EIA Network Modeling Workshop Notes, September 4, 2014

The following participants were in attendance (apologies for any misspellings or omissions):

- Niko Kydes, OnLocation
- Sandy Sanders, OnLocation
- Michael Schaal, EIA
- Liam Leahy, RBAC
- Robert Brooks, RBAC
- Frank Brock, ICF
- David Daniels, EIA
- Angelina LaRose, EIA
- Robert Baron, NERA
- Pete Whitman, DOE
- Lauren Busch, Leidos
- John Meyer, Leidos
- Joe Benneche, EIA
- Aloulou Fawzi, EIA
- Leon McGuinnis, GA Tech (WebEx)
- Bill Pepper, ICF
- Steve Gabriel, UMD
- Jill Scotcher, Chevron (WebEx) (afternoon)
- David Manowitz, EIA
- John Conti, EIA
- Justine Barden, EIA (afternoon)
- Elizabeth May, EIA (afternoon)
- Michael Cole, EIA (afternoon)

A. Morning Session: NGTDM Model Requirements

The morning session was devoted to an understanding of the current state of the NGTDM system and a discussion of the current needs in developing an improved model. Joe Benneche of EIA [JB] provided the introduction to the NGTDM and moderated the discussion, focusing on the practical consequences of adopting alternate modeling approaches.

In general, models are often designed to address current conditions, and may become obsolete as markets evolve—for example, the predecessor model, GAMS, was designed specifically to address wellhead decontrol and market restructuring. GAMS' 300 nodes and extensive pipeline network proved difficult to maintain. GAMS was eventually replaced by the first iteration of NGTDM, whose design was ultimately revealed to be too aggregate to accurately model historical gas transmission/distribution patterns using a linear program. The model was subsequently replaced by an updated version of which kept the same network but used a heuristic algorithm where volume flow down through network nodes, and prices flow up. The resulting flows are more closely linked to history and driven by economic choices based on relative price factors.

In contemplating a new model design, the baseline inputs are expected to remain the same; principal outputs are expected to be regional prices, consumption, production, export/import of LNG, and storage (both peak and off-peak). The new model should be able handle bi-directional flows. [JB] Invited feedback from the participants on the requirements and limitations of the proposed redesign of the NG model, asking, how much regional detail is necessary?

Bill Pepper of ICF [BP] observed that significant issues may be sub-regional, and asked how they can (or should) be accommodated.

Frank Brock of ICF [FB] suggested that localized detail may be justified in markets facing constraints on capacity and seasonal extremes in demand, like New England.

[JB] recognized the need to model pipelines dynamics at a more micro level, but conditions may change over time and too much detail may be problematic from a practical modeling perspective. Angelina LaRose [AL] emphasized the primary importance of interregional flows in the modeling system.

Robert Brooks of RBAC [RB] noted the need to more clearly define the questions intended to be answered—exactly how much flexibility is needed/desired will ultimately determine the level of effort and associated costs of a redesigned model.

Pete Whitman of EIA [PW] emphasized the need to focus on differences between alternate scenarios, and the need to ensure response consistency in the model so that different policy scenarios can be evaluated. [JB] responded that the primary role of the model is within NEMS, ensuring that other modules get the proper price response, and that there are limited opportunities within the model for scenario development, such as testing the impacts of new tax structures.

[JB] noted that there is an increased focus on LNG imports/exports and the need to enhance the mode'ls interaction with the International Natural Gas Model.

David Daniels of EIA [DD] mentioned the goal of modeling the way the world works and discussed the difficulties of anticipating policy questions from NEMS stakeholders—NEMS is designed to address questions of current concern, and designing a model to handle any conceivable scenario would be impractical. He acknowledged the benefit of increasing the granularity of regional representation, but noted the increased development and maintenance costs associated with that approach.

[JB] emphasized that the focus should be on getting the right price signals, and that modelers should be aware that bottlenecks in relatively minor nodes may have a disproportionate impact on prices.

