Simulation Modeling of Coordinated Operation of Natural Gas and Electric Markets with GECO ENELYTIX

Presented at the FERC Technical Conference: Increasing Real-Time and Day-Ahead Market Efficiency and Enhancing Resilience through Improved Software

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Technical Expertise

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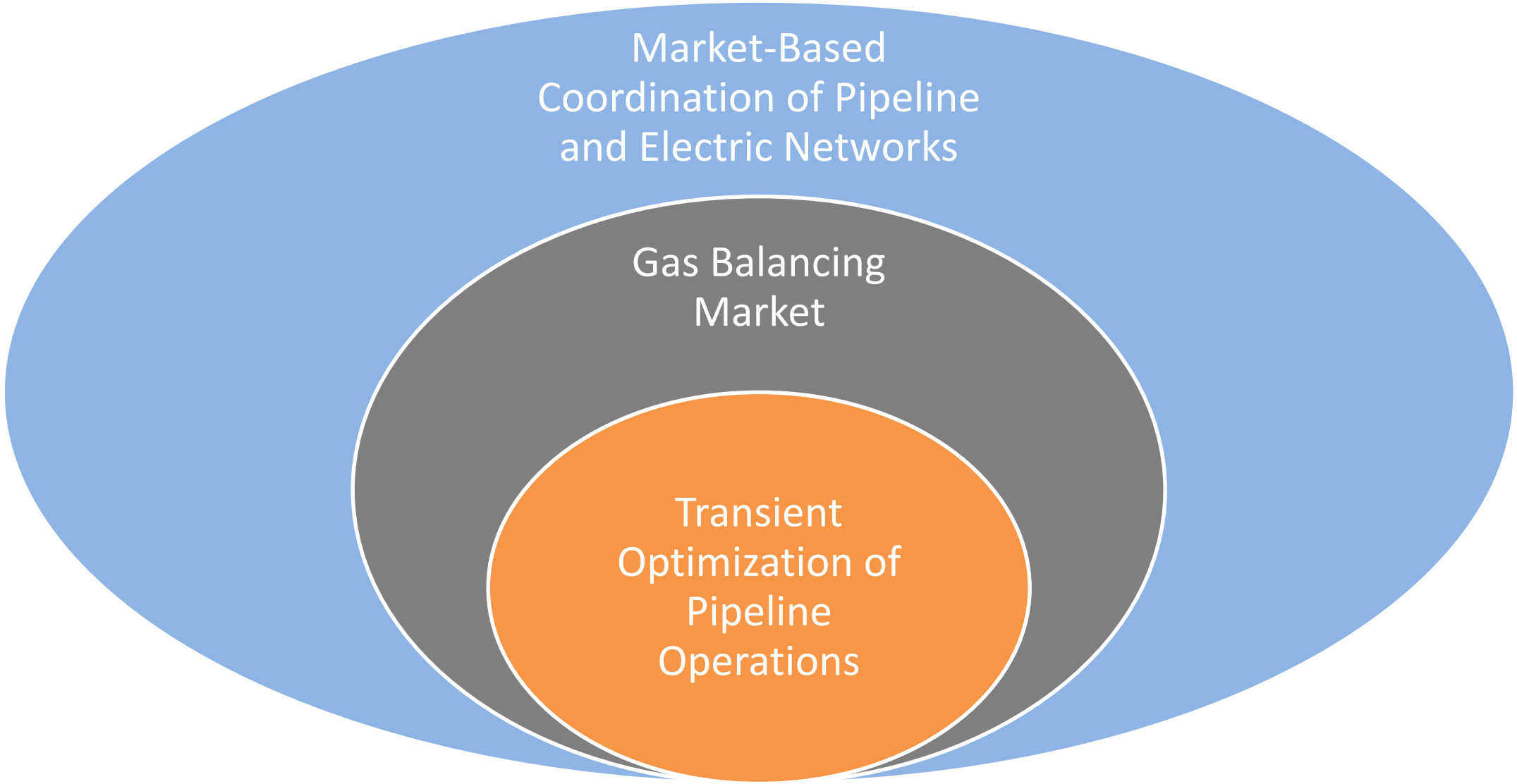
Outline

- Background and GECO Project
  - Transient optimization of pipeline operations
  - Gas Balancing Market
- GECO ENELYTIX – a System of Modeling Gas – Electric Interactions
- Numerical Experiments
  - Business as Usual
  - Gas Balancing Market Implementation
  - Benefit Assessment
- Conclusions

GECO Project Summary

- 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
- 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. Now extended through summer of 2019
- ARPA-E project summary: https://arpa-e.energy.gov/?q=slick-sheet-project/gas-electric-co-optimization

