Gas Analysis

I. Analytical Models

In August 2004, PSE acquired SENDOUT® and VectorGas™ from New Energy Associates. SENDOUT is a widely used model that helps identify the long-term least cost combination of resources to meet stated loads. Avista, Cascade Natural Gas, and Terasen all use the SENDOUT model. VectorGas is an add-in that facilitates the ability to model price and load uncertainty. These valuable new tools enhance our ability to ensure robust long-term resource planning and acquisition activities. The following provides a description of SENDOUT and VectorGas followed by a detailed explanation of the uncertainty factors PSE modeled for VectorGas.

The SENDOUT and VectorGas software products are an integrated tool set for gas resource analysis. SENDOUT models the gas supply network and the portfolio of supply, storage, and transportation to meet demand requirements. VectorGas simulates uncertainties regarding weather and commodity prices using Monte Carlo methods. It then runs the SENDOUT portfolio over many draws to provide a probability distribution of results from which to make decisions.

A. SENDOUT

SENDOUT can operate in two different modes. It can be used to determine the optimal set of resources (energy efficiency, supply, storage, and transport) to minimize costs over a defined planning period. Alternatively, specific portfolios can be defined, and the model will determine the least cost dispatch to meet demand requirements for each portfolio. SENDOUT solves both problems using a linear program (LP). SENDOUT determines how a portfolio of resources (energy efficiency, supply, storage, and transport), including associated costs and contractual or physical constraints, should be added and dispatched to meet demand in a least-cost fashion. By using an LP, SENDOUT considers thousands of variables and evaluates tens of thousands of possible solutions, in order to generate the least cost solution. A standard dispatch considers the capacity level of all resources as given, and therefore performs a variable-cost dispatch. A resource mix dispatch can look at a range of potential capacity and size resources, including their capacities and fixed costs in addition to variable costs.

Energy Efficiency

SENDOUT provides a comprehensive set of inputs to model a variety of energy efficiency programs. Costs can be modeled at an overall program level or broken down into a variety of detailed accounts. The impact of efficiency programs on load can be modeled at the same detail level as demand. SENDOUT has the ability to optimize the size of energy efficiency programs on an integrated basis with supply-side alternatives in a long-run resource mix analysis.

Supply

SENDOUT allows a system to be supplied by either flowing gas contracts or a spot market. Specific physical and contractual constraints can be modeled, such as maximum flow levels and minimum flow percentages, on a daily, monthly, seasonal, or annual basis. SENDOUT uses standard gas contract costs; the rates may be changed on a monthly or daily basis.

Storage

SENDOUT allows storage sources (either leased or company owned, and either natural or production gas) to serve the system. Storage input data include the minimum or maximum inventory levels, minimum or maximum injection and withdrawal rates, injection and withdrawal fuel loss, *to* and *from* interconnects, and the period of activity (i.e., when the gas is available for injection or withdrawal). There is also the option to define and name volume-dependent injection and withdrawal percentage tables (ratchets), which can be applied to one or more storage sources.

Transportation

SENDOUT provides the means to model transportation segments to define flows, costs, and fuel loss. Flow values include minimum and maximum daily quantities available for sale to gas markets or for release. Cost values include standard fixed and variable transportation rates, as well as a per-unit cost generated for released capacity. Seasonal transportation contracts can also be modeled.

Demand

SENDOUT allows the user to define multiple demand areas, and it can compute a demand forecast by class based on weather.

B. VectorGas

Monte Carlo modeling set-up, simulation (running just the draws for weather and price inputs), and optimizations (running each of the draws through SENDOUT) is accomplished in the VectorGas module. In VectorGas, the assumptions for weather and price uncertainty are defined below. Scenario data from SENDOUT is exported to VectorGas, which produces simulations and generates optimizations.

Monte Carlo simulation is a statistical modeling method used to imitate the many possibilities that exist within a real-life system. By describing the expectation, variability, behavior, and correlation among potential events, it is possible through repeated random draws to derive a numerical landscape of the many potential futures. The goal of Monte Carlo is for this quantitative landscape to reflect both the magnitude and the likelihood of these events, thereby providing a risk-based viewpoint from which to base decisions.