[RB] observed that a very granular model would be more realistic than a too-aggregate model, and that data are currently available for near-term projections. This led to a general discussion, primarily among [DD], [JB], [AL], and [FB], about (1) the desirability/(im)possibility of running multiple scenarios to establish some sort of probabilistic result; (2) the minimum level of detail required to get the correct price response; and (3) how a model should aggregate pipelines without sacrificing sensitivity. [JB] emphasized wanting to use marginal pricing instead of average pricing which the current NGTDM is forced to do because it is very aggregated.

[FB] responded to questions about ICF's model, and the level of aggregation employed, noting that there is some pipeline aggregation under limited circumstances, and emphasizing the importance of geographic disaggregation and the need for temporal granularity. Disaggregating regional results may have significant localized implications—notably, for example, the treatment of the Marcellus Shale, where the presence of wet-gas and dry-gas regions justifies a sub-regional analysis. Other important questions include how storage is currently being used and how that will change over time. ICF uses a monthly model, with volatility introduced by a daily model. [FB] also noted the different focuses

between the short-term and long-term models, observing that the short-term models will take current information from NOAA during hurricane season to improve temporal granularity.

[DD] noted that information flows from the STEO to the AEO, calibrated to the September results, and discussed the integration of the model with other models in NEMS—demand is provided at an annual level, which could be disaggregated algorithmically to permit the NGTDM to operate at a monthly level. He posed the question: what level of aggregation is enough so that the model is credible, and can accommodate spikes in demand? [JB] pointed out that the model uses normal weather.

[RB] pointed out that with modern software a more granular model can still solve quickly and that aggregation results in a loss of meaning. [JB] noted that the NGTDM runs in less than five minutes and is run over 100 times during each NEMS run.

[JB] expressed concern about the implications of having to disaggregate data, noting that supply was now being forecast by county in OGSM, but that demand is forecast only at the Census Region level and the 17 EMM regions.

[BP] asked if consideration was being given to integrating the electricity module (EMM) with the NG model in order to improve the representation of seasonality. [JB] acknowledged that the supply curves in the EMM may provide some capabilities in that regard, and that there is some limited integration currently, as NG consumption per household is used as a driver for the NG distribution tariff.

[RB] inquired about the practical problems of ICF using a perfect foresight model; [BP] responded that a stochastic approach is used as a complement to perfect foresight, and [FB] added that seasonal storage is used to smooth-out uncertainties, and temporal issues are complementary.

[JB] asked if Mexico should be included as part of the North American network model, given the differences in Mexico's market/regulatory system.

[RB] responded affirmatively, noting that major structural changes make it increasingly important. However, there is not much information or transparency on market-based pricing. Economic distortions, non-competitive pricing, and state subsidies can cause problems in a market-based model, but it is still important to attempt to incorporate this important component of the North American network.

During a discussion of pipeline tariffs and expansion [RB] and [BP] indicated that they use a similar approach to developing pipeline cost curves as a function of utilization. Curves are developed by fitting to historical data looking at utilization versus basis values. Published tariffs are used so the curves are not just based on variable costs; fuel is separate.

[RB] also commented that it is difficult to apply information on contracts on interstate pipelines.

Regarding storage, it was noted that high deliverability storage is coming more into play but that is beyond scope of NGTDM which focuses on seasonal storage. Storage usage is not just based on price signals because of regulated requirements.

[JB] asked the participants to consider the treatment of LNG exports and imports, particularly, how LNG exports may affect the domestic market, and how the supply and pricing effects should be modeled.

Also to be considered is the supply for LNG exports—whether it should be modeled as new production or a drain from existing supplies.

[FB] observed that most LNG contracts are on a tolling basis, with a fixed Henry Hub adder. LNG is currently considered a "demand sink" in the North American market, which impacts US prices, but with no feedback of world prices.

End of Morning Session

B. Afternoon Session: Network Modeling Workshop

The afternoon session addressed alternate NG modeling systems, and was moderated by Steven Gabriel [SG] of the University of Maryland at College Park.

