Gas-Electric Co-Optimization (GECO)

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Project Team

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Technical Expertise

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Disclaimer

The opinions presented herein are solely those of the authors and do not necessarily reflect those of the entities of which the authors are a part or those of the full Project Team. Specifically, no opinion or conclusion expressed or implied in this document may be attributed to our cooperating entities -- the PJM Interconnection and Kinder Morgan.

GECO Project Summary

- Formal Project Title: *Coordinated Operation of Electric And Natural Gas Supply Networks: Optimization Processes And Market Design*
- Leading Organization: Newton Energy Group LLC
- ARPA-E Program: OPEN-2015
- Project started: April 20, 2016
- Project term: 2 years through April 19, 2018
- ARPA-E Award: $2.9 million
- ARPA-E project summary: https://arpa-e.energy.gov/?q=slick-sheet-project/gas-electric-co-optimization

GECO Objectives and Program Elements

Objectives: algorithms, software and an associated market design to dramatically improve coordination and / or co-optimization of natural gas and electric physical systems and wholesale markets on a day-ahead and intra-day basis

Program Elements

Software & Algorithms

- Modules for pipeline simulations and optimization
- PSO SCUC/SCED for electric system simulation
- Data, cloud-based system simulating gas - electric interactions

Market Design

- Joint gas-electric theory and computation methods of granular prices consistent with the physics of operations
- Market design proposal including coordination mechanisms using granular prices

Realistic Market Simulations

- Gas-electric simulation model using realistic data
- Simulated scenarios comparing performance of gas-electric coordination policies under different assumptions

GECO Project Team and Technical Expertise

Institution	Expertise
Newton Energy Group	• ENELYTIX® Cloud platform for parallel modeling and analytics of energy systems and markets • Optimal dynamic pricing and market design • Commercialization
Los Alamos National Laboratory EST.1943	• Advanced computational methods and algorithms for simulation and optimization of gas & electric networks
POLARIS SYSTEMS OPTIMIZATION	• Advanced power systems simulation engine within ENELYTIX® • Power systems optimization expertise
Boston University	• Market design, coordination algorithms
AIMMS	• Modeling language, optimization

