Gas Analysis

Contents

1. Analytical Models

PSE uses the SENDOUT® software model from Ventyx for long-term gas supply portfolio planning. 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 as well. The current version of SENDOUT used by PSE (Version 12.5.5) incorporates a Monte Carlo capability allowing analysis of uncertainty about future prices and weather driven loads. The following provides a description of SENDOUT, including the Monte Carlo features.

SENDOUT is an integrated tool set for gas resource analysis. SENDOUT models the gas supply network and the portfolio of supply, storage, transportation, and Demand Side Resources (DSR) to meet demand requirements. The Monte Carlo capabilities allow simulation of uncertainties regarding weather and commodity prices. 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 determine the most cost-effective 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) 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. Monte Carlo Analysis

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. The SENDOUT network optimizer provides a detailed dispatch for each Monte Carlo draw.

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.

Monte Carlo Uncertainty Inputs

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 included for Monte Carlo analyses and explains the analysis used to define each factor.

But first is a list and brief description of each input needed 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 HDD 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. Standard deviation is 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 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.
- *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 over the most recent 30 years. 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 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.

Expected Monthly Price Draw. The gas price forecast is used as the expected monthly price draw.

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. The correlation between HDD and prices was calculated based on daily temperatures and daily prices by season. The correlations produced using this approach show 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 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 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 percent. 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 percent or greater on nine 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 percent. If the jump occurred, the magnitude was calculated as follows: When the spread between daily prices exceeded average daily prices by 40 percent or more, the average percentage increase was used. For Sumas, this was a jump multiplier of 1.53.

2. *Analytical Results*

Seven planning scenarios were analyzed for the gas sales portfolio using the Sendout Model. As discussed in Chapter 4, the planning scenarios are:

1. Base
2. Base + CO2
3. Low Growth
4. High Growth
5. Green World
6. Very Low Gas Prices
7. Very High Gas Prices

Three sensitivity cases were analyzed for the combined gas sales and gas for power portfolio. The focus of these analyses is to determine the lowest cost mix of resources to meet the combined needs of the gas sales and gas for power loads. The three cases are:

1. Base gas sales combined with Base gas for power
2. Base gas sales combined with the Base + Thermal Mix gas for power
3. Base gas sales combined with the Base + No Peakers gas for power

The resource need for the three gas sales load forecasts, the three gas for power scenarios, and the three combined need cases are shown in Figures J-1 thru J-3, respectively.

The optimal portfolios of supply and energy efficiency resources for each of the scenarios and sensitivity cases were identified using SENDOUT. The results of the analyses are shown in Figures J-4 thru J-13. The specific resource additions for each of these scenarios are described in Chapter 6, Section 3.

Figure J-1

Gas Sales Resource Need (MDth/day)

	2016-17	2020-21	2025-26	2030-31
Base Load Forecast	26	115	234	353
Low Load Forecast		62	146	225
High Load Forecast	56	172	330	498

Figure J-2

Gas for Power Resource Need (MDth/day)

	2016-17	2020-21	2025-26	2030-31
Base				
Thermal Mix	169	169	225	188
No Peakers	169	226	338	357

Figure J-3

Combined Gas Resource Need (MDth/day)

	2016-17	2020-21	2025-26	2030-31
Base + Base	20	109	228	310
Base + Thermal Mix	194	284	459	541
Base + No Peakers	195	342	572	709

