Evolution of North American Gas & Power in the Post-Obama Era

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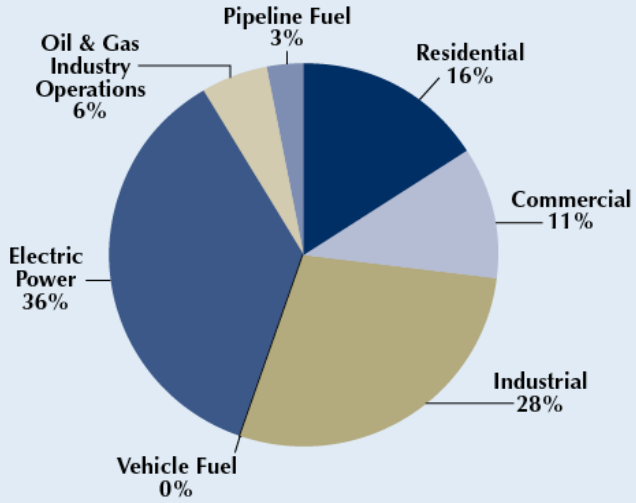
Presentation Overview

- Electric power generation is becoming increasingly dependent on natural gas
- But these two markets are usually modelled separately and employ only simplistic exogenous assumptions about each other
- The authors have developed a workable methodology which combines proven gas and power market models into a unified system.
- This combined system is designed to produce realistic and mutually consistent forecasts which satisfy the unique characteristics and constraints of both markets
- This presentation describes the use of this modeling approach to address an important question:
  - How effective would the Federal Clean Power Plan be in achieving significant reductions in greenhouse gas emissions compared with the plans of the individual US states alone?

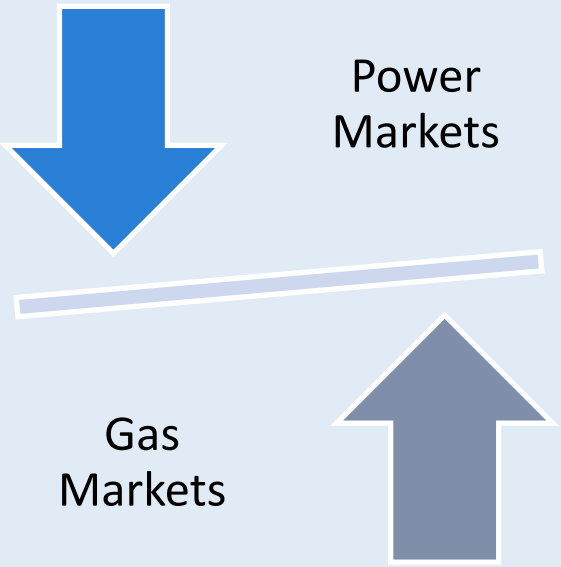
Gas is tied increasingly to power



- Electricity generation is now the largest NG consumer in the US
- In 2016 NG surpassed coal as the dominant fuel used in generation

- Policy changes affecting one market have ramifications on the other that are not straightforward to outline

- Traditional modeling approaches don't do justice to their complex interdependence



What's being missed by modeling gas and power separately?

- Power models ignore gas infrastructure and non-generation demand
  - Pipeline constraints and expansions, storage, LNG imports and exports, growth or decline in other consuming sectors
- Gas models ignore power market infrastructure, regulation, trends
  - Transmission constraints, emissions regulations, renewables growth, coal and nuclear plant retirements
- For the long-term, models must also be "dynamic" not "static":
  - A combination gas-power model must include running both models in "capacity expansion" mode
  - Changes in forecast of gas prices and gas demand affects both gas and power infrastructure build-out

Potential integrated modeling schemes

Gas and Power Super Model

- One model that accounts for both markets
  Major Drawback: Complexity

Reduced Form Model

- Regression equations for gas in a power model
  Major Drawback: Rapid obsolescence of regressions

Combined Modeling System

- Iterate between highly granular, industry standard gas & power models to find mutually consistent solution

Selected modeling approach

Combined modeling system

- Iterate between highly granular, industry standard gas & power models to find mutually consistent solution
- Major advantage: a great starting point in leveraging the capabilities of existing well-calibrated models
- But we need to prove the feasibility of the combined approach
- And we need to see whether it is practical, i.e. is the performance of the combined system “good enough”

Market models used in this study

GPCM®

- RBAC, Inc.,
- First released in 1997
- Used by over 35 energy industry consultancies and firms, FERC, MISO, and NEB of Canada