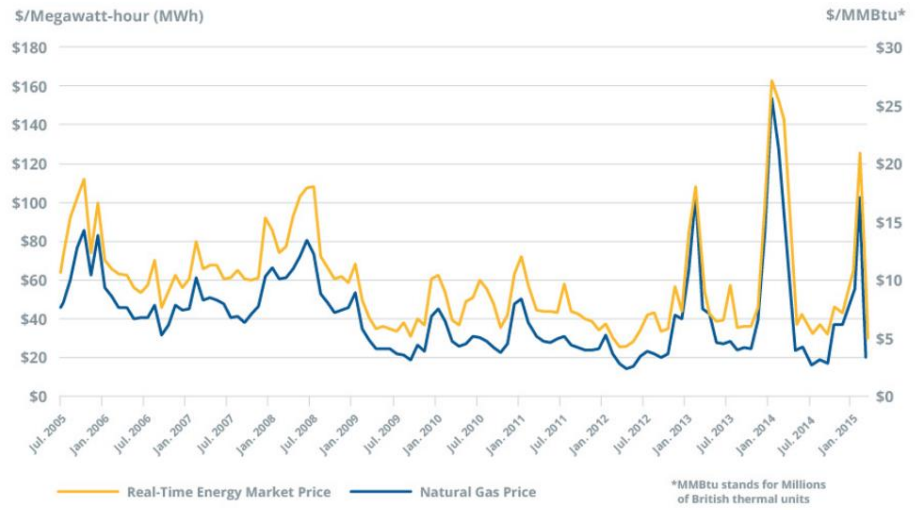
External Technical Expertise

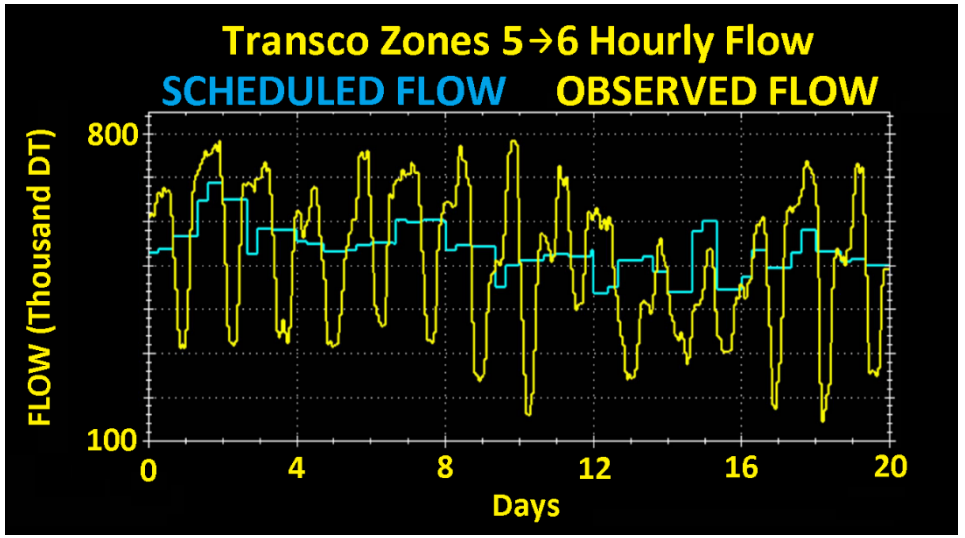
pjm

KINDER MORGAN

Motivation

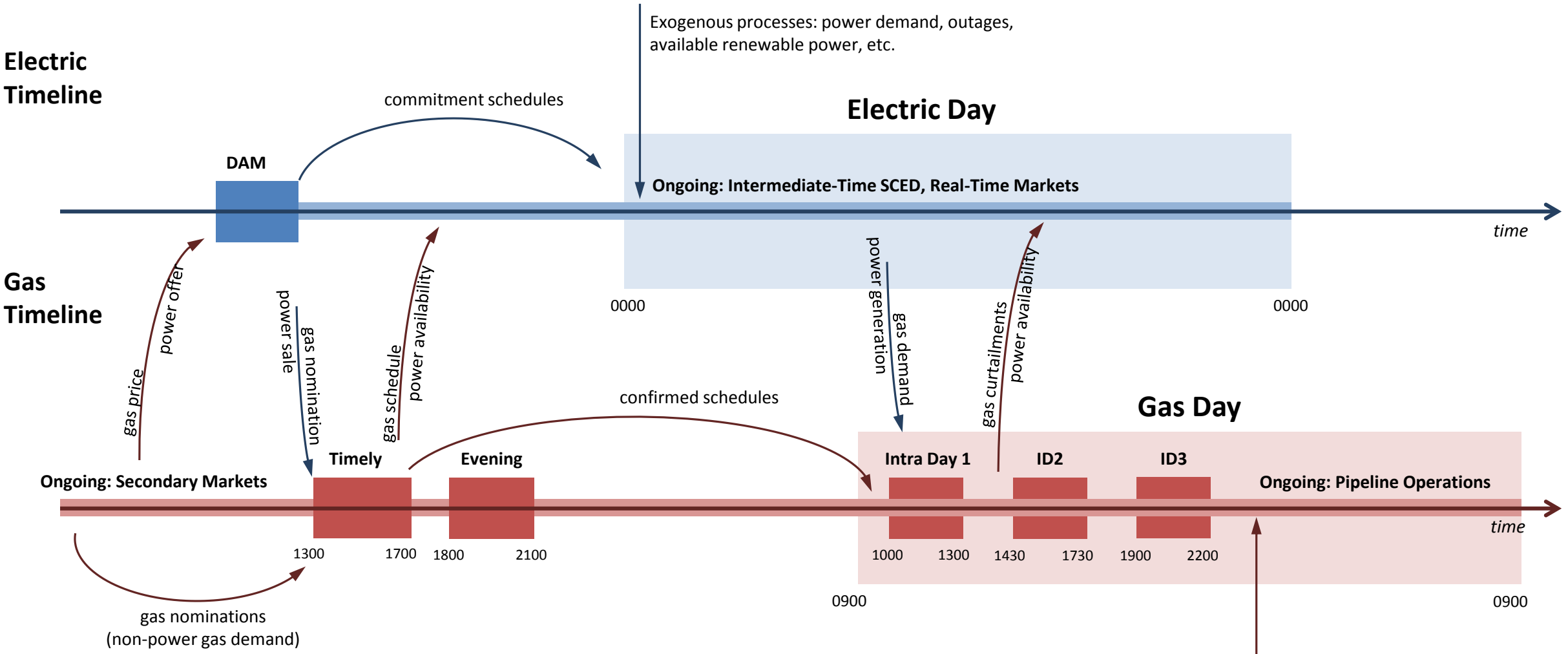
- Rapidly increasing role of gas-fired generation both as energy and A/S needed to integrate renewable resources
- Price of natural gas drives the price of electricity
- Gas fired generation is a “marginal consumer” of natural gas → gas-fired generation drives the price of natural gas
- Lack of coordination between natural gas and electric grids may produce massive simultaneous price spikes for natural gas and electricity consumers (e.g. Polar Vortex of 2014)
- Radical improvement in coordination of natural gas and electric operations is necessary for the advancement of modern electricity and natural gas delivery systems
- Recent advancements in pipeline simulation and optimization methods developed by the LANL team create an opportunity to achieve such radical improvements