The GECO Approach



Transient Optimization

Economic Optimization of Pipeline Operation: a Conceptual Formulation

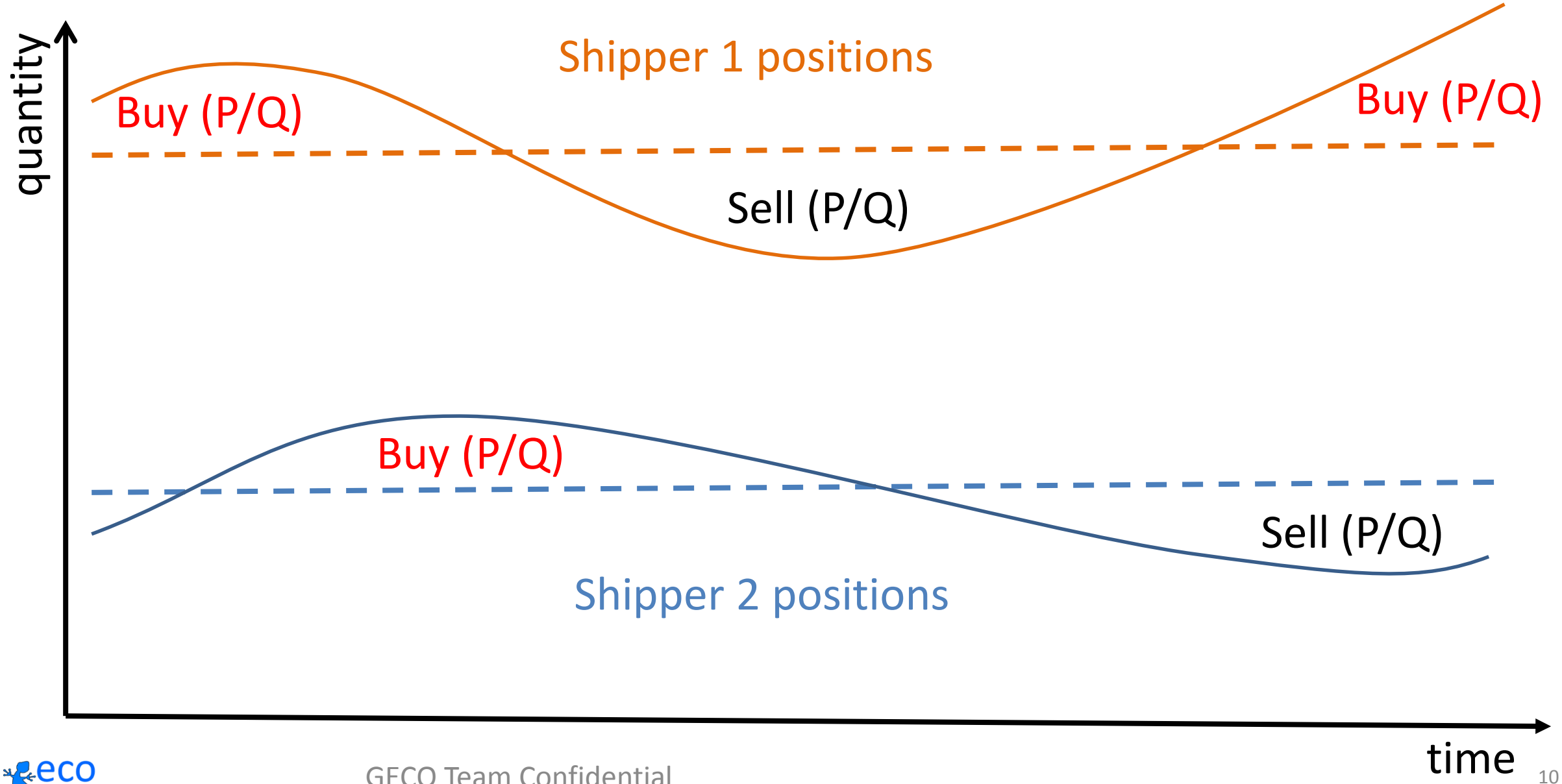
- A two-sided auction
- Conducted on gas pipeline network subject to engineering constraints
- Participants: buyers and sellers of gas submitting Price/Quantity (P/Q) offers/bids
- Offers and bids are node-specific, with hourly time step for an optimization horizon (e.g., 36 hours)
- Auctioneer's objective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

Locational Trade Values of Natural Gas

- Auction clearing will produce Locational Trade Values (LTVs) of natural gas as shadow prices of nodal flow balance
- LTVs are highly granular:
  - any node
  - hourly or sub-hourly time step
- LTVs are fully consistent with the physics of gas flow and the pipeline engineering constraints
- Transacting parties could have a guarantee of gas delivery at settled prices

Gas Balancing Market

Gas Balancing Market will trade deviations from ratable schedules



High Level Overview of the 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

GBM 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

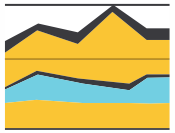
GECO ENELYTIX

GECO ENELYTIX system consists of:

Power market simulation engine *Power System Optimizer* (PSO) by Polaris.

