# Natural Gas Transmission and Distribution Module Component Design Report

*Discussion of model design*

*Joe Benneche, Natural Gas Analyst, EIA*

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# Requirements

- *Primarily: Project delivered, wellhead, import, and export prices given delivered volumes and a set of regional supply curves. Balance market and establish production, imports, and exports, as well as lease, plant, and pipeline fuel, and supplemental supplies.*
- *Secondarily: Project region-to-region flows and pipeline capacity.*
- *Must align well with history, but capture likely future market behavior*
- *Must be relatively easy to maintain, update, and modify*

# 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***

# Other models

- *LP vs NLP (quadratic in Obj) vs MCP vs Agent-based*
- *International and domestic*
- *Different levels of granularity regionally and temporally, but also different focuses (e.g., client's planning issues)*

*Concluded:*

- *For competitive market, no practical difference in algorithms, so pick one easiest to mange*
- *Speed of quadratic comparable to LP*
- *Greater granularity preferable, but balance w/overhead*

# General approach

- *Nonlinear optimizer (NLP), quadratic objective function*
  - *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, state-to-neighboring state transport*
  - *Some production represented at substate*
- *Limited international nodes*
- *Probably run monthly, with capacity limits set before the model is solved each year.*
- *Additional runs for peak periods to determine pipeline capacity expansion given extreme weather demands*
- *Each month balanced separately, no connection between months.*

# General Approach – Questions for Discussion

- ***Any concerns with using an NLP instead of an LP?***
- ***Any other ways to address marginal versus average pricing issues?***
- ***Concerns/issues/opinions about level of disaggregation used?***

# 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 – Questions for Discussion

- ***Any other drivers we should consider for splitting annual regional consumption to month and state?***
- ***How important is it to try to break consumption into substate (i.e., North/South California, North/South Louisiana, East/West New Mexico, and Texas into three or more regions)?***
- ***Any concerns in using or not using demand curves?***
- ***Implications of defining demand curves based on wholesale prices?***
- ***Any suggested ways of assuring consistency (and convergence) with NEMS and using demand curves?***

# Demand (cont)

- *Alaska/Hawaii -separate submodule, same as current NGTDM*
  - ***Any thoughts on modeling shifts in demand in Alaska if supplies from the North Slope should become available? Can much be done short of an exogenous assumption?***

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

# Demand – 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*
- ***Questions for Discussion:***
  - ***How much interest is there in lease and plant fuel (i.e., is there an interest in breaking it out)? Is it important to break it out to obtain a better result?***
  - ***How significant do you foresee the use of electricity instead of gas? If important, is there a reasonable way to model it short of making an assumption?***
  - ***Could natural gas use for lease operations grow because of switching out of diesel?***

# 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 (?)*
- ***Questions for Discussion:***
  - ***Is the process of defining pipeline fuel losses based on regional historical data reasonable?***
  - ***Is the accounting for pipeline fuel charges reasonable?***
  - ***How significant might the use of electric compressor stations be in the future?***
  - ***Are the other factors influencing fuel use at compressor stations (i.e., efficiencies)?***

# 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*

# Imports and Exports - Questions for Discussion

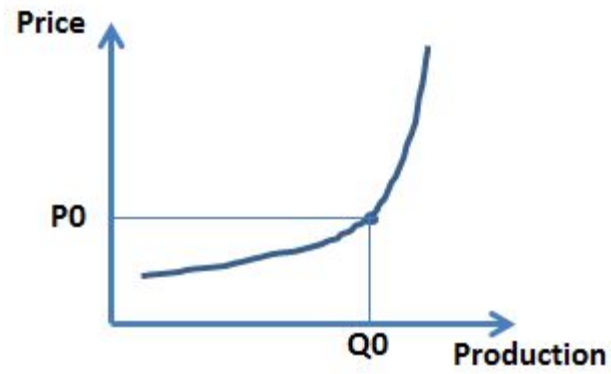
- ***Is it reasonable to assume that Mexico will be a competitive market going forward and model it as part of the NLP? Is it reasonable to divide the country into four quadrants?***
- ***Since the market in Mexico is evolving rapidly in the short-term, and historical data are nonexistent or not relevant, how should transportation rates be set?***
- ***Presuming EIA has a separate international model, how might a reduced form be generated and applied in attempt to simulate its response in setting LNG imports and exports?***

# 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*

# Supply - Questions for Discussion

- ***Is there any issue in fixing some of the supplies in the model?***
- ***Do you believe that specifying the supply function with a "knee" as described will effectively push the model to solve across regions in that area?***
- ***Is the specification of the supply curve reasonable? Particularly, Is it reasonable to set P0 to the equilibrium price from the previous year? Any concerns about the shape/slopes?***
- ***Any suggested functional form to use other than a piece-wise linear? Any problems with using a piece-wise linear?***
- ***Implications of using seasonal/monthly supply curves versus an annual supply curve feed into each season/month? Potential inconsistences with seasonal and annual curves?***