The Proposed Coordination Mechanism with Gas Balancing Market (GBM)

Current Gas-Electric Decision Cycles



Notes:

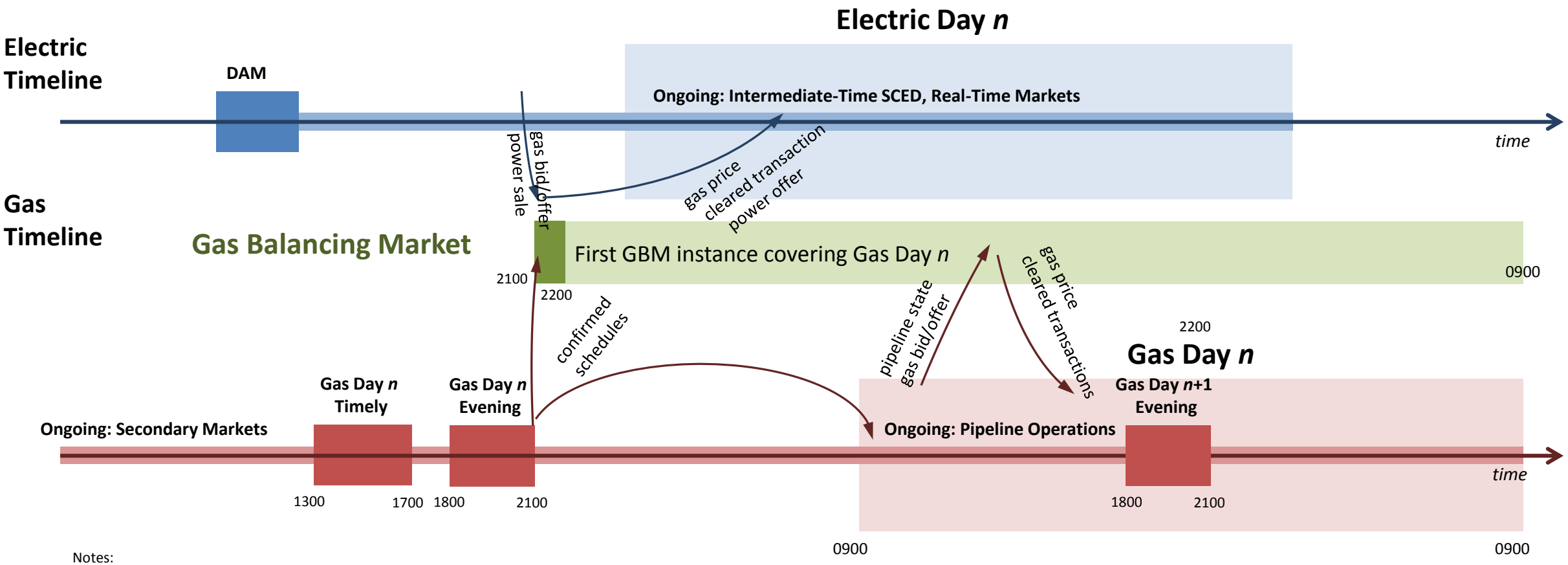
- All times are in Central prevailing time.
- The gas cycles depicted are the standard cycles required by FERC. Each pipeline may offer additional cycles. Under emergency conditions scheduling could be done outside of these cycles.

