FINAL MODELING RESULTS

Linear Programming Optimization Model

For a number of years, Questar Gas has utilized a computer-based linear-programming optimization model to evaluate both supply-side and demand-side resources. Ventyx maintains this software product and markets it under the name of "SENDOUT." Ventyx is owned by ABB, a global power and automation technology group headquartered in Zurich, Switzerland with approximately 150,000 employees. Roughly 100 energy companies use SENDOUT for gas supply planning and portfolio optimization.

SENDOUT has the capability of performing Monte Carlo simulations thereby facilitating risk analysis. The Monte Carlo method utilizes repeated random sampling to generate probabilistic results. It is best applied where relative frequency distributions of key variables can be developed or where draws can be made from historic data. Because of the need for numerous random draws, the availability of high-speed computer technology helps facilitate this process.

Questar Gas is using a new release of the SENDOUT modeling software, Version 14.3. This new version was recoded to keep the grid manager attached to the SENDOUT database. A previous version would stop looking for scenarios to optimize after it had been idling for several hours. The grid manager waits for scenarios to optimize whether the run is deterministic or uses Monte Carlo.

In performing gas supply modeling, Questar Gas representatives work closely with consultants from Ventyx. The Ventyx consultants are very familiar with the gas supply modeling conceptual approach of the Company and they are comfortable with how the Company utilizes and configures the SENDOUT model.

Constraints and Linear Programming

While the concepts of linear programming date back to the early 19th century, it was not until the middle of the 20th century that this approach began to be more widely accepted as a method for achieving optimal solutions in practical applications. In summary, linear programming problems involve the optimization of a linear objective function subject to linear constraints.

Constraints are necessary in determining a maximum or minimum solution. Constraints must be linear functions and can either represent equalities or inequalities. An example of an inequality constraint in the natural gas business would be that the quantity of natural gas that can be physically transported over a certain segment of an interstate pipeline must be "less than or equal to" a certain level previously contracted for with that pipeline company. Another example of an inequality constraint would be the forecast production available from a group of wells providing cost-of-service natural gas. The level of this resource that can be taken can never exceed the forecast maximum level available as production naturally declines over time. All resources are defined by constraints including purchased gas.

Constraints must be carefully defined to accurately reflect the problem being solved. The arbitrary removal of required constraints results in an inaccurate solution. For example, if the Company removed the constraint on how quickly it filled Clay Basin, the model would assume that it could be done instantaneously, resulting in an unrealistic solution. The removal of all constraints in a linear programming problem would result in no solution ever being able to be reached. Questar Gas periodically reevaluates the constraints in its SENDOUT model to determine if they accurately reflect the realities of the problem being solved.

Model Improvements

The Company made several significant modifications to the SENDOUT model prior to the modeling for the 2015-2016 IRP. These changes included adding operational constraints at Clay Basin and removing gas purchases from interruptible customers from the supply portfolio.

The Company made a change to restrict the amount of gas that it can receive from Clay Basin during extreme cold-weather events. During extreme cold-weather events and low-inventory conditions, Questar Gas will likely be allocated to its Minimum Required Deliverability level which would reduce the Company's ability to withdraw gas to 111.8 MDth/D. The Company added constraints to the model to begin restrictions at 16°F and fully restrict gas to 111.8 MDth/D when temperatures reach 6°F.

Additionally, the Company included a constraint that required some gas remain in Clay Basin for the April test. As part of the spring Clay Basin test, Questar Pipeline requires all shippers to have withdrawals based on contract volumes for the first two days of the test. Under normal temperature operating conditions, the model tends to empty the Company's share of Clay Basin in the early part of the year. With this constraint, a minimum amount of gas now remains in Clay Basin for the required test.

Questar Gas has historically included, in its modeling process each year, the availability of supplies that may be purchased from the Company's interruptible transportation customers in Utah and Wyoming. Prior to the 2014-2015 heating season, the Company changed its Tariff such that the Company may (but was not required to) purchase these supplies. Likewise, transportation customers may (but were not required to) sell these supplies to the Company. Because the Company is no longer planning to purchase this supply in the event of a peak day, it did not include this supply in the SENDOUT modeling. During curtailment events experienced over the past two heating seasons, supplies for the interruptible transportation customers experienced reductions. The Company does not believe this supply will be available on a reliable basis during a peak event. Even if the supply is available, the customer may not choose to sell it to Questar Gas as other markets may be available.

Monte Carlo Method

When performing Monte Carlo analysis, the length of computer run times can become an issue. To have a meaningful simulation, it is important to have a sufficient number of draws (typically hundreds). Each draw consists of one deterministic linear programming computer run. With the complexity of the Company's modeling approach, one simulation can take as long as several days to run. The base Monte Carlo simulation developed by the Company this year utilized 1,591 draws.

