FINAL MODELING RESULTS

Linear Programming Optimization Model

Questar Gas uses 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 utilities 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.

The Company is using Version 14.3 of the SENDOUT modeling software. This version was recoded to keep the grid manager attached to the SENDOUT database. In performing gas supply modeling, Questar Gas works 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 that represent either equalities or inequalities. An example of an inequality constraint in the natural gas business would be the quantity of natural gas that is physically transported over a certain segment of an interstate pipeline must be "less than or equal to" a certain level of transportation previously contracted for with that pipeline company. Another example of an inequality constraint would be the forecast production available from a group of cost-of-service wells. The amount this resource can be taken can never exceed the forecast maximum level available as production naturally declines over time. All resources are defined by constraints.

Constraints must accurately reflect the problem being solved. The arbitrary removal of required constraints results in an unacceptable 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 a few modifications to the SENDOUT model for the 2016-2017 IRP. These included changes to injection and withdrawal requirements at the Aquifers and Clay Basin based on actual operating constraints. Changes to the modeling of cost-of-service production were made related to the Canyon Creek Stipulation. Specifically, the rate-of-return for future wells was changed to the Commission Allowed Return (currently 7.64%).

Monte Carlo Method

To have a meaningful Monte Carlo 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 1,643 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 determined necessary 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.

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 reports are the headings "p95," "p90," "p10" and "p5." The label "p95" on 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, 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 six 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 Kern River (2), SoCal Gas and White River Hub and four baskets containing different combinations of the Kern River, Northwest Pipeline and White River Hub indices.

To develop a future probability distribution, the Company assembles historical data and determines the means and standard deviations associated with each price index. Questar Gas then uses the average of two price forecasts developed by PIRA (19 months) and CERA (295 months) as the basis for projecting the stochastic modeling inputs. The Company adjusts 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 provides 87 years of weather data 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 1,643 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 scans through 87 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.

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 2016-2017 winter-heating season is approximately 1.317 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 the same.

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.[82] 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 series of deterministic SENDOUT scenarios, removing the unused RFP packages, and leaving those “cluster point” packages. One of the purposes of these runs 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 1,501 draws generated in this process, 12 draws would exceed the design peak-day requirement of 1.317 MMDth. In other words, this scenario has enough resources to meet a peak-day event. Most of the seasonal baseload purchased-gas resources are committed prior to the beginning of the IRP year. Storage, daily spot gas and cost-of-service gas supply do not need to be committed to before the IRP 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

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

and general understanding, the Company removed the base case reference from the IRP and references to the "base case" have been replaced with "normal case."

It should be understood that stochastic modeling still occurs and that a stochastically-created base case still exists, but for ease of comparison, those references are 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 lists monthly data for each category of cost-of-service gas and each purchase-gas package. The Company also includes planned injections and withdrawals for each of the storage facilities currently under contract. The Company did not include 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. Gas purchased for the first plan year under the normal case is approximately 53.6 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 contracted for too much gas.

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 64.0 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 $636 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 $11.6 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.[83] The Company models lost-and-unaccounted-for gas as a percent of the other demand classes and lists 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 133 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 133 MMDth demand for the normal case.

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