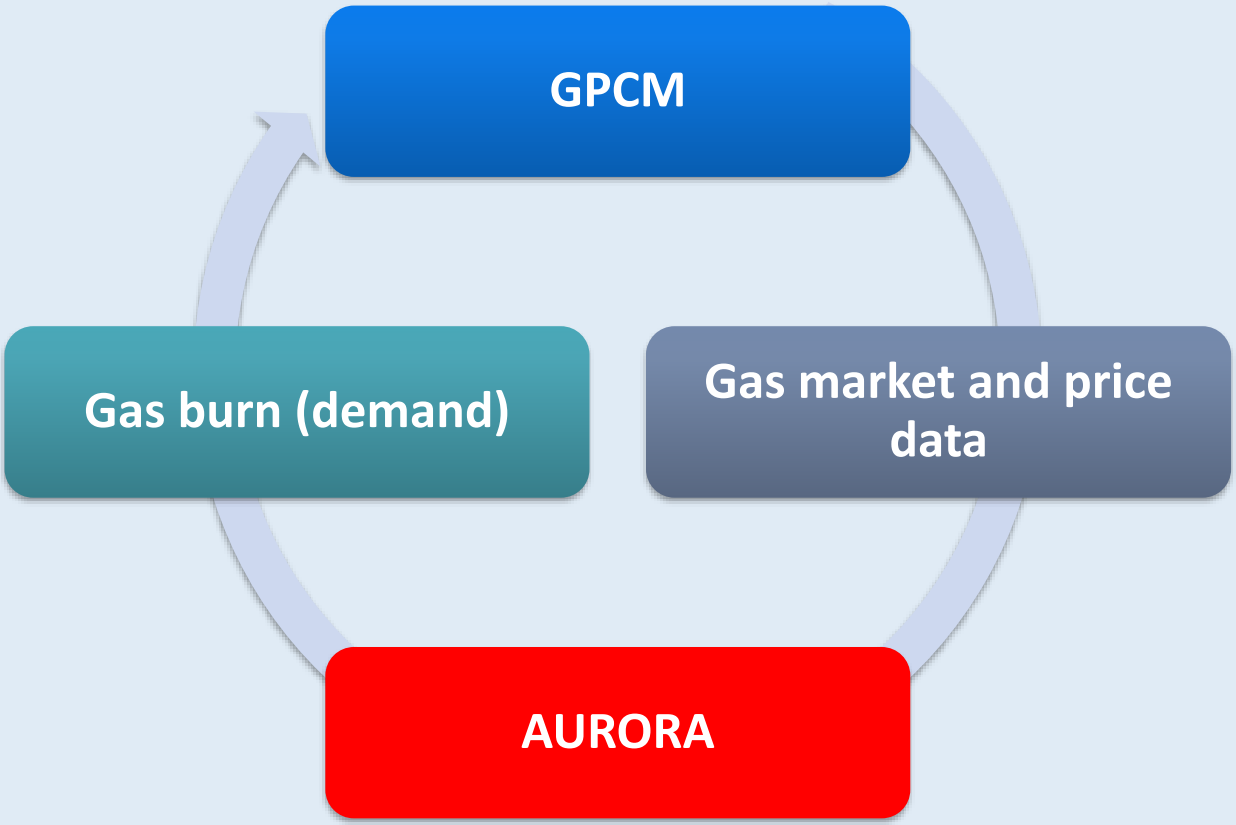
AURORA®

- EPIS, LLC.,
- First released in 1997
- Used by over 90 energy companies in North And Latin America, Europe, Asia and the Middle East