# 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*

# Storage – Questions for Discussion

- ***Any concerns about not setting storage dynamically? Other options? Can storage really be set on a pure economic basis?***

- ***What storage costs should be added (variable and fixed)? On what basis should they be set? Is it really necessary to add storage costs since the pipeline reservation fees should already be indirectly including storage fees in the citygate prices?***

# 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 Tariffs - Questions for Discussion

- ***Is the disaggregation of the variable tariff into a pipeline fuel and other variable charge reasonable?***
- ***Is this a reasonable manner to define a variable tariff curve or essentially a basis differential curve and will it achieve the desired results of aligning the model with history?***
- ***Should the variable tariff curves stand-up over time (e.g., as pipeline capacity is added)?***
- ***Is the expectation that the data will demonstrate a somewhat consistent relationship between average monthly basis differentials from state to state and monthly flows (i.e., pipeline utilization) reasonable?***
- ***Is it reasonable to expect the calculated annual fixed charges will be somewhat stable across the historical years (assuming no pipeline builds)?***

# 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*

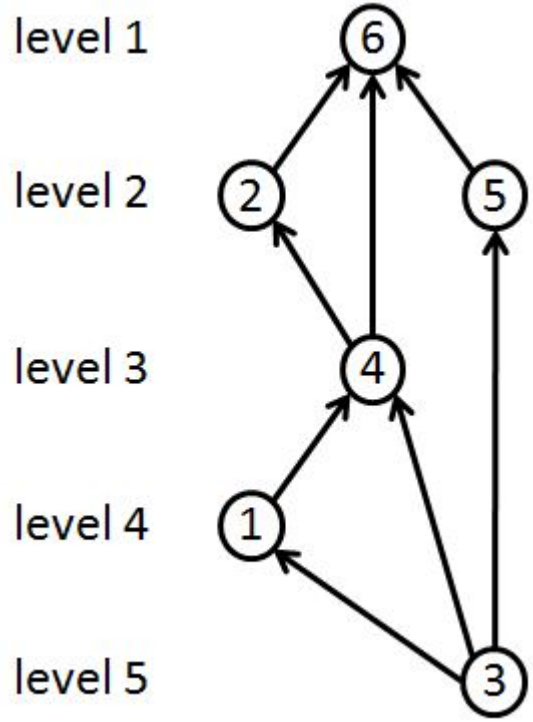
# Pipeline Expansion - Questions for Discussion

- ***Is this a reasonable to assume that pipeline capacity will be added if the market selects the route even with a hurdle rate applied?***
- ***Should consumption be represented with a demand curve when setting pipeline expansion to test if demand holds up with the hurdle rate? [The demand curves would need to be based on the wholesale prices.]***
- ***Any suggestions for setting the hurdle rate?***
- ***Any suggestions for approximating the degree by which the fixed charges will increase relative to the amount of capacity added?***
- ***Is there any way to represent the role that electric generators play in either choosing to sign up for firm service or not doing so depending on the competitiveness of the regional electricity market?***

# 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



# Pricing Submodule - Questions for Discussion

- ***Are these the correct volumes to use as weights?***
- ***Since the unitized reservation fee can be expected to increase as flows decrease, is it likely to create a "snowball" effect in making the route less desirable and just decreasing the flows further?***
- ***Is it reasonable to align the model to citygate prices? If so, is this a reasonable approach?***

# 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*

# Delivered Prices - Questions for Discussion

- ***What level of detail seems most appropriate for adding distributor tariffs?***
- ***What wholesale prices should be used in setting delivered prices?***
- ***Should delivered prices be set as an adder to the wholesale price, or include the wholesale price in its calculation?***

# 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)*

- ***Question for discussion: Suggested ways of analyzing results given multi-dimensions?***

# Benchmarking

- *Run model in historical years*
  - *Determine benchmark factors where feasible (e.g., align to historical prices as necessary)*
- *STEO*
  - *NGTDM results must be within 2% of STEO*
  - *Run NGTDM multiple times to achieve STEO convergence*
  - *Phase out benchmark factors over forecast years*

# Benchmarking – Questions for Discussion

- ***Drawbacks on basing the model on historical relationships and the ability to represent potential changes in relationships going forward?***
- ***Other approaches to benchmarking the model to history? Is it worth the extra effort to run the model with a somewhat different formulation in the historical years to set benchmark factors?***
- ***What do you think about the approach of modeling volumes in the NLP and adding fixed charges after the fact? Is there a better way to do the same thing?***