When the developers of SENDOUT incorporated the Monte Carlo methodology, they limited the number of variables for which stochastic analysis can be applied to avoid excessive computer run times. The two variables which they appropriately determined should be included are price and weather (within SENDOUT, demand is modeled as a function of weather). No other variables have a more profound impact on the cost minimization problem being solved by SENDOUT than these two.

The output reports generated from the SENDOUT modeling results consist primarily of data and graphs. Most of the graphs are frequency distribution profiles from a Monte Carlo simulation. Many of the numerical-data reports show probability distributions for key variables in a simulation run. The heading "max" in these reports refers to the value of the draw in a simulation with the highest quantity. The heading "min" refers to the value of the draw in a simulation with the lowest quantity. The heading "med" refers to the median draw (or the draw in the middle of all draws).

Questar Gas believes that the mean and median values are good indicators of likely occurrence, given the underlying assumptions in a simulation. Many exhibits in this report also include a Normal Case number to show how the Normal Case compares to the mean and median. The Company will discuss the normal case in more detail later in this section. Also in these data reports are the headings "p95," "p90," "p10," and "p5." The label "p95" on an output report means, based on input assumptions, that a 95% confidence exists that the resulting variable will be less than or equal to that number. Likewise, a "p10" number suggests that there is a 10% likelihood that a variable will be less than or equal to that number. These statistics and/or the shape of a frequency curve help define the range and likelihood of potential outcomes.

Natural Gas Prices

It is extremely difficult to accurately model future natural gas prices. Most of Questar Gas' natural gas purchases are tied contractually to one or more of 10 area price indices. Two of those indices are published first-of-month prices for deliveries to the interstate pipeline systems of Kern River and Northwest Pipeline. The remaining are published daily indices for

CIG, Kern River, Questar Pipeline, SoCal Gas, White River Hub, Northwest Pipeline, and three baskets combining CIG, Northwest Pipeline and Kern River indices. To develop a future probability distribution, Questar Gas assembled historical data and determined the means and standard deviations associated with each price index. Questar Gas then utilized the average of two price forecasts developed by PIRA (18 months) and CERA (307 months) as the basis for projecting the stochastic modeling inputs. The Company adjusted forecasted standard deviations pro rata based on the historical prices to more accurately mirror reality. Exhibits 9.01 through 9.12 show, for the first model year, the resulting monthly price distribution curves for the first-of-month prices and the daily prices for each of the price indices used in the base simulation.

Weather and Demand

Weather-induced demand is the single most unpredictable variable in natural gas resource modeling. Questar Gas makes 86 years of weather data available to the SENDOUT model. When forecasting future demands, heating degree days are stochastic with a mean and standard deviation by month. Questar Gas uses this number, along with usage-per-customer-per-degree-day and the number of customers, to calculate the customer demand profile used by the model.

The stochastic nature of the heating-degree-days creates a normal plot for degree days based on the 1,591 draws. For each month of simulation, the model randomly selects a monthly-degree-day standard-deviation multiplier to create a draw-specific monthly-degree-day total. It then scans through 85 years of monthly data to find the closest matching month. Then the model allocates daily degree-day values according to the degree-days in this historic month pattern. Exhibits 9.13 through 9.36 show the annual and the monthly demand distribution curves for the first year of the base simulation. Exhibit 9.50 shows the annual heating-degree-day distribution.

In prior years, before Questar Gas has used Monte Carlo modeling techniques, it modeled a high demand and a low demand scenario as part of a sensitivity analysis. Currently, with the use of a Monte Carlo modeling approach, the wide variability in weather-induced demand resulting from historical weather data is broader than any reasonable range of load growth scenarios. This year there are 1,591 deterministic cases in the Monte Carlo simulation, each with a different demand level, thus obviating the need to model just one high and one low demand case.

Peak Day and Baseload Purchase Contracts

Another important consideration in the modeling process is the need to have adequate resources sufficient to meet a design-peak day. The sales-demand design-peak day for the 2015-2016 winter-heating season is approximately 1.306 MMDth per day at the city gates. The design-peak day is defined to be a 1-in-20-year weather occurrence. The most likely day for a design peak to occur is on January 2, although, the probability of a design peak occurring on any day between mid-December and mid-February is relatively flat. Even though it is unlikely that a design-peak day will occur this year, the Company must be prepared should it occur.

Selecting a draw from a Monte Carlo simulation that utilizes, on the maximum demand day, a level of resources approximately equaling the design-peak day has proven to be problematic in that it results in the SENDOUT model selecting too much baseload purchased gas for a typical weather year. The draws which have a design-peak-day occurrence also tend to be much colder than normal throughout the entire year. The solution to this dilemma is to perform a statistical clustering analysis of all the Monte Carlo draws for first-year peak demand versus the median level of first-year annual demand.[74] The result of this clustering exercise is a scatter plot that shows groups of draws. These cluster points or groups represent draws that are most closely alike in terms of peak-day requirements and annual demand. The Company then chooses a cluster point that it believes will meet annual demand without falling short on peak day.