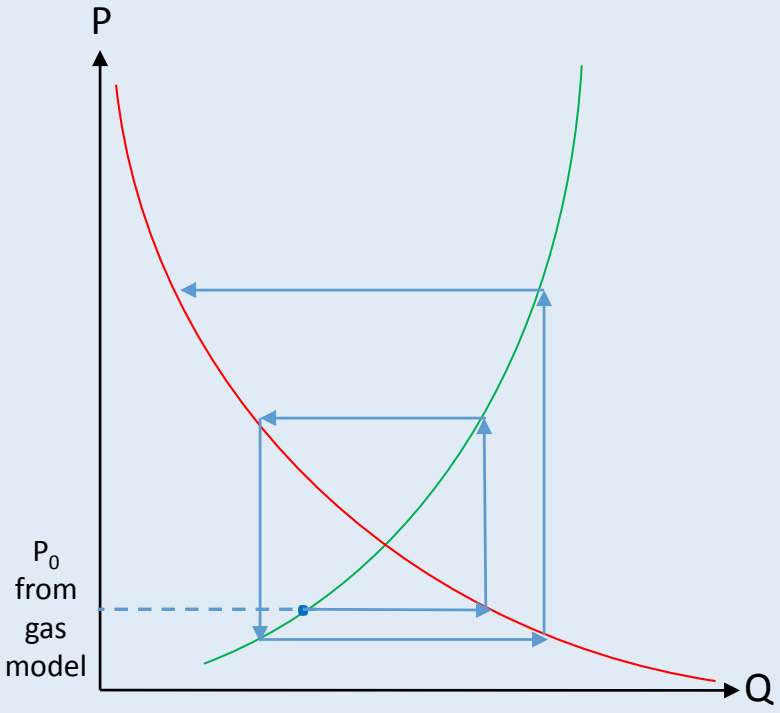
GPCM is a registered trademark of RT7K, LLC.

AURORA is a registered trademark of EPIS, LLC.

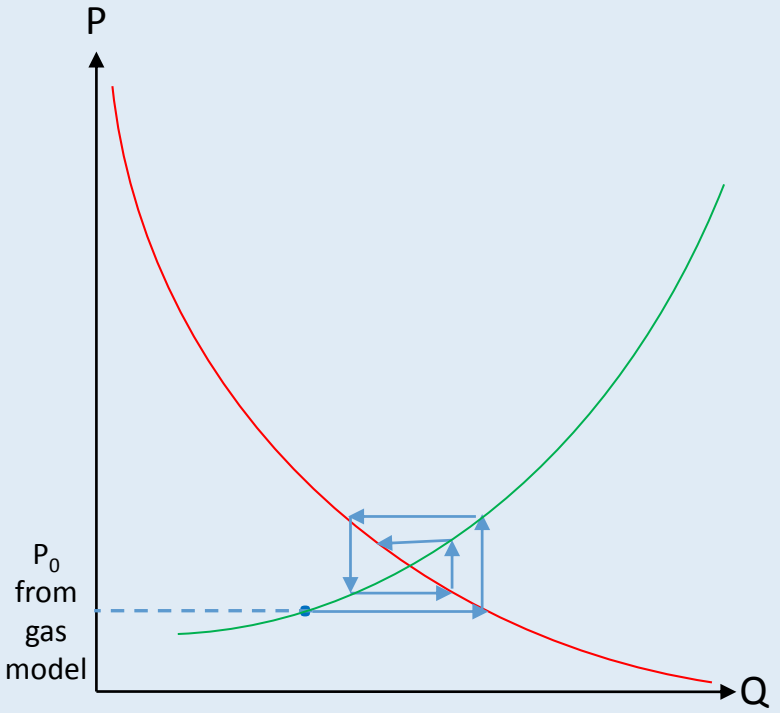
Can GPCM and AURORA work together?



Will an iterative process converge?



