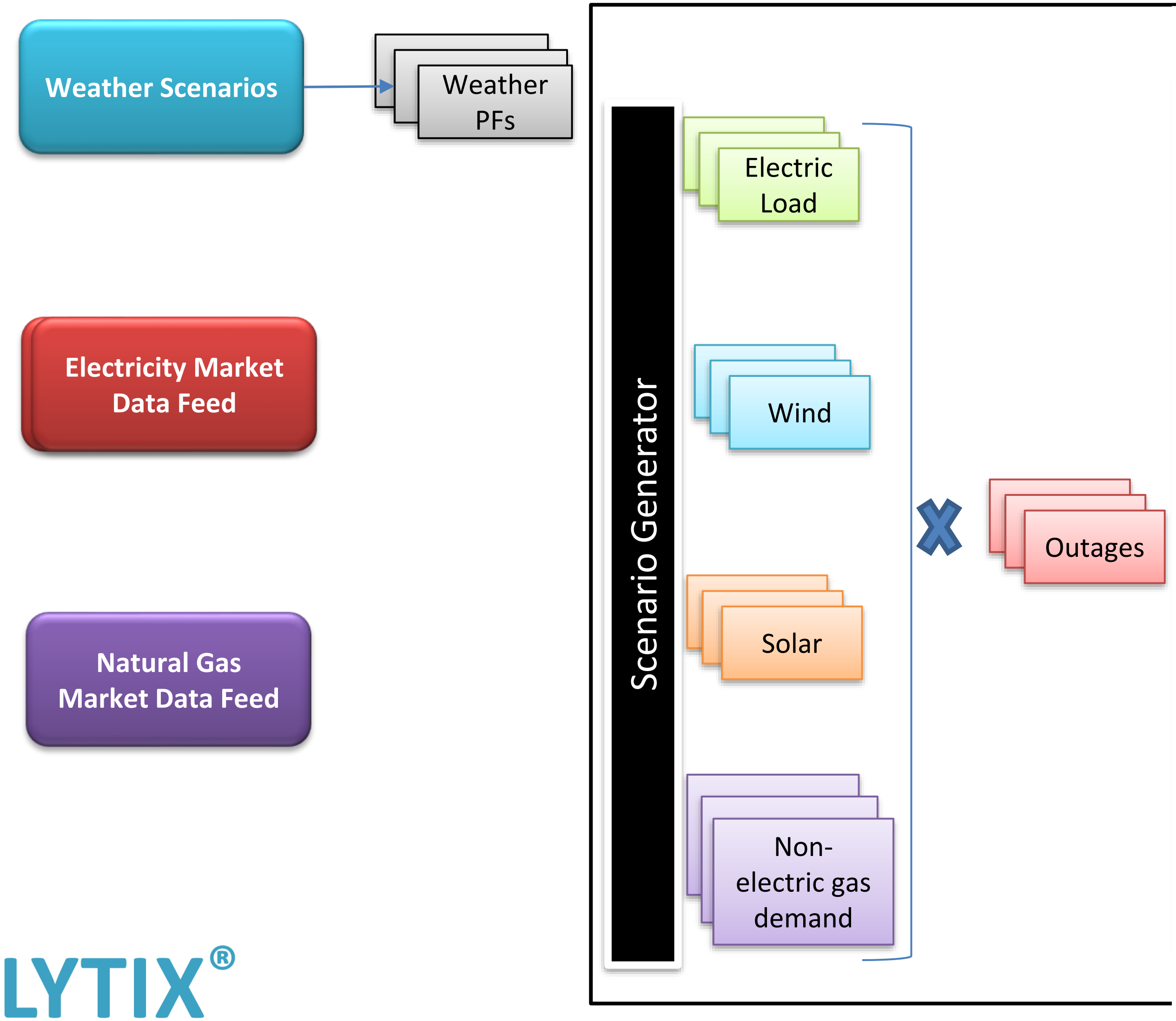
Summary of Simulation Results using GECO ENLYTIX for the Test System

- By improving operational efficiency using transient optimization the overall throughput of the system under the same Polar Vortex conditions could have been increased by 12% - 14%, of those by 7% - 9% during highest price hours
- Improving gas-electric coordination using price-based intra-day balancing of deviations from ratable schedules would:
  - Reduce delivered natural gas prices by 3% - 12 % depending on the location
  - Increase operating margins for generators participating in intra-day balancing market by 45% - 380% depending on the location

Moving forward– Creating a modeling framework for gas–electric reliability assessment



Moving forward– Creating a modeling framework for gas – electric reliability assessment (cont'd)