Gas System Optimizer by Los Alamos National Laboratory

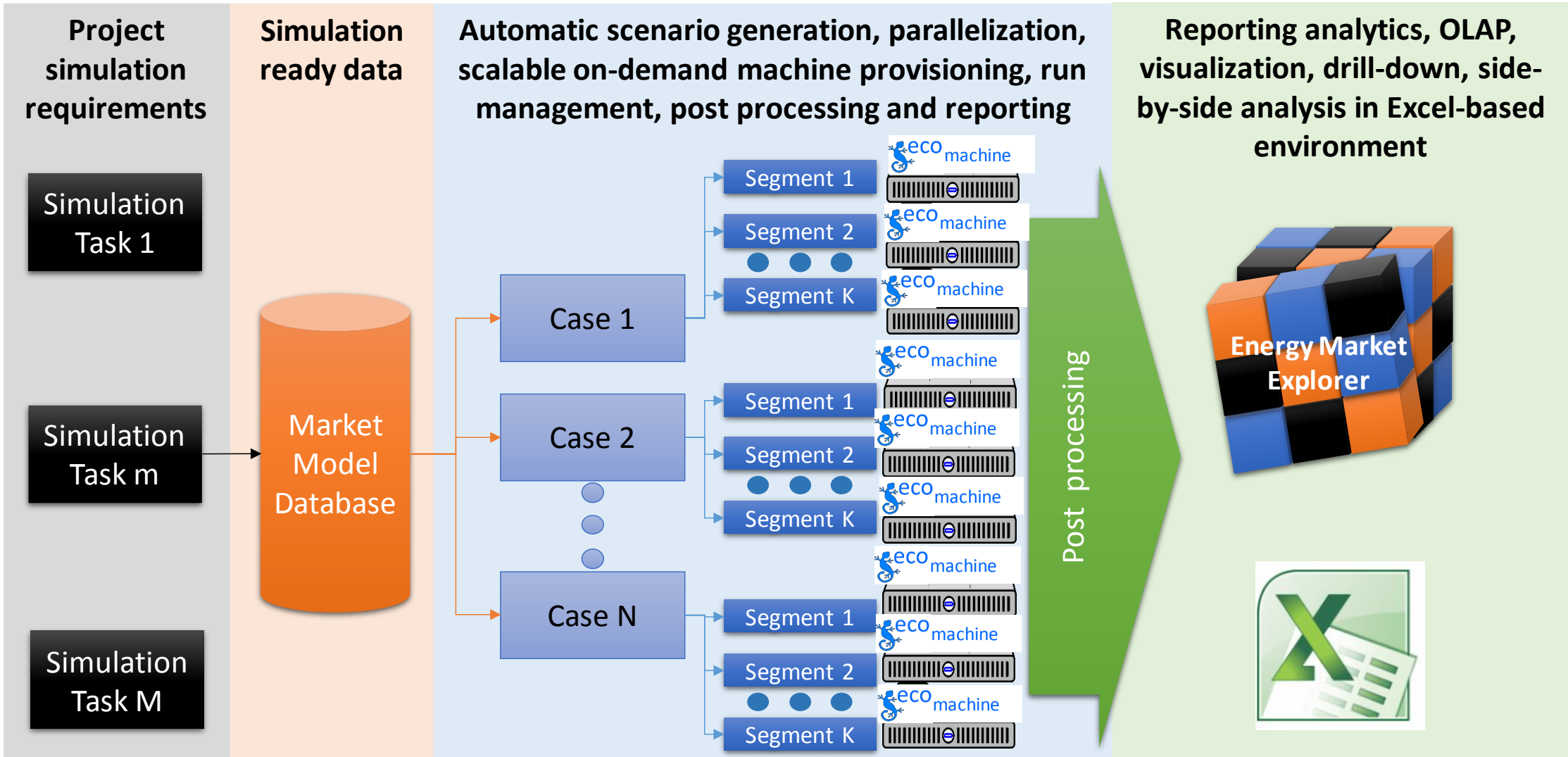
Scalable and flexible cloud-based architecture for massive on- demand parallel execution.
Private cloud for each customer implemented in AWS