Divergent Case: $|E_D| > |E_S|$



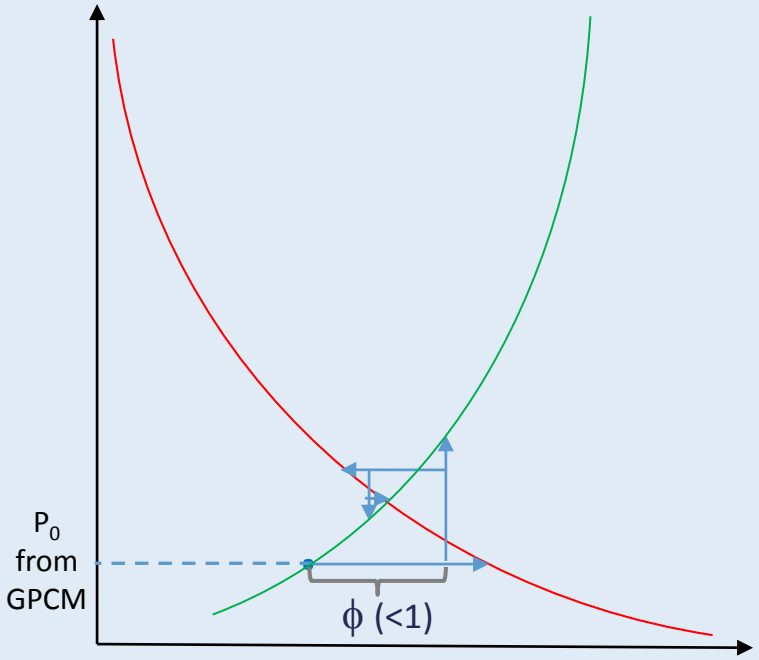
Convergent Case: $|E_D| < |E_S|$

Note the similarity to the "Cobweb Model" from Econ 101

Iterative processes

- Analogy to cobweb models
  - Initial price from supply model (GPCM) used to compute point on demand curve (AURORA)
  - This demand is then used to compute a new price on the supply curve which results in a different demand
  - This procedure is iterated until either it converges, diverges, or obtains a stable alternating state
- But can we force convergence using a modified procedure?

Exponential weighting is analogous to a "Modified Cobweb Model"



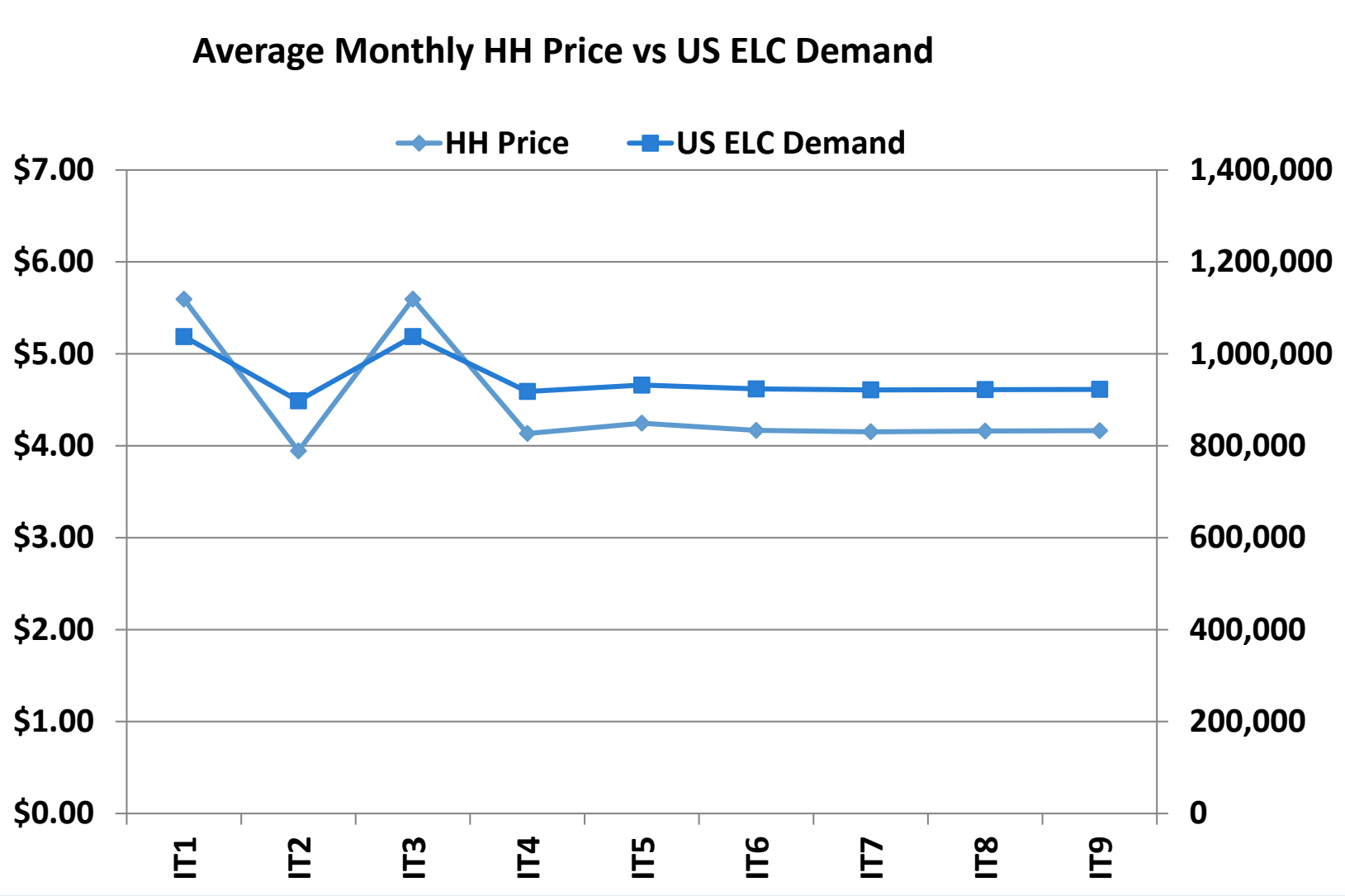
Divergent Case: $|E_D|>|E_S|$

By stepping only a fraction ϕ of the distance to the S or D curve, can we force convergence even when $|E_D|>|E_S|$?