Gas Balancing Market

The Gas Balancing Market (GBM) would:

- Be pipeline specific
- Have ***voluntary*** participation
- Honor existing transportation rights and contracts
- Enable trades of hourly imbalances from ratable schedules
- Assure that intra-day transactions cleared in the market are physically implementable
- Enable intra-day gas transactions between parties in a liquid, transparent, flexible and simple manner
- Provide transparent pricing signals to all gas players to inform decision making
- Enable more economically efficient utilization of the gas and power infrastructures

Proposed Timing of the Gas Balancing Market



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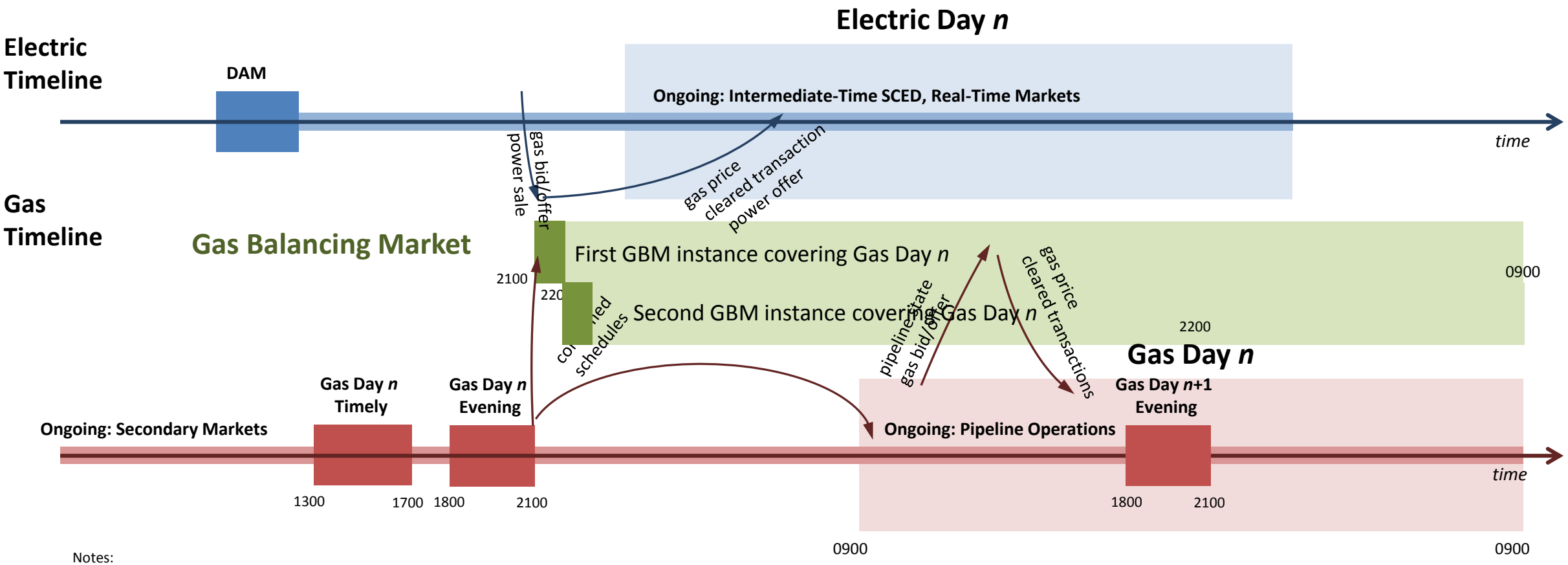