The Company then executes a second SENDOUT scenario, removing the unused RFP packages, and leaving those “cluster point” packages. One of the purposes of this run is to verify that adequate purchased gas resources, at the lowest cost, will be available in the event that a design-peak day were to occur. The optimizing nature of the SENDOUT model helps to make this happen. This year, of the 1,591 draws generated in this process, seven (7) draws would exceed the design peak-day requirement of 1.306 MMDth. In other words, this scenario has enough resources to meet a peak-day event. Most of the baseload purchased-gas resources, with their associated time-availabilities, must be committed, during the springtime, prior to the beginning of the gas supply year. Storage usage, spot gas and cost-of-service gas do not need to be committed to before the gas year begins. This modeling approach also lends itself to performing operational analysis periodically during the year as natural gas prices change.

Exhibit 9.51 shows the resources utilized to meet the design-peak day. Exhibit 9.52 shows the firm-peak-day demand distribution for the base simulation for the first plan year. As expected, the design-peak day for Questar Gas is in the upper portion of the curve.

Normal Temperature Case

One of the limitations of the stochastic scenarios, including the base case, is that they lack a draw with normal temperatures for the entire year. This issue surfaced as the Company worked on data for its pass-through cases and has continued to be a source of some confusion in Quarterly Variance Reports. To provide clarity for both pass-through data, variance reports and general understanding, the Company removed the base case reference from the IRP this year and references to the “base case” have been replaced with “normal case.”

[74] See the cluster analysis discussion in the Modeling Issues subsection of the Purchased Gas section of this report.

It should be understood that stochastic modeling still occurred and that a stochastically-created base case still exists, but for ease of comparison, those references have been replaced with a deterministically created normal case using normal mean temperatures. In this document, the normal temperature scenario can be seen in Exhibits 9.83 through 9.88. These show additional planning detail for the first two years of the normal case. The Company listed monthly data for each category of cost-of-service gas and each purchase-gas package. The Company also included injections into and withdrawals from each of the four storage facilities utilized by the Company. The Company included parameters for the Ryckman Creek storage facility. Although no actual gas-supply year will ever perfectly mirror the plan, these exhibits are among the most useful products of the IRP process. They are used extensively in making monthly and day-to-day nomination decisions.

Purchased-Gas Resources

Exhibits 9.53 through 9.64 show the probability distributions for purchased gas for each month of the first plan year from the base simulation. Exhibit 9.65 shows the annual distribution from the simulation. Exhibit 9.66 shows the numerical monthly data with confidence limits. Purchased gas for the first plan year from the normal case is approximately 57.63 MMDth. Questar Gas is confident that, for a colder-than-normal year, sufficient purchased-gas resources will be available in the market. Likewise, Questar Gas is confident that in the event of a warmer-than-normal year, it has not “over-bought” baseload purchase contracts.

Cost-of-Service Gas

Another important output from the SENDOUT modeling exercise each year is a determination of the level of cost-of-service gas to be produced during the upcoming gas-supply year. Exhibits 9.67 through 9.78 show the distributions for cost-of-service gas for each month of the first plan year from the base simulation. Exhibit 9.79 shows the annual distribution from the simulation. Exhibit 9.80 shows the numerical monthly data with confidence limits. Cost-of-service production for the first plan year from the normal case is approximately 66.2 MMDth.

First-Year and Total System Costs

The linear-programming objective function for the SENDOUT model is the minimization of variable cost. A distribution curve for first-year total cost from the base simulation is shown in Exhibit 9.81. The first year total cost from the normal case is approximately $673 million. A similar curve for the total 31-year modeling time horizon is shown in Exhibit 9.82. The normal case cost for this time period is approximately $12.2 billion.

Gas Supply/Demand Balance

Exhibits 9.89 and 9.90 show monthly natural gas supply and demand broken out by geographical area, residential, commercial and the non-GS categories of commercial, industrial and electric generation.

This report is available in SENDOUT and is titled “Required vs. Supply.” The data in these exhibits represent the Normal Case. The Company slightly adapted the SENDOUT report to show geographical areas and lost-and-unaccounted-for gas. Because the Company measures demand at the customer meter and modeling occurs at the city gate, in years past the Company grossed-up demand by the estimated lost-and-unaccounted-for volume to model natural gas demand at the city gate.[75] In past years, The Company modeled lost-and-unaccounted-for gas as a percent of the other demand classes and shows it as its own specific demand class.

Exhibit 9.89 of the report shows the requirements of the system. Those are specifically demand, fuel consumed, and storage injection. This results in a total requirement of 139 MMDth for the Normal Case. Exhibit 9.90 shows sources of supply which include purchased gas categories, cost-of-service gas, Clay Basin and the Aquifers. The total supply meets the 139 MMDth demand for the Normal Case.

[75] Also included are compressor fuel, Company use, and gas loss due to tear outs.