The discussion centered on a presentation by Lauren Busch of Leidos [LB], which compared various model constructs and approaches for representing NG market behavior. The presentation addressed the following models:

- Gas Market Model (GMM): ICF
- International Natural Gas Model (INGM): EIA
- GPCM Natural Gas Market Forecasting System: RBAC
- MarketBuilder series of models designed by Deloitte
- World Gas Model: UMD

The text of the presentation has been made available, and should be considered to be incorporated by reference. [LB] discussed significant characteristics of each of the modeling systems, noting how they differed from each other and the current NGTDM.

- ICF's Gas Market Model is a quadratic, non-linear model operating on a monthly basis in a competitive market environment.
- The INGM is an LP that maximizes producer and consumer surplus, subject to constraints that represent non-competitive behavior. It can be run with either perfect foresight or rolling optimization. Justine Barden from EIA commented that for capacity expansion in the long-term portion of the horizon, the INGM still has some constraints on how much expansion is allowed. She also noted that the perfect foresight option runs are faster than rolling optimization with not much difference seen in results. This is likely due to the fact that the model is not stochastic.
- The GPCM is an LP maximizing return on investment and operating with perfect foresight subject to maximum capacity constraints, and where supply, demand, and transportation curves are linearized. It was noted that past production does not influence future supply. [RB] commented that the transportation curves model the spot market for near term transportation capacity and can be thought of as a supply curve for pipeline capacity. Parameters defining the curve are determined by calibrating to history. Capacity expansion is modeled by adding capacity to the transportation curve but at a higher cost.

- The MarketBuilder series of models relies on an agent-based microeconomic modeling framework, where each agent (producer, consumer, transporter) maximizes its own profit. The model maximizes the NPV of resource extraction based on anticipated prices. Later during the workshop Jill Scotcher of Chevron [JS] added that Market Builder uses perfect foresight and a cobweb algorithm to solve. In a subsequent e-mail she noted that the pre-preprogrammed equation underlying MarketBuilder's transportation links are full production functions that represents thermal losses with variable costs, fixed costs, and capacity which serve are an upper bound. The world model has 800 supply nodes, 2400 demand nodes, and 2000+ transportation nodes and can take 18 hours to solve.
- The World Gas Model is an MCP where each each player (producer, marketer, etc) has its own optimization problem. [SG] noted that the model has 80,000 variables and also that pipeline operators charge a two-part fee – a regulated price and congestion fee.

[PW] noted that the allocation of flows across pipelines in the GMM is smoother than in the NGTDM as a result of the quadratic approach, and inquired about the calibration of the model to history.

As noted in the morning session, the current NGTDM is too aggregate, and there was continued discussion about the tradeoffs between too much and too little aggregation. The emphasis was on the desire to model marginal pricing and bidirectional flows. It was noted that more detail provides a more real world model but NGTDM does not need as much detail as industry models because the NGTDM is looking at trends over the long-term and comparing scenarios. No conclusion on regional detail was reached.

[SG] discussed the benefits of modularity in model design, including the ability to disaggregate as circumstances dictate.

[RB] discussed convex cost functions, approximation methods, and quadratic vs. stepwise linear estimation methods.

[SG] described COLUMBUS[1]—a monthly tracking gas market model that uses game theory and includes gas storage detail—as another modeling approach that may provide additional insights. It uses mixed complementary programming (MCP) that allows for the simulation of strategic behavior of different market participants.

[DD] asked if it is entirely necessary to have a monthly model to get the "right" annual result. [SG] said yes, but that a four-season model might be a reasonable compromise. More discussion took place on temporal detail. Models that use 12 months are driven by client needs and again a minimum of four seasons was recommended. It was noted that AEO reports annual prices, but seasonal prices impact annual pricing. Gas fired generation peak in summer is lost if only two seasons are modeled. Four seasons would also capture summer peak in the South better. Temporal detail is also needed for marginal pricing to capture the impact of seasonal demand on infrastructure decisions and storage.

[1] http://www.ewi.uni-koeln.de/fileadmin/user_upload/Publikationen/Working_Paper/EWI_WP_12-06_Columbus_global_gas_market_model.pdf

Michael Schaal of EIA [MS] emphasized the need for seasonal distribution, noting that it may be used to identify major players/drivers in network expansion plans. This led to further discussion of the possibility of developing load duration curves for NG supply, similar to those used in the EMM for electricity, and the question of which demand segment would be required to pay for any expanded capacity.