Previous results

- Application to North American market
  - Convergence achieved using the modified cobweb approach in 2015
  - Results presented at the World Gas Conference, Paris, June 2015
- Application to European market
  - Similar results obtained using G2M2® Global Gas Market Model with AURORA for Europe in 2016
  - Presented at the 5th Electricity Price Forecasting & Market Coupling Conference, Amsterdam, Jan 2017

Iterative algorithm leads to convergence



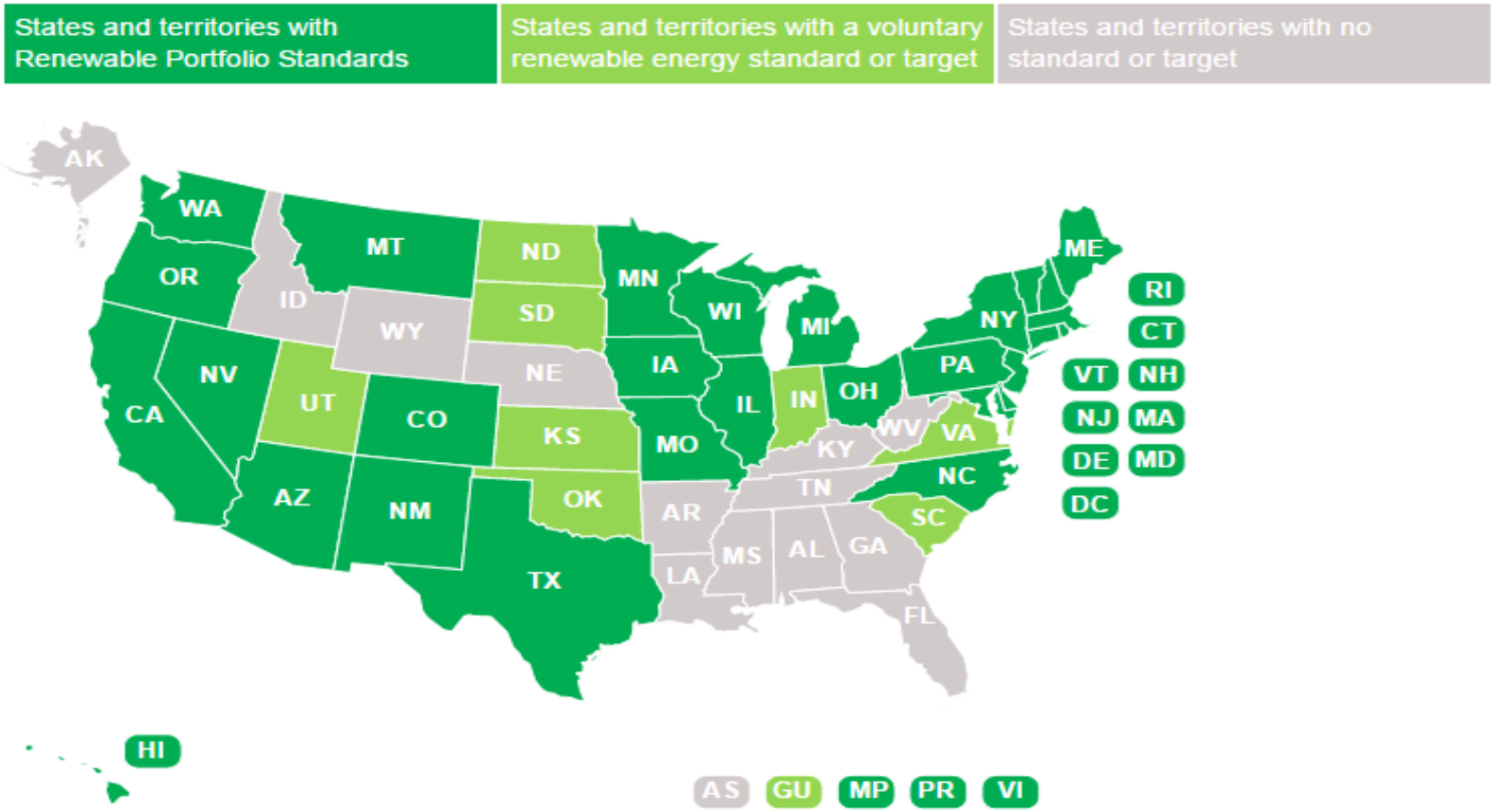
Policy Evaluation using Integrated Gas-Power Modeling Framework