Traditional optimization is deterministic. That is, the inputs for a given scenario are fixed (one value to one cell), and there is a single solution for this set of assumptions. Monte Carlo simulation allows the user to generate the inputs for optimization with hundreds or thousands of values (draws) for weather and price possibilities. VectorGas utilizes the SENDOUT network optimizer to provide a detailed dispatch for each Monte Carlo draw.

The advanced probability-based metrics yield a more insightful picture of the portfolio, and form the basis for risk-based resource decisions. The most common of these probability measures include: Expected Value (μ) - EV is then more meaningful than the traditional deterministic measure (total system costs, for example) for a normal scenario since it directly and proportionately captures the portfolio’s response to the whole range of weather and price events. Variability (σ) – the level of variance for critical objectives (e.g., cost exposure) should be a key component when comparing portfolios. Probability (P) – measures the likelihood of a key event (10% to exceed $500 million in annual costs, for example).

Another application for Monte Carlo and optimization is to study the resource trade-off economics by optimally sizing the contract or asset level of various and competing resources for each draw. This can be especially helpful in determining the right resource mix that will lower expected costs. This mix of resources is difficult to identify using deterministic methods, since it is difficult to determine at which points various resources are better or worse.

Performing Monte-Carlo analysis in conjunction with the level of detail included in SENDOUT for long-term resource planning requires a considerable degree of computing power. In addition to the SENDOUT and VectorGas software, PSE also acquired additional hardware. VectorGas essentially runs on a server that is connected to five personal computers that are grid machines, all of which run the SENDOUT linear programming model. VectorGas creates the Monte Carlo draws. Then, through distributed processing, it sends each draw to one of the five grid computers. When the grid machines complete analysis of a Monte Carlo draw, results are posted back to VectorGas and another process job is sent to the grid machine. This is a flexible system that operates over PSE's IT network.

VectorGas Uncertainty Inputs

VectorGas's Monte Carlo analysis provides helpful information to guide long-term resource planning as well as to support specific resource acquisitions. Monte Carlo analysis is performed by creating a large number of price and temperature (and thus demand) scenarios that are analyzed in SENDOUT. Creating hundreds or thousands of reasonable scenarios of prices at each relevant supply basin with different temperatures requires a new and significant set of data inputs that are not required for a single static optimization model run. The following discussion identifies the uncertainty factors needed for VectorGas and explains the analysis used to define each factor.

Uncertainty Factors for VectorGas

The following is a list and brief description of each input needed for Vector Gas to create reasonable sets of scenarios:

- *Expected Monthly Heating Degree Days.* The expected summation of daily heating degree days (HDD) for each month is required. Daily heating degree days are calculated 65 minus the average daily temperature.
- *Standard Deviation of Monthly HDD.* A measure of variability in total monthly HDD that can be assigned a different value for every month.
- *Daily HDD Pattern.* Daily HDDs are derived by applying a historic daily HDD pattern to each monthly HDD draw. This daily pattern can be drawn independently from the monthly HDD level or can be set to reflect a different historic period in each month. Different months can have different daily pattern settings.
- *Expected Monthly Gas Price Draw.* The basis of determining prices each month, this measure can be considered the average of daily gas prices prior to factoring in effects of daily temperature.
- Standard Deviation of Monthly Price Draw: This is a measure of the variability of prices at each basin, such as at AECO. VectorGas uses standard deviation expressed in dollars. A different standard deviation can be assigned to each month for the planning period.
- *Temperature to Price Correlations at each Basin.* Ensures that a reasonable relationship exists between prices and temperatures in each Monte Carlo scenario. Linear/simple temperature to price correlation coefficients are used in VectorGas and a different value can be assigned to each month.
- *Price to Price Correlations between Basins.* Ensures reasonable relationships for prices between each basin for the Monte Carlo scenarios. Linear/simple temperature to price correlation coefficients are used in VectorGas.
- *Daily Price to Temperature Coefficients.* Daily temperatures drive changes from the monthly price draw. Daily price is modeled as an exponential function of daily temperature and has the ability to include a second level of sensitivity to model a price “blow-out” due to an extreme temperature.

Basis of Each Uncertainty Factor

Expected Monthly HDD. PSE is using the average monthly HDD for each month based on temperature data going back to January of 1950, in VectorGas. This period was chosen because it includes the period during which PSE has hourly temperature data with which to calculate HDD, and because it is consistent with the period used to establish the Company's gas peak day planning standard.