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Market Outcome

- Hourly schedules for receipt and delivery:
  - schedules result from
    - Cleared market buy/sell positions and/or
    - Self-schedules
- Hourly Gas Locational Trade Values (LTV) of gas by node (receipt and delivery points)
- Cleared schedules are settled at LTVs

Granular Pricing Signals at Work

- Electric Side
  - Hourly gas trade values (LTVs) to support bidding into DA and RT markets
  - Simplifies gas purchases for gas-fired fast-start power plants that clear in the real-time power markets and/or that are called upon to provide ancillary services
  - Redispatch of electric generation in response to high gas LTV under scarcity caused by pipeline constraints
  - Transparent economic signal to help generating companies to determine the level of FT coverage they need to manage risk
- Gas Side
  - Relief of pipeline constraints through
    - LTV-sensitive optimization of compressors
    - Redispatch of electric generation
  - Help pipeline customers make investment decisions
  - Help pipeline owners to
    - Identify constrained system elements with better granularity
    - More precisely assess economic benefits of alternative solutions
    - Justify investments in economic solutions before regulatory agencies

What are the *Secret Sauces* of the GECO Project?

(1) Transient Pipeline Optimization
and
(2) Locational Trade Value (LTV) of Natural Gas

GECO brings forward pipeline modeling and optimization capabilities

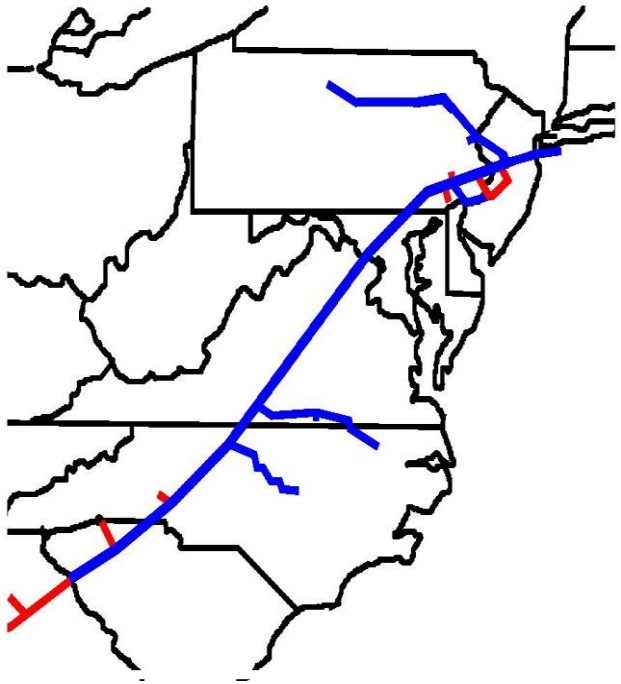
- Transient optimization of pipeline operations
  - Optimal dynamic operation of compressors
  - Economically optimal gas purchases and sales, line pack and use of storage
- Scalable methods and algorithms
  - Can optimize a large pipeline network
  - Can solve optimization problems for real size systems in a matter of minutes
- Development of economic signals that are:
  - Granular in time (e.g. hourly)
  - Granular in space (e.g. at each meter station)
  - Consistent with the physics of gas flow and engineering constraints on pipeline operations