- The Clean Power Plan (CPP) was the hallmark clean energy program of the Obama Administration
- But state governments had designed their own plans well before Obama
  - Renewable Portfolio Standards (RPS)
- How much actual effect could be expected due to implementation of the CPP in addition to the already existing RPS programs?
- We used the RBAC-EPIS integrated gas & power modeling framework to address this question

The Clean Power Plan

- Clean Power Plan was legislation from the Obama Environmental Protection Agency aimed at limiting carbon pollution from power generation
- States would have various options to meet the reduction goal
  - A rate-based state goal measured in lb./MWh;
  - A mass-based state goal measured in total tons of CO2;
  - A mass-based state goal with a new source complement measured in total short tons of CO2.
- States were allowed to group together and/or form emission trading markets
- In 2016 the Supreme Court stayed the legislation while the judiciary deliberated on CPP's merits and legality.
- In 2017 the Trump EPA filed a motion to repeal the CPP.
- But many analysts ask "Will it really matter?"

Renewable Portfolio Standards



- Some state legislatures have set (legally binding) targets for renewables, others have set voluntary ones
- Policy sets out a wide range of incentives for renewable capacity expansion

Understanding Impact of CPP

- There is a general expectation that an expansion in natural gas fired power generation will be needed if CPP or other national carbon policy becomes binding

- RPS compliance helps with CPP compliance, but not necessarily vice-versa!

- All of this makes for a very complicated set of interacting legislation and regulation that affects power and gas markets
  - Proper modeling is crucial, especially in a deregulated setting

Integrated Gas-Power Modeling

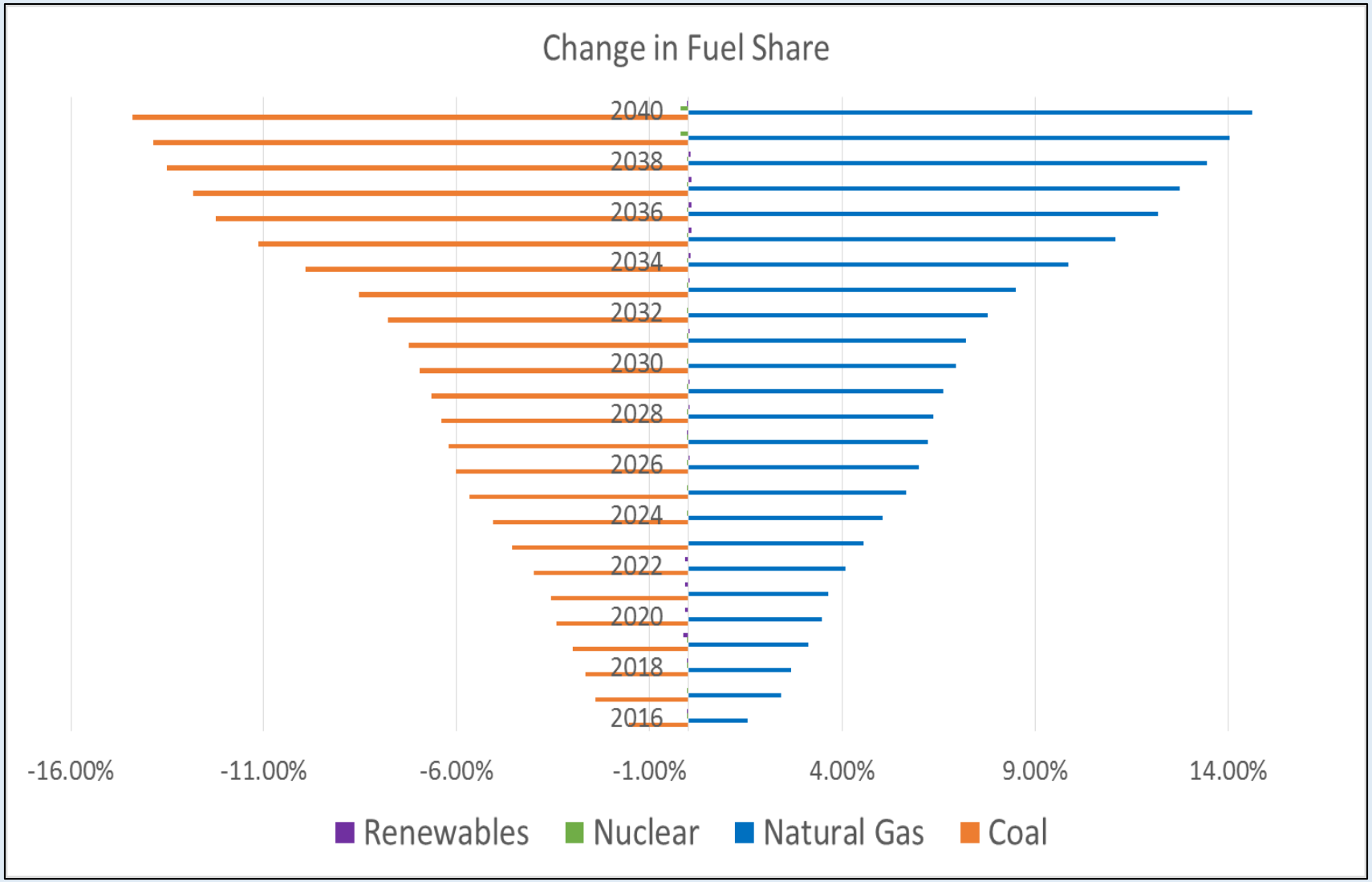
- The integrated GPCM-AURORA framework can be used a tool for evaluating the impact of CPP.
- We can *control* for various regulations and market scenarios and isolate the impact of a regulations like CPP and RPS.