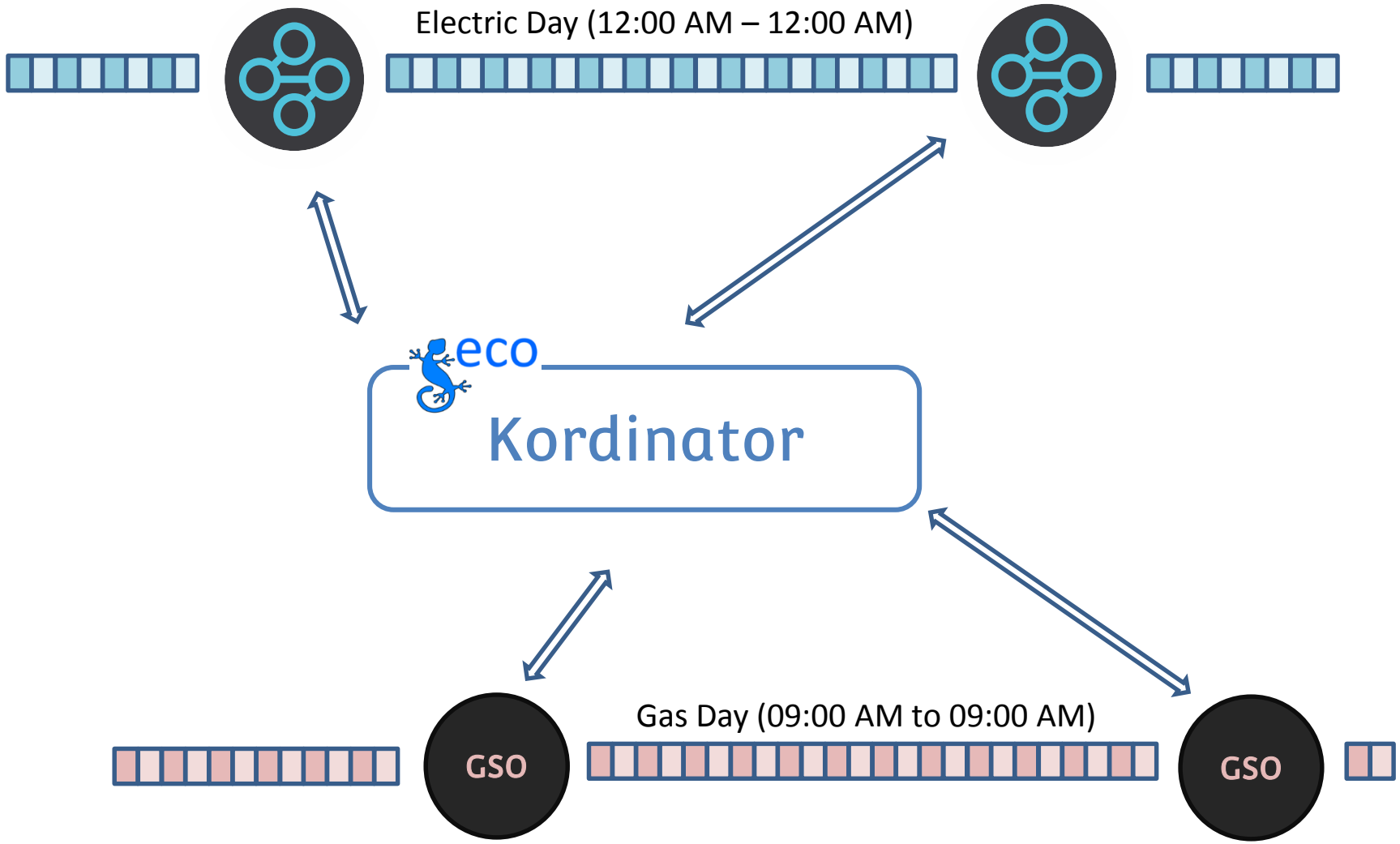
Efficient self service Business Intelligence: user defined reports to explore simulation results visually and dynamically

Benchmarked and vetted datasets of electric data assembled by modeling experts from public sources