Figure J-4
Base Optimal Portfolio – Gas Sales

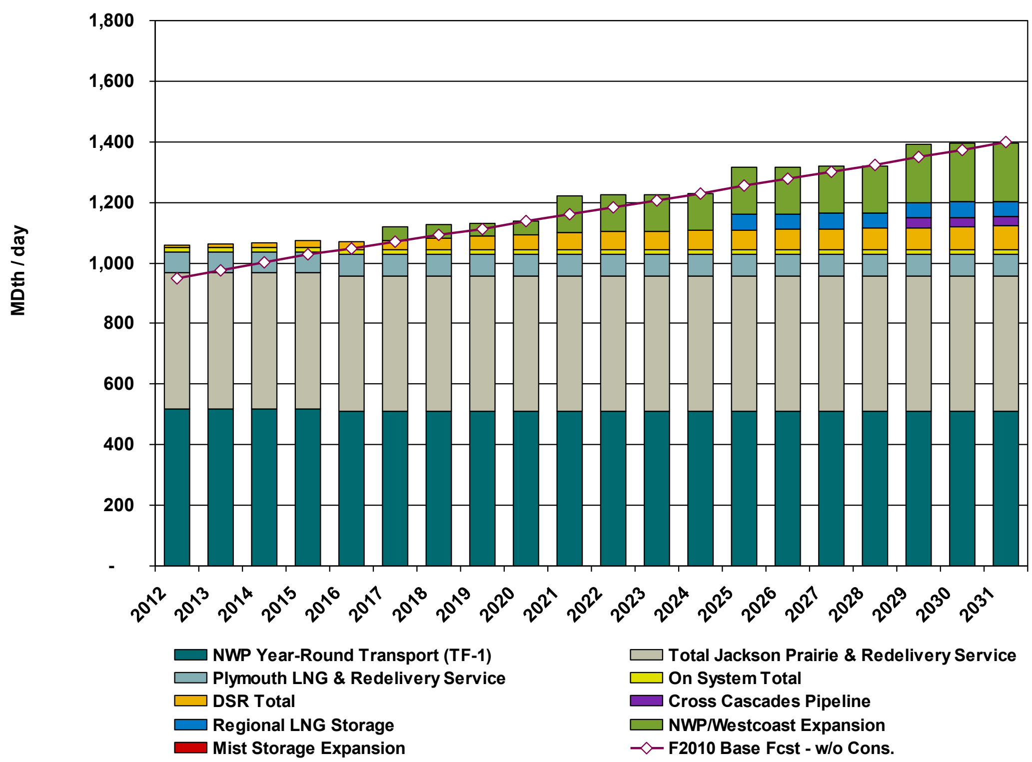


Figure J-5
Base + CO2 Optimal Portfolio – Gas Sales

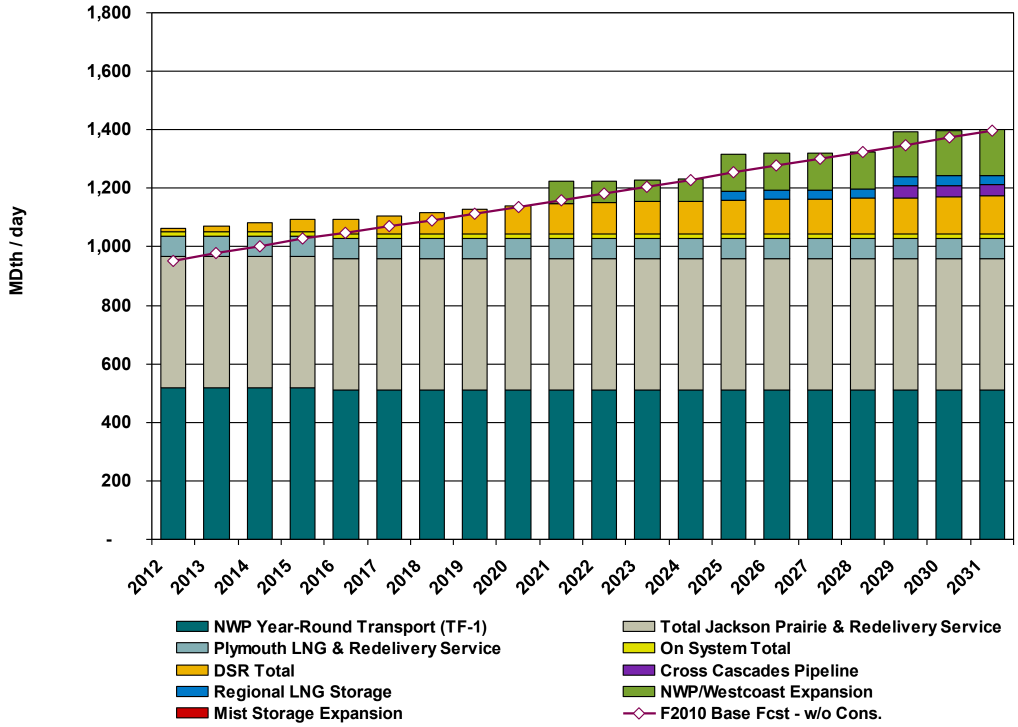


Figure J-6
Low Growth Optimal Portfolio – Gas Sales