- For example,
  - How will fuel usage change with both CPP and RPS compared to a scenario with neither CPP nor RPS?
  - Is RPS necessary for renewable expansion?
  - What is impact of CPP on locational gas demand, gas prices, power prices, etc.?
  - and others similar questions…

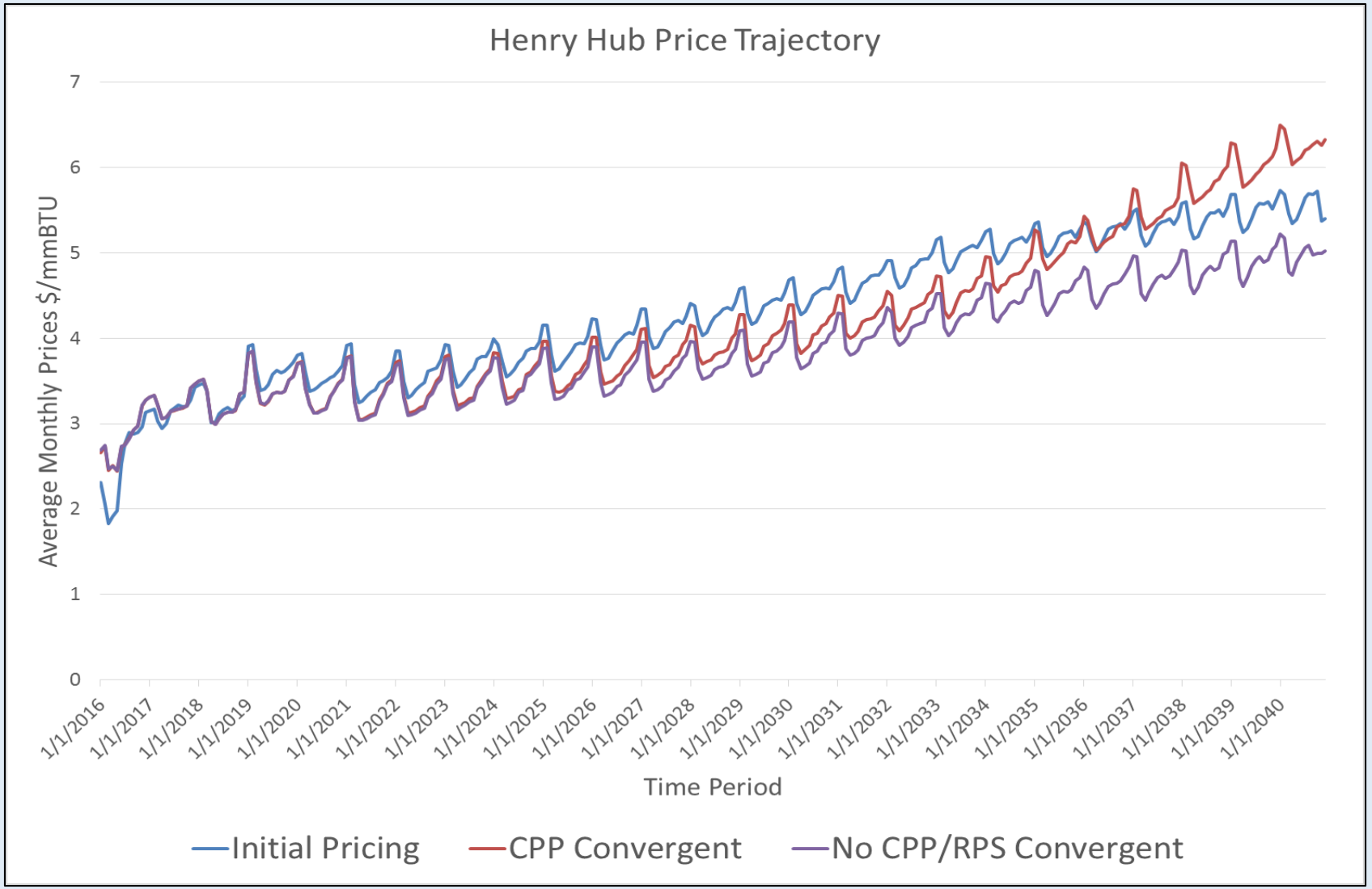
Study Scenario: CPP vs No-CPP

- Clean Power Plan specs
  - Mass-Based New Source Complement target
  - Targets derived based on EPA estimates
  - Starts in 2022, progressively more binding till 2030
  - States independently meet their targets
- State level RPS plans enforced in both scenarios
  - Targets based on each state's legislation
- Study objective
  - Quantify the incremental impact of the CPP on power market investments and gas prices while enforcing the RPS
- Forecast Horizon: Jan-2017 to Dec-2040 (monthly)
- High gas supply scenario

Power Capacity Expansion



Impact on Gas Prices



Integrated Model Application Results

- CPP produces significant changes in the fuel mix
  - By 2040 natural gas fueled generation increases by 15% as the expense of coal
  - But we see no significant change in generation by renewables
  - Higher gas demand in generation results in a significant increase in natural gas prices
- Renewables do not grow beyond RPS legislation mandate
- In summary, the CPP stimulates the on-going switch from coal to natural gas in power generation
  - But it **does not** increase market penetration of renewables beyond that generated by the state Renewable Portfolio Standards by themselves

Questions?

Thank you!

Any questions?

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About RBAC