Schematic Architecture of GECO ENELYTIX



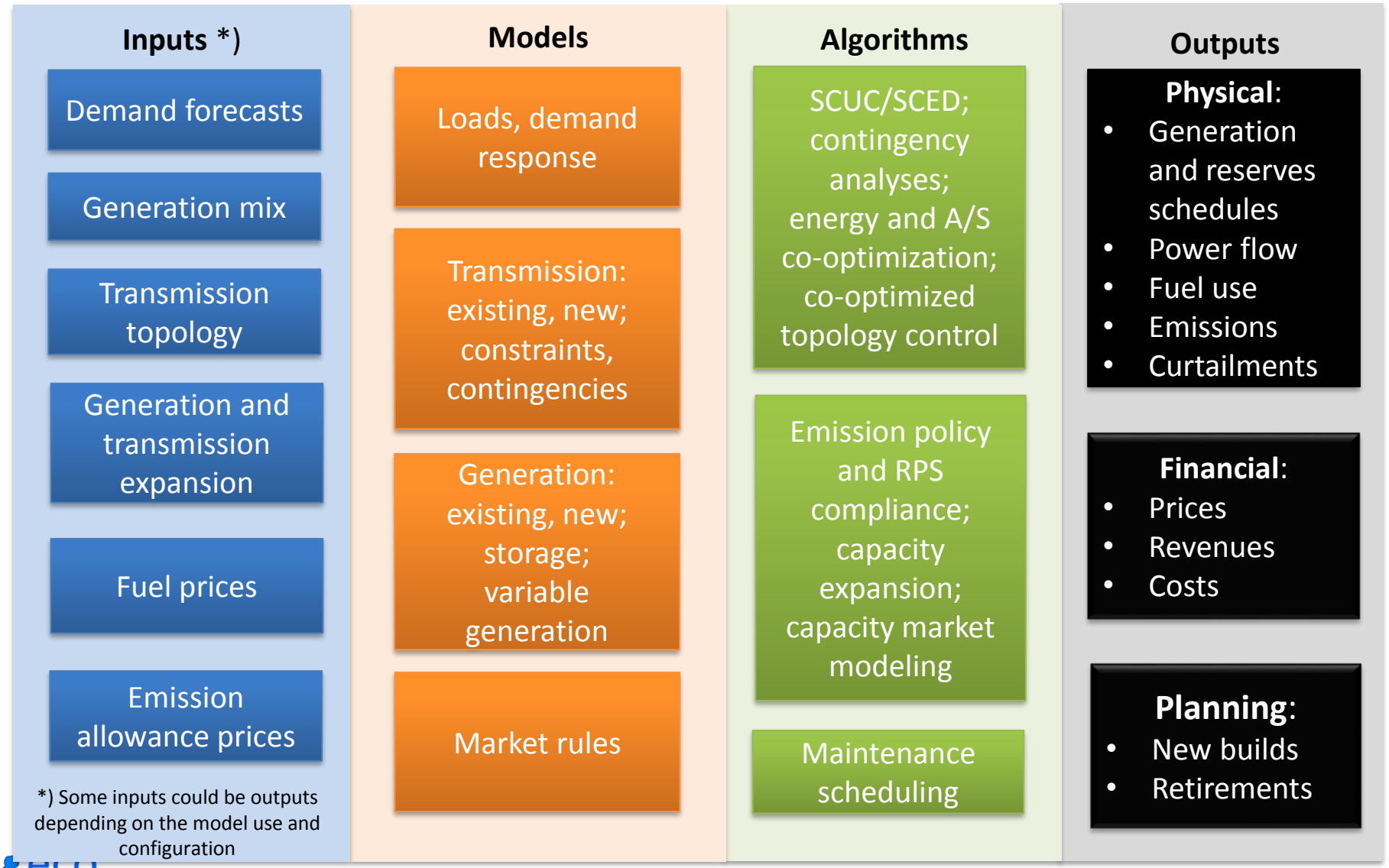
The GECO Machine



eco

Solution Overview: PSO, ENELYTIX Simulation Engine

PSO has features and capabilities of all other similar models



… and unique capabilities

- as a production costing modeling tool

and

- as a system expansion modeling tool

Gas System Optimizer (GSO)

Transient pipeline optimization solver by LANL

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:

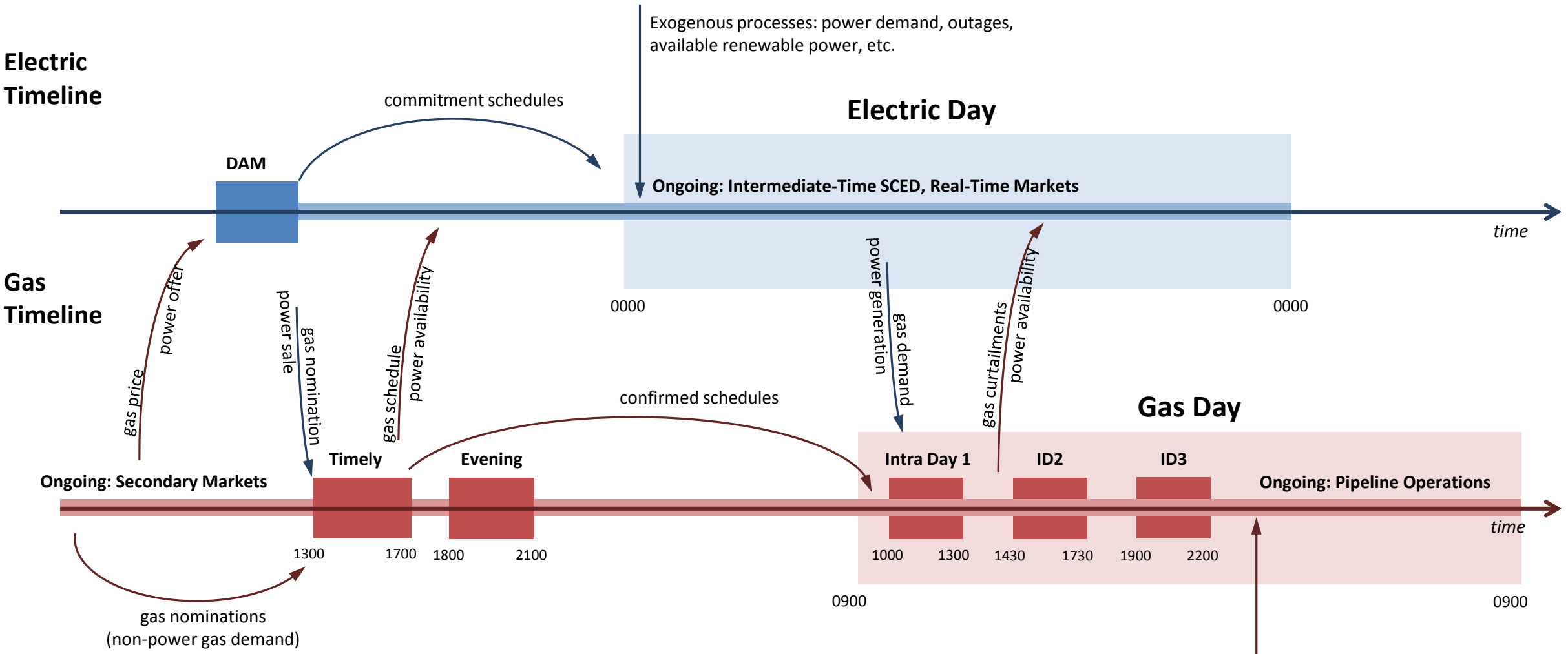
- Gas flow and pressure dynamics
- Compress details
- Delivery and curtailments