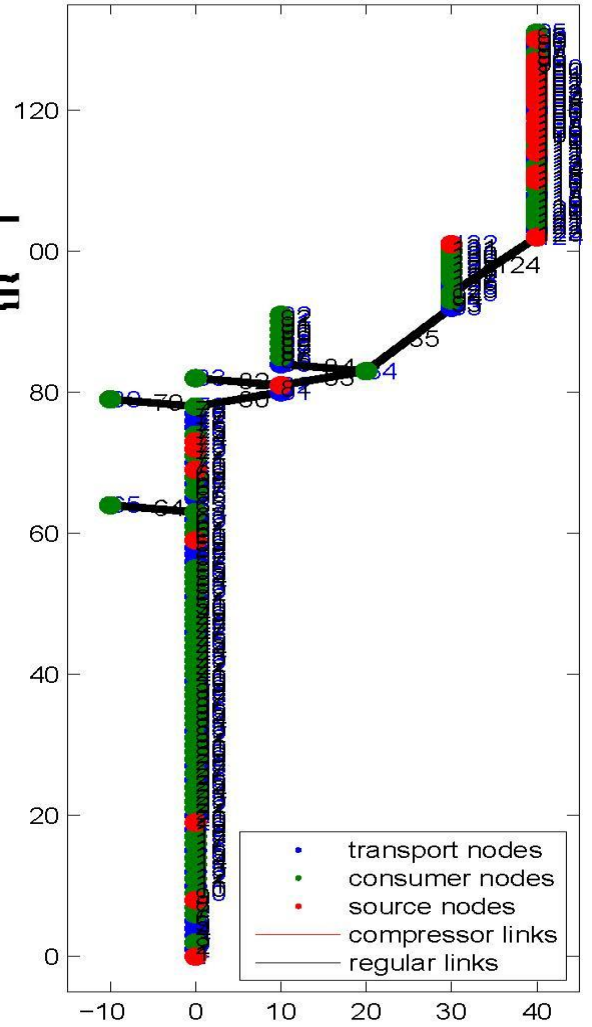
Economic Optimization of Pipeline Operation: a Conceptual Formulation

- A two-sided auction
- Conducted on gas pipeline network subject to engineering constraints
- Participants: buyers and sellers of gas submitting Price/Quantity (P/Q) offers/bids
- Offers and bids are node-specific, with hourly time step for an optimization horizon (e.g., 36 hours)
- Auctioneer's objective function: maximize summed over the optimization horizon market surplus between accepted bids and offers less compressor costs of running the pipeline

Pipeline Optimization Case Study: a 1600+ mile pipeline network

- Based on data for Williams – Transco pipeline Zones 5 and 6
- Spans Georgia to New York City, includes Pennsylvania
- 132 nodes, 131 pipes, 31 compressors
- Total network length of 2679 km (1664.9 miles)
- Solution time for a 24-hour optimization horizon is approximately 5 min