Standard Deviation of Monthly HDD. The standard deviation for each month was calculated using the monthly data back to 1950 noted above. That is, the standard deviation of monthly HDD totals was calculated.

Daily HDD Pattern. The daily HDD pattern for each month was prevented from varying randomly, independent of the monthly HDD draw. Preliminary analysis showed that randomly pairing monthly HDD levels with daily patterns can result in temperatures significantly colder than those recorded in history. To avoid overstating temperature variability, PSE applied the daily temperature pattern from the coldest month in the historical period. The next version of VectorGas is scheduled to have a matching feature to select the daily pattern from the period that best fits the monthly HDD draw—a feature included at PSE's request.

Expected Monthly Price Draw. The base or reference scenario gas price forecast was used as the expected monthly price draw in VectorGas for AECO, Sumas, Rockies, and San Juan price points.

Standard Deviation of Monthly Price Draw. Historical data was used to establish the range of variability for each price basin. Selecting a consistent time period for all four basins provides a reasonably consistent basis for calculating the standard deviation.

Temperature to Price Correlations. Historic price correlations for each supply basin to SeaTac HDD were calculated. There are a number of different ways such correlations could reasonably be calculated. For VectorGas, the correlation between HDD and prices was calculated based on daily temperatures and daily prices by season. Then the strongest positive seasonal correlation was selected. As one would expect, the correlations produced using this approach shows a positive, but weak correlation of prices at Sumas, AECO, Rockies, and San Juan to SeaTac temperatures.

Price Correlations between Basins. Similar to the price to weather correlations, price to price correlations were calculated seasonally. Price correlations between supply basins are strongly positive, which is to be expected given the infrastructure in the Pacific Northwest.

Temperature Effects on Daily Price-normal Variation. Deviations between daily price and monthly price draw in VectorGas are driven solely by daily HDD, which is a combination of the monthly HDD draw and daily shape, as noted above. Effects of daily temperatures are modeled as an exponential effect on prices, as daily temperature moves up and down relative to the average daily temperature. A different daily price/temperature factor was calculated for each month of the year and applied to the full 20-year period. To calculate the daily price-temperature factor, a target standard deviation of daily prices was selected. Then the factor estimated that, when applied to expected daily temperatures and the 20-year average monthly price, it would result in Vector Gas daily prices exhibiting the target standard deviation.

Temperature Effects on Daily Price-jump Statistics. The jump statistics to estimate a price blow-out require defining the temperature threshold at which such daily price events can occur, the probability of occurrence if that temperature threshold is exceeded, and the magnitude of the blow-out. Using daily price data back to 1999, the first step was to develop a definition of "price blow-out." Analysis of the data shows a few instances where daily prices exceed the daily average price by more than 40%. This was used as the definition of a blow-out event. The warmest temperature at which daily prices exceeded the average daily price for the month occurred at 21 HDD (39 degrees average daily temperature). The probability of a jump event occurring was calculated by examining the number of days that a jump event occurred at each basin, divided by the total number of days in the historic period with HDD at 21 HDD or higher. For example, during the period, there were 257 days where HDD was 21 HDD or greater. Daily prices were 40% or greater on 9 of those days. Thus, at the HDD threshold of 21 HDD, the probability of a jump event occurring was calculated to be 9/257= 3.5%. If the jump occurred, the magnitude was calculated as follows: When the spread between daily prices exceeded average daily prices by 40% or more, the average percentage increase was used. For Sumas, this was a jump multiplier of 1.53.

II. Analytical Results

Four planning scenarios were analyzed using the Sendout Model: the Base Case scenario (the reference case), Reduced Growth, Robust Growth, and Green World. A description of these scenarios is provided in Chapter 3. The optimal portfolios of supply and energy efficiency resources for each of the scenarios were identified using Sendout. The results of the analyses are shown in the following figures. The specific resource additions for each of these scenarios are described in Chapter 6, Section V.