Dual/Financial:

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

Gas Electric Co-Ordination with GBM

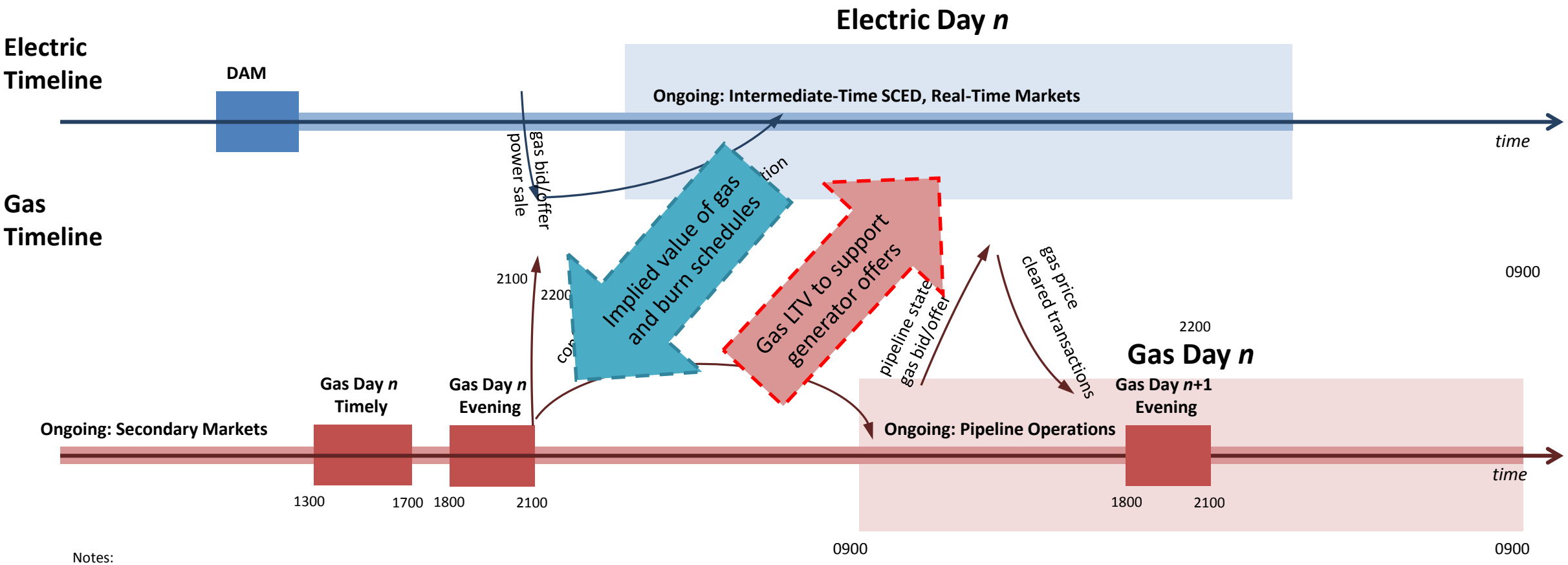
Current Parallel Operations of Natural Gas and Electric Markets



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.