There was further discussion on model formulation factors, including the use of perfect foresight vs. adaptive expectations, and the need to consider the utility of Agent-based or MCP approaches. [SG] noted that foresight is not a major consideration in models that are not stochastic. [JB] later commented that the implication for expansion would be to include a hurdle rate in the pipeline cost curve as opposed to using a net present value. The inherent assumption used in the current model is that if a pipeline is built, demand will continue to support the project.

[SG] engaged in a conversation with Jill Scotcher of Chevron [JS] via WebEx about their application of the MarketBuilder approach to modeling. [JS] indicated that a major benefit of the modeling system was the ability to perform quick response market analyses, and receive actionable results within a limited time frame.

In a subsequent e-mail [JS] expanded on her views saying, "First, I wouldn't characterize global welfare maximization and complementary as economic solutions. If you introduce any constraints, your La Grange multiplier is no longer price, but shadow price. Markets do not transact on shadow price, thus to me as an economist it has no real economic interpretation. That is unsatisfying to me as an economist. The other thing that concerns when trying to model markets is integration. Integration of all the pieces of the value chain into a single model is very important because markets do not operate separately. What happens on the supply side effects the demand side and the transportation sector, as well. Energy value chains are not independent optimization problems. All pieces of gas markets (or oil or power markets) react to each other dynamically. They do not optimize separately and independently. We have found the integrated nature of energy markets be pivotal to understanding these markets."

In the e-mail, [JS] also advocated for the use of a system such as MarketBuilder which allows a practitioner to easily set-up the agent based model instead of having to spend significant time programming and debugging.

Following his conversation with [JS], [SG] discussed the possible benefits of Mixed Integer Programming (MIP), which may be used to address the Unit Commitment Problem (electricity dispatch). He noted, however, that the iterative nature of the methodology would make MIP a problematic choice for the proposed NG model. He explained that if a MIP is not convex, the duals cannot be used to obtain prices. However, one can solve the MIP and then do an LP run at the end, using the MIP solution, to get price information. [SG] also discussed the advantages of MCP approaches, noting it is useful in game theory, and that modularity and expandability is a significant benefit to this approach.

[SG] Noted that a quadratic program and a linear program are computationally the same if all constraints are linear so a QP will not take longer to solve. All of the model techniques can result in alternate optima. The "knife edge" effect of an LP should be mitigated with more disaggregation.

Incorporating game theory would also help but this is not relevant for the competitive market of the domestic model.

It was generally agreed that the domestic natural gas market can be assumed to be competitive with no arbitrage opportunities.

[RB] observed that, while transmission models may respond to congestion constraints with a price spike, the reverse is not necessarily true, and price spikes may have other causes than congestion in the transmission system.

[BP] described ICF's experience with modeling pipeline issues in Australia, where conditions of constant supply and variable demand would result in reduced delivery capability.

In further discussions on capacity expansion, it was brought up that a MIP could be used to evaluate a large pipeline project such as the Alaskan pipeline. [BP] suggested that one could just assume that project is built if the fraction is over a certain level and then rerun the model forcing project in. [JB] noted the need to account for the impact of price decreasing once pipeline is built.

International Model considerations were then raised for general discussion—particularly, how to effectively model non-competitive behavior on the international side, such as the influence of government-owned utilities. Participants were asked to consider the use of non-cooperative game theory, and the degree to which such non-market behaviors may be modeled as constraints in an LP.

[SG] suggested that international models should have a diversity constraint added to an LP, which would set an upper limit on the fraction of total supply that may be obtained from a single node (or country).

Other questions were raised for consideration:

- How do you model political instability and government subsidies?
- What is the global vision of how international markets currently operate?
- How do you accommodate the use of options and spot market pricing?

[RB] indicated that contracts mitigate risk in the short term, and that long term supply arrangements determine the perception of future market price. He suggested the use of competing models, comparing outputs, and using test models to duplicate the existing market environment. Such an approach would require careful analysis, debugging, and understanding of interim results, with an eye toward detecting infeasibilities in the model.