Figure J-1
Base Case Optimal Portfolio

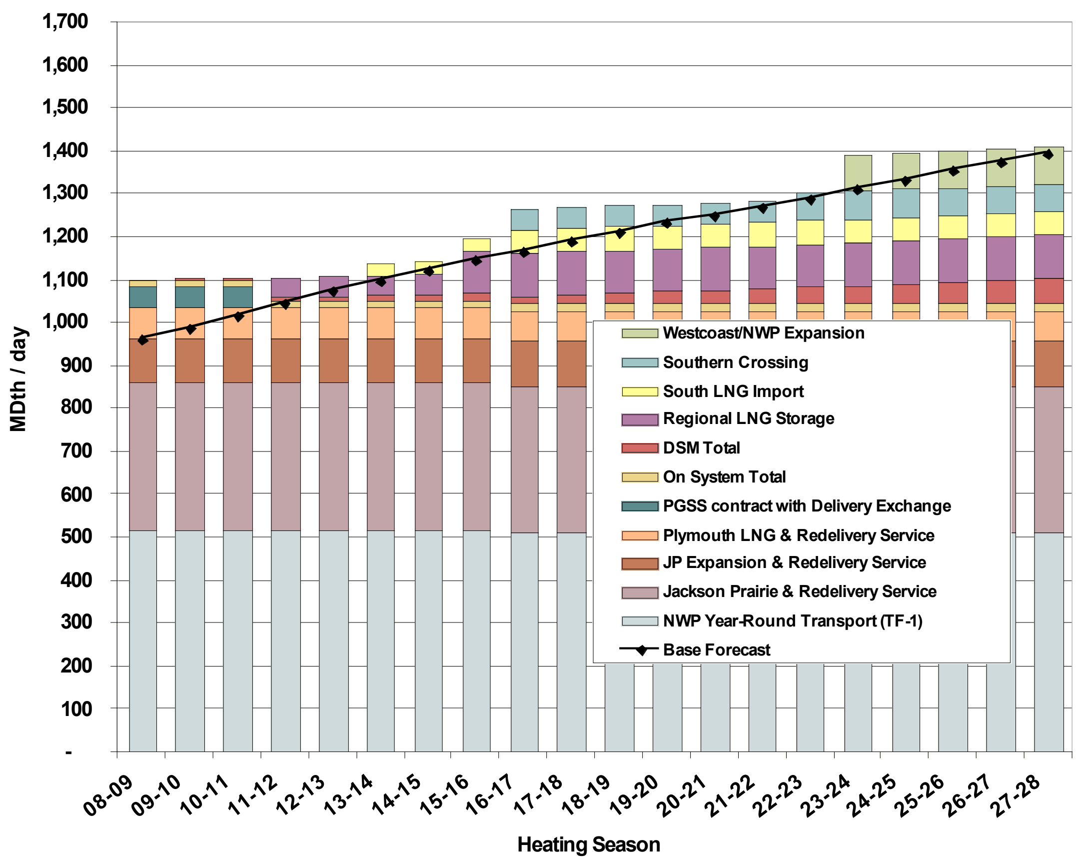

Figure J-2
Reduced Growth Optimal Portfolio