Value (price) based Intra-day coordination of gas and electric systems



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- All times are in Central prevailing time.
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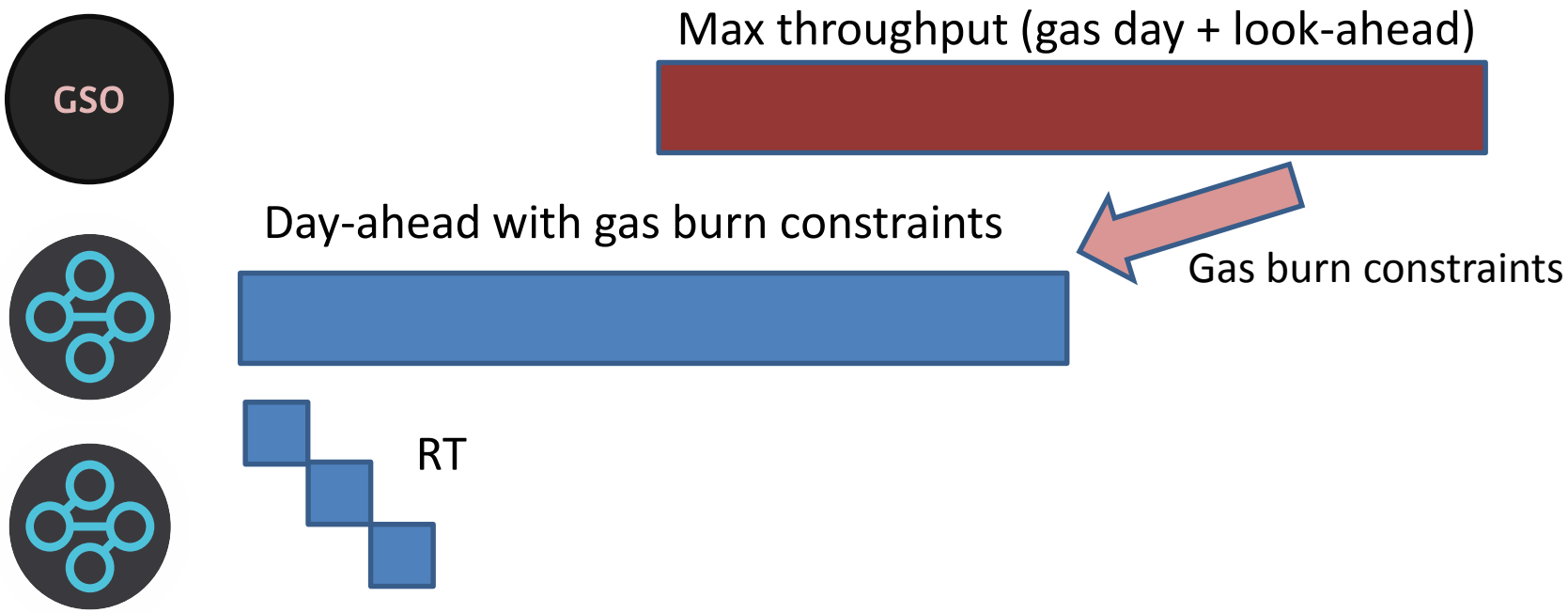
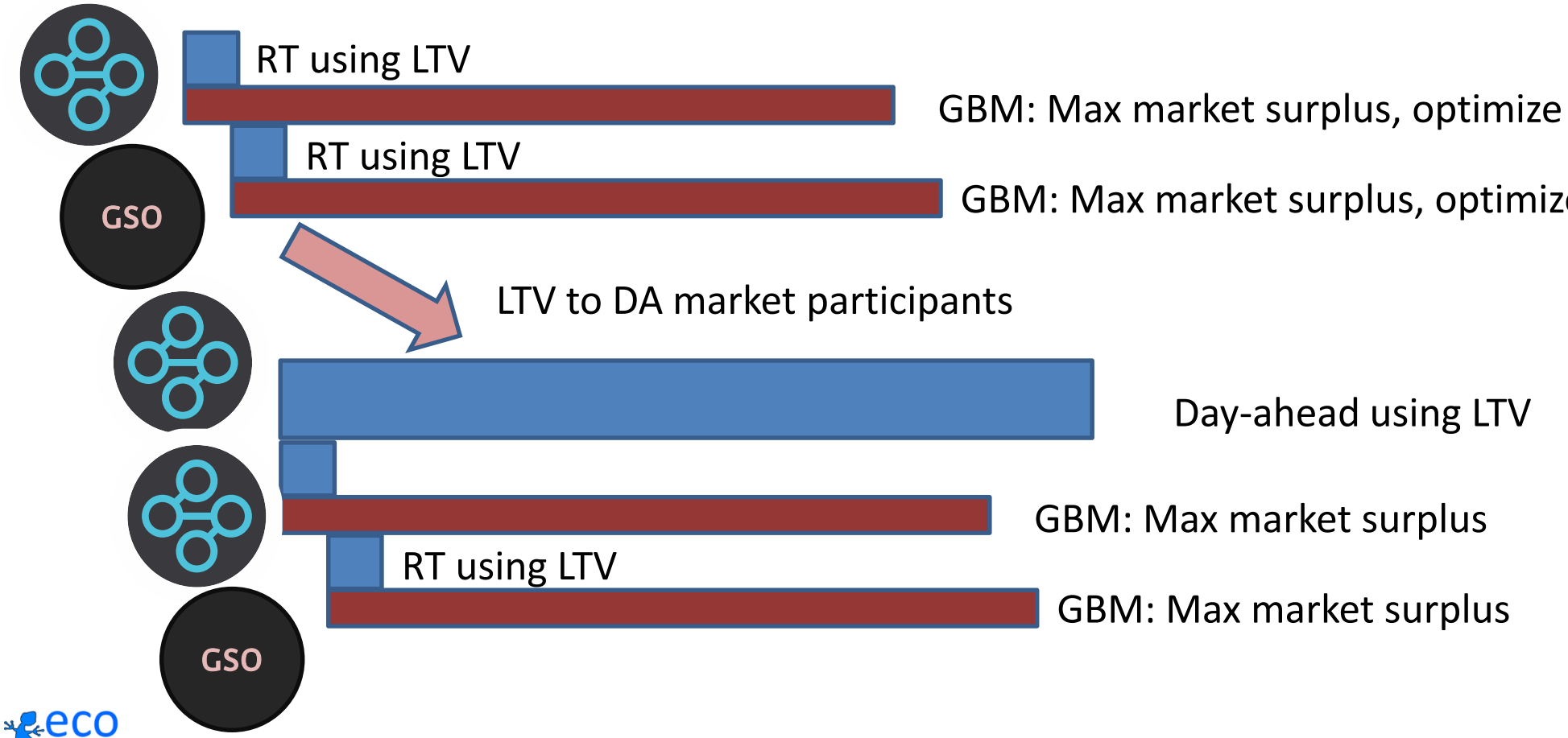
- Business as Usual Description
  - Indicative day-ahead gas procurement by generators
  - Generators schedule output and gas burn day-ahead
  - Generators schedule/confirm gas deliveries with pipeline
  - Generators burn gas and produce power in real-time