RBAC Inc. licenses economic forecasting tools the energy industry, as well as State and Federal government agencies involved with Energy, Transportation and the Environment. RBAC's principal products include the industry standard GPCM® Natural Gas Market Forecasting System™, the GPCM® Base Case Database for North America, and GPCM Viewpoints® on Natural Gas.

We continuously advance our modeling tools through technology, feature development and regularly released updates based on client requests and energy industry needs. Those needs resulted in our development of RBAC's North American Natural Gas Liquids Model (NGL-NA™) and GPCM Daily™.

Additional forecasting tools scheduled for release include:

- G2M2® Global Gas Market Modeling System .NET Ver. 3.5
- GPCM® for MS-SQL

Licensees of RBAC's systems are involved in natural gas exploration and production, LNG infrastructure development and marketing, natural gas marketing and transportation, electric power generation, natural gas distribution, and commodities trading, as well as most of the major consulting firms that service business and planning needs of the energy industry and its bankers.

Dr. Robert Brooks founded RBAC in 1987 based on experience developing several well respected predictive models since his first work on his doctoral research in natural gas transportation economics at MIT in the 70's.

Designing forecasting tools for global energy market prices, basis, and flows is RBAC's core business.

RBAC's staff includes experts in natural gas supply, demand, marketing and transportation as well as the dynamic global pipeline and LNG markets. Our team applies its world class expertise in mathematical modeling, statistical analysis, mathematical algorithm development, software engineering, and database design to current and future challenges, risks and opportunities in energy.