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

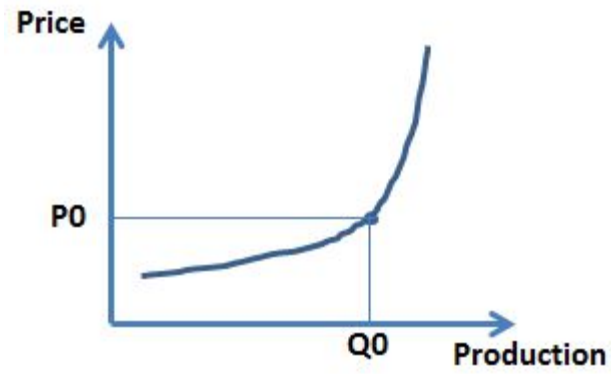
- *Ultimate goal is to represent Canada and Mexico with same level of detail as U.S. and consistent with GHSM*
- *Project LNG imports and exports*
- *LNG imports set at a minimum level into New England in most cases*
- *Canada divided into east and west regions*
  - *Consumption based on IEO but responsive 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 (p0,q0) from OGSM*
- *Change in production is less responsive at volumes above (p0,qo) and more responsive below (p0,q0)*



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*
    - *P0 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:*

$$pipeline\ fuel\ charge\ \left(\frac{\$}{Mcf}\right) = Spot_A * \left(\frac{1}{1 - \%loss} - 1\right)$$

$$variable\ charges(\$/Mcf) = Spot_B - \frac{Spot_A}{1 - \%loss}$$

$$AnnualFixedCharge\ (\$) = \sum_{month} \left((Citygate_B - Citygate_A) - (Spot_B - Spot_A)\right) * associated flow\ into\ B$$

- *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*

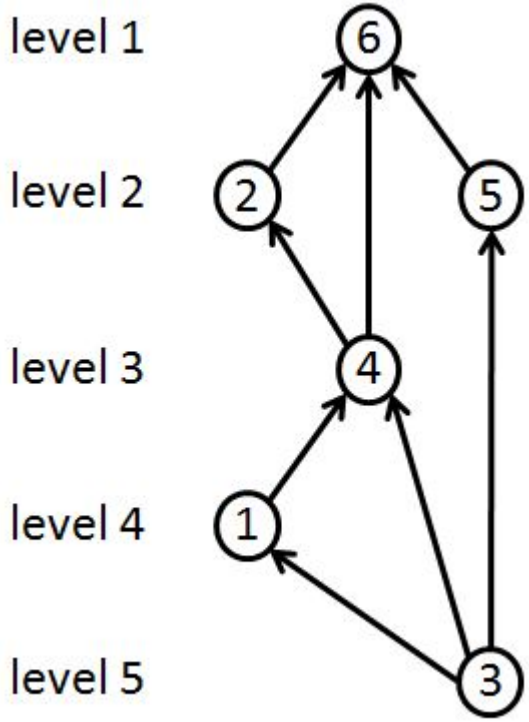
Pipeline expansion

- *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)*