- Flow of information should be regularly updated
  - at least daily
- Probabilistic weather forecasts would form a foundation for developing electricity and natural gas demand scenario along with weather driven wind and solar outputs
- The models would will play out >100 weather scenarios capturing all temporal and spatial correlations of weather and renewable resources
- Concurrently, the system accumulates information about the state of the pipeline system and electrical grid and key planning/scheduling decisions for the next 24-48 hours
- Weather-driven uncertainties are combined with simulated physical contingencies

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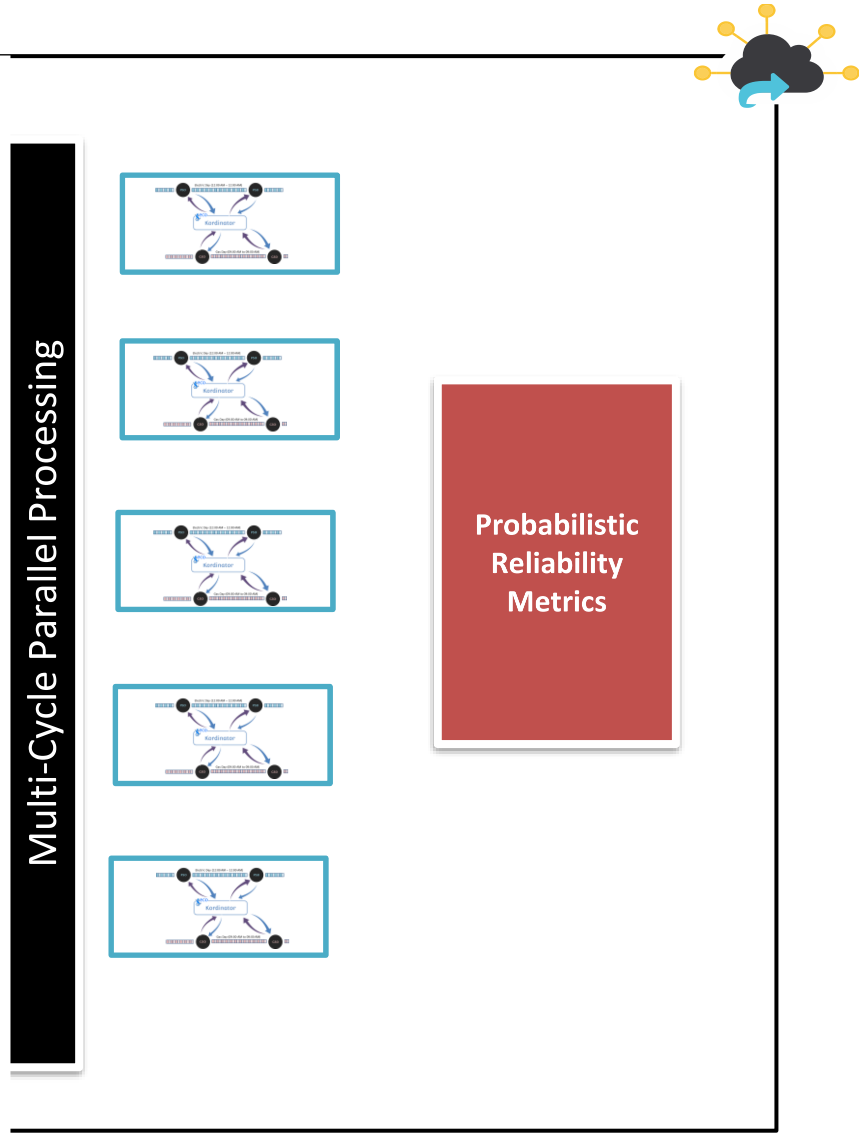
Moving forward – Creating a modeling framework for gas – electric reliability assessment (cont'd)

- Scenario inputs focusing on the next 24 – 48 hours of system operation will perform specific combined gas-electric feasibility assessments using a systems like GECO Machine
- Assess electric system adequacy
- Simulate pipeline capability to deliver required natural gas quantities taking into account coordination mechanisms
- Use parallel computing technology for a large number of Monte Carlo simulations
- Post process the results to compute critical resource adequacy metrics reflecting gas-electric conditions with nodal locational and hourly temporal granularity



Conclusions

- Natural gas contingencies are a significant reliability concern for the electric system
- Most generator fuel shortages are a result of operational decisions that reflect a lack of closer power market - gas coordination including the lack of liquid intraday gas market
- A more efficient resolution of gas – electric coordination issues may require an understanding of, and a way to address, the gas distribution utility concerns
- Assessment of the impact of gas contingencies on reliability of electrical system need to rely on detailed physical and operational model of pipeline systems and coordinated simulation of gas-electric interactions
- Development of such systems is feasible
- Availability of pipeline data may be a challenge but is not insurmountable
- Development of models and software system of gas-electric reliability assessment will benefit both the electric and natural gas industries