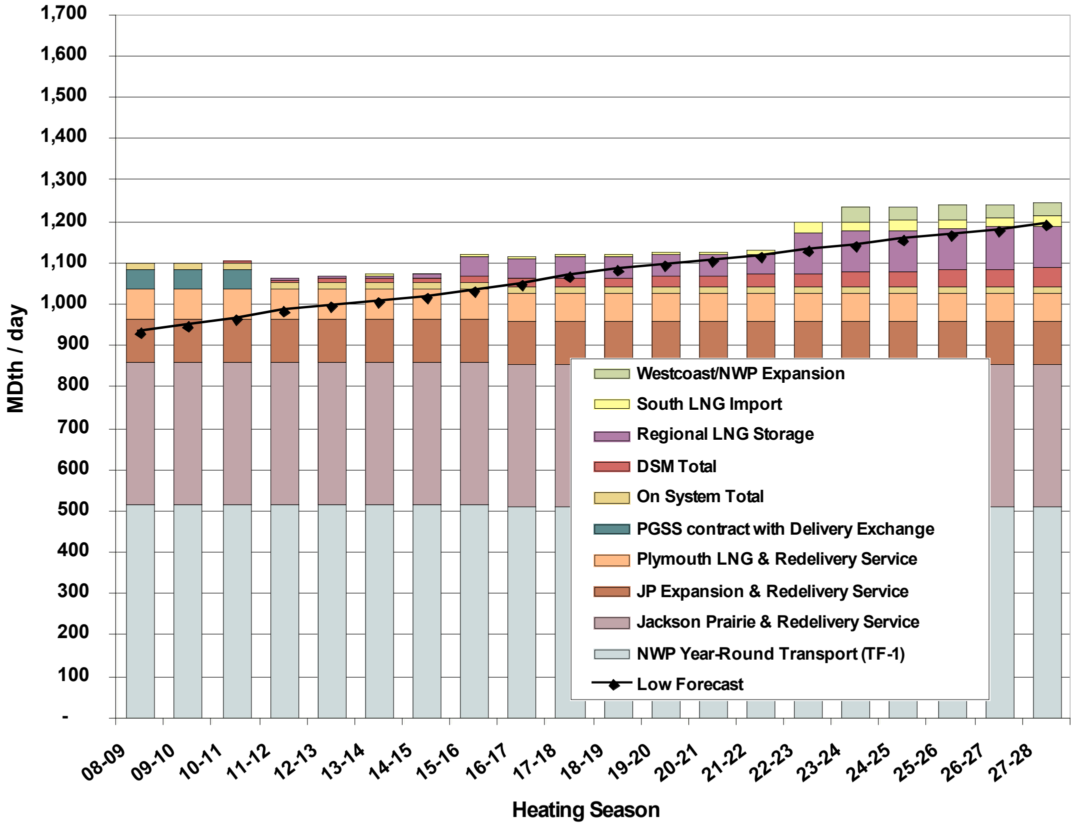

Figure J-3
Robust Growth Optimal Portfolio

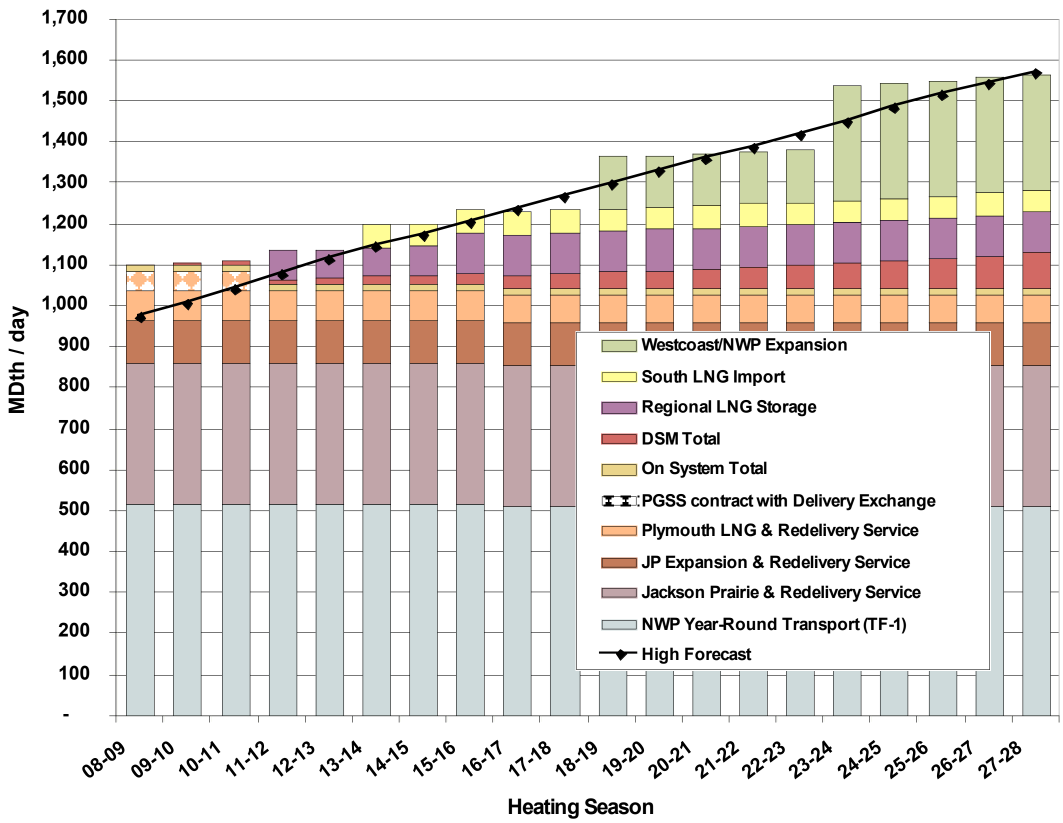

Figure J-4
Green World Optimal Portfolio