Natural Gas Transmission and Distribution Module Component Design Report

Discussion of model design

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Background

- **Gas Analysis Modeling System (GAMS)** – LP, annual, 300 demand nodes, 17 pipeline systems (modeled transactions (e.g., contracts)) – *unwieldy to manage*

- **NGTDMv1** – LP, 12 regions and Canada, 2 seasons, firm and interruptible flows, separate capacity planning module – *overly constrained to force to align with history, shadow prices do not reflect market prices*

- **NGTDMv2** – Heuristic, acyclic hierarchical network, 12 regions and Canada, 2 seasons, build as needed, change from lagged values, – *tie to history too constraining*
General approach

• **Nonlinear optimizer (NLP)**
  – *Max consumer plus producer surplus minus variable transportation costs, s.t. mass balance constraints*
  – *Output volumes and flows and marginal prices (fixed charges not reflected)*

• **Pricing Submodule**
  – *NLP flows used to create hierarchical network*
  – *Trace prices through network adding reservation fees*
  – *Determine regional delivered prices*
Regional and sectoral detail

• *Hub in each state*
  – *Some production represented at substate*
• *Limited international nodes*
• *Three seasons (user option to run monthly)*
• *Additional runs for peak periods to determine pipeline capacity expansion*
Benchmarking

- **Run model in historical years**
  - Determine benchmark factors
  - Fill in missing data

- **STEO**
  - NGTDM results must be within 2% of STEO
  - Run NGTDM multiple times to achieve STEO convergence
  - Phase out benchmark factors over forecast years
Demand

• *Disaggregate annual sectoral levels from NEMS into state and season*
  – Residential, commercial, industrial function of population and HDD
  – Electric sector function of population and cooling degree days
  – *Fixed consumption in NGTDM (option to include curves)*
Demand (cont)

- Alaska/Hawaii - separate submodule, same as current NGTDM

- Discrepancy (balancing item)
  - Determined in routine which fills in missing historical values
  - Held constant throughout forecast

- Lease and Plant Fuel
  - Assume lease plus plant fuel is a percentage of dry gas production
  - Special handling for plant fuel in Illinois to process wet gas
Demand - pipeline fuel use

- Derive use factor for each pipeline segment in the model based on historical data
- Possible to change factor or hold constant throughout forecast
- Impact of penetration of electric compressor stations (?)
Imports and exports

- **Ultimate goal is to represent Canada and Mexico with same level of detail as U.S. and consistent with GHSM**
- **Project LNG imports and exports**
- **LNG imports set at a minimum level into New England in most cases**
- **Canada divided into east and west regions**
  - Consumption based on IEO but responsive to world oil prices
  - Eastern production fixed, Western production price responsive
  - Some data items will be derived or assumed (storage, monthly consumption, historical prices and flows)
- **Mexico**
  - LNG imports and consumption set exogenously and fixed
  - Production varies with deviations of the projected Henry Hub price
Fixed supply

- Associated-dissolved domestic production (from OGSM)
- Eastern Canada production
- LNG imports (?)
- Mexico imports
- Alaska production
- Supplemental supplies
- Model will have allow for an option of using a supply curve instead of fixed supply
Price responsive supply

- Primarily nonassociated dry gas production
- Curve is based on expected production \((p_0,q_0)\) from OGSM
- Change in production is less responsive at volumes above \((p_0,q_0)\) and more responsive below \((p_0,q_0)\)
Price responsive supply (cont.)

- Piece-wise linear
- OGSM county level summed to state, but annual
- Need seasonal or monthly in NGTDM
  - Option 1 Use annual curve
    - Mass balance would force monthly/seasonal production to sum to the annual production on the curve
    - Supply price in each month would be the same (exclusive of gathering charge)
  - Option 2 Define curve for each time period by scaling
    - $P_0$ set at the price from previous year
    - Result may not be on annual supply curve
Storage

- **Key assumptions**
  - Weather is normal
  - Annual net storage withdrawals are zero except for STEO years
  - Storage decisions are not purely economic
  - Not trying to model storage decisions – just account for storage use and cost

- Storage will be set outside of NLP and included as fixed supply/demand

- Net storage for each month based on previous year
  - Deviation of the monthly consumption minus monthly supply from the corresponding average monthly level for the year
  - Allocate across regions/states (based on data analysis)
  - Cost added to price paid by end-users, potentially
Pipeline tariffs

- Based on difference between region/state spot prices and difference in citygate prices
- Components of basis differentials
  - Pipeline fuel charge
  - Variable Tariff
  - Fixed charges
- Assumptions
  - Differences in spot charges are pipeline and variable charges
  - Difference between spot and citygate prices are the fixed charges
Pipeline tariffs (cont.)

- **Historical values set using:**
  
  \[
  \text{pipeline fuel charge} \left( \frac{\$}{Mcf} \right) = \text{Spot}_A \times \left( \frac{1}{1-\% \text{loss}} - 1 \right)
  \]
  
  \[
  \text{variable charges (\$/Mcf)} = \text{Spot}_B - \frac{\text{Spot}_A}{1-\% \text{loss}}
  \]

  \[
  \text{AnnualFixedCharge (\$)} = \sum_{\text{month}} \left( ((\text{Citygate}_B - \text{Citygate}_A) - (\text{Spot}_B - \text{Spot}_A)) \times \text{associated flow into B} \right)
  \]

- **Variable tariff set in the NLP using a curve for each arc**
- **Variable tariff function of pipeline utilization**
- **Curve held constant throughout forecast**
- **Tariff curves based on flow one direction will be assumed to be the same for flow in opposite direction**
Pipeline expansion

• Initial years set to capacity under construction and highly likely to be constructed
• Later years determined by running NLP for colder than normal day and a hotter than normal day
• Tariff curve extended to include reservation fee (assuming a utilization rate) and a hurdle rate for adding capacity beyond current forecast levels
• If capacity is added, it is included in model run for that year and fixed charges are increased
Pricing submodule

- Used to add fixed charges to the spot prices to determine citygate price
- Use flows from NLP to create hierarchical acyclic network
  - Flow gas through the network and add fixed charges
  - Flow down the network to determine flow associated with consumers paying fixed charges
  - Flow up network adding the fixed charges
Hierarchical network example
Delivered prices

• Apply distributor tariffs to wholesale prices
• Residential and commercial and some industrial are firm customers with price based off citygate
• Other sectors priced based off spot price
• Options for setting delivered prices
  – Estimate distributor tariffs based on volumes (e.g., consumption per household), add to wholesale prices
  – Estimate distributor tariffs based on volumes and wholesale prices (if statistically significant), add to wholesale prices
  – Directly set as a function of wholesale prices and other variables
Primary outputs

- Average annual delivered prices by sector and Census Division, except electric generators (2-3 seasons, 18 regions)
- Prices – to producers, import/export, citygate, and spot
- Nonassociated dry gas production by state/substate
- Supplemental supplies by Census Division
- Imports/exports – pipeline (Canada, Mexico) and LNG
  – Production in Canada and Mexico
- Interregional flows
- Interregional pipeline capacity (and possibly expenditures)