- Interactions of DA and RT with GBM
  - GBM interacts with RT but it has long look-ahead
  - GBM look-ahead provides hourly price discovery for DA



Modeled GBM horizon of 48 hours
Clearing scenarios
- Every hour
- Every 4 hours
- Every 12 hours

Simulation Experiments

Gas – Electric Model Used

- Electric System
  - Large electrical system with over 50 GW of peak demand
  - Used ENELYTYX nodal dataset representing that system during February 2014 (Polar Vortex)
  - PSO results benchmarked to historical data in terms of replicating actual generation and LMPs
- Natural Gas System (data provided by Kinder Morgan)
  - A segment of actual pipeline network (over 400 miles of pipes, 4 compressor stations)
  - Historical data for February 2014 (Polar Vortex)
  - GSO modeling benchmarked against SCADA data provided
  - Modeling of that segment of the pipeline system was described in our presentation in 2018
- Gas Electric Intersection
  - 3 CCGT plants directly served by the pipeline segment modeled (1% of thermal capacity, 1.7% of gas capacity)
  - 3 more CCGT plants located downstream (together 3% thermal, 4.7% of gas capacity)

Summary of Results

- Gas price impact for GBM participants
  - Depending on the location GBM participants would see 3% to 12% in gas price reduction from the actual day-ahead zonal index paid
  - Participating generators see increase in operating margin by 45% - 380% depending on the location
  - **With just 3 units trading in GBM, most of the instantaneous congestion in that pipeline segment could have been eliminated**
- With 3 units in GBM (1% of thermal capacity), we did not observe significant impact on the electricity market – the change it too small to produce differences outside of the MIP Gap
- With 6 units in GBM (3% of thermal capacity), we observed reductions in production costs and prices
  - System-wide RT production costs reduced by 2.2% to 2.8%
  - Reduction in LMPs within the zone where most of the affected capacity is located by 2.1% - 2.3%

Conclusions

- Adoption of transient optimization and implementation of market-based intra-day coordination mechanism would benefit both gas and electric industry
- Transient optimization should become a standard tool used by the pipeline industry. This is just “good utility practice”
- FERC should provide an incentive mechanism to pipelines to expedite adoption of transient optimization and adoption of transparent and liquid market for intra-day trading
- Electric industry needs models like GECO ENELYTIX for planning studies, reliability assessment, integration of renewables, market design and other applications. These models need gas industry data. Data sets could be developed with sufficient funding

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