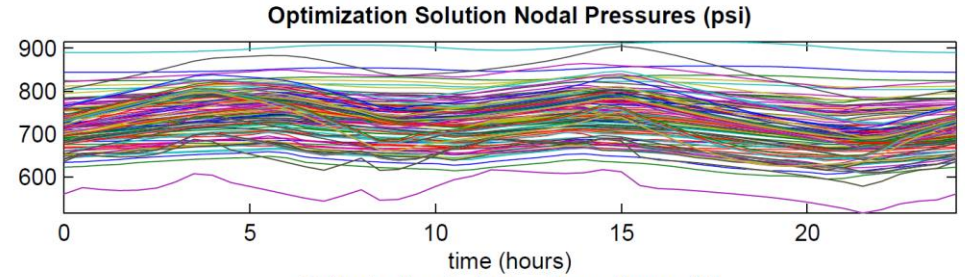


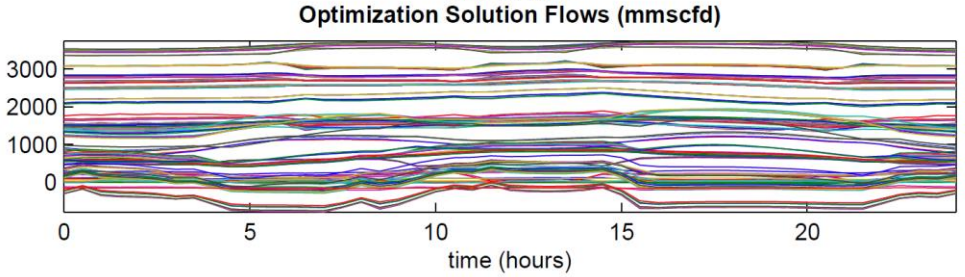


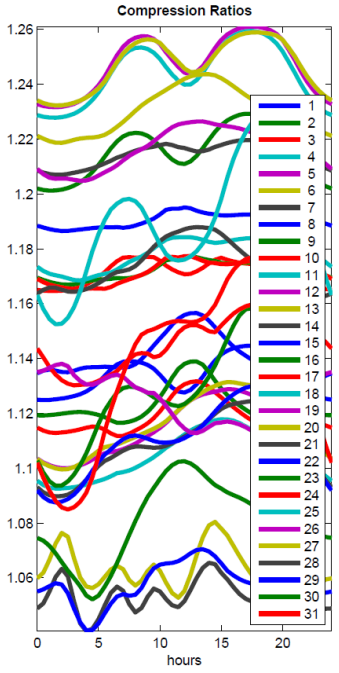
Optimization can guide an operational regime for the pipeline

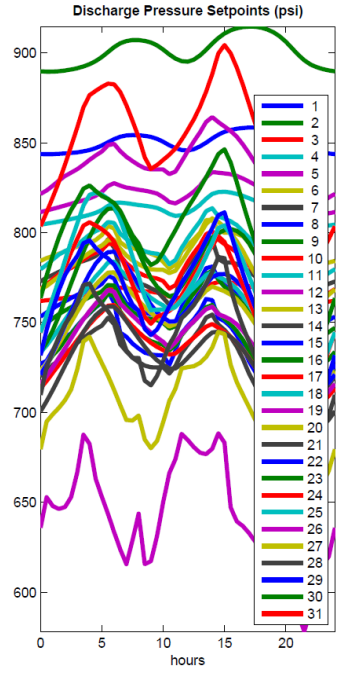
- Time dependent pressure regime for each node
- Gas flow through each pipe and compressor station

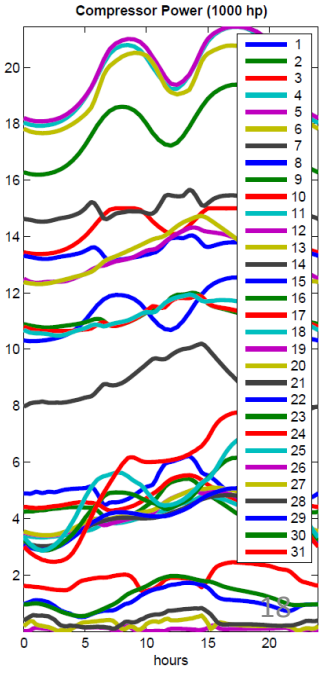
- Compression ratios
- Discharge pressure settings
- Horsepower use for each compressor





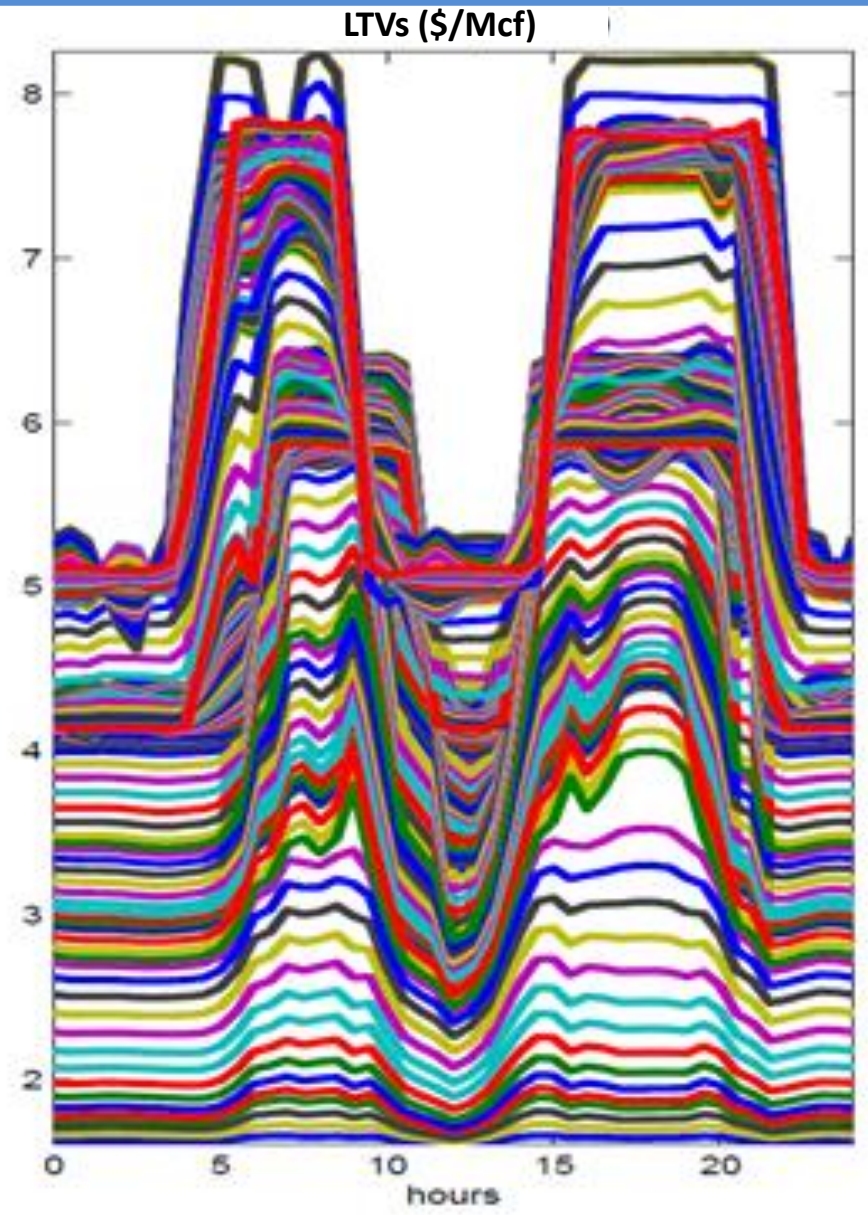






Optimization as a market clearing engine determines accepted bids and offers and Locational Trade Values

- Market engine determines accepted receipt and delivery schedules by location
- In parallel, the engine sets Locational Trade Value (LTV) of gas at all network nodes
- At time of constrained operation, LTVs vary significantly by location
- LTVs reflect *actual* physical capacity of the pipeline system under *current* and *anticipated* conditions



SUMMARY

GECO Novel Technology

Innovation	
Optimized intraday pipeline operation	• Fast and scalable optimization methods and software for operations of large pipeline networks
Gas-electric coordination	• Exchange of dynamic pricing data enables co-optimized operation of both infrastructures
Market design for intra-day gas trading	• Two-sided auction for trading hourly deviations from ratable schedules • Pipeline clears the auction subject to gas flow physics and engineering constraints using novel optimization methods
Gas price formation mechanism	• Dynamic Locational Trade Values of natural gas (LTV). Clearing mechanism sets *hourly* LTVs of natural gas at *each pipeline network node* • Prices are consistent with the physics of gas flow • Prices reflect pipeline engineering constraints
Delivery and price guarantee	• Gas delivery quantity, timing and prices are guaranteed for market cleared quantifies • Financially binding gas use schedules

Conclusions

- Advancement of the GECO project creates a unique opportunity to:
  - Optimize pipeline operation using economic criteria
  - Develop near real-time pricing of natural gas that is consistent with the real-time physics of gas flow in the pipeline
  - Efficiently coordinate the gas and electric networks through optimization methods and market signals based on locational prices for electricity and natural gas
- Realizing this opportunity is very important for both electric and gas industries

Thank you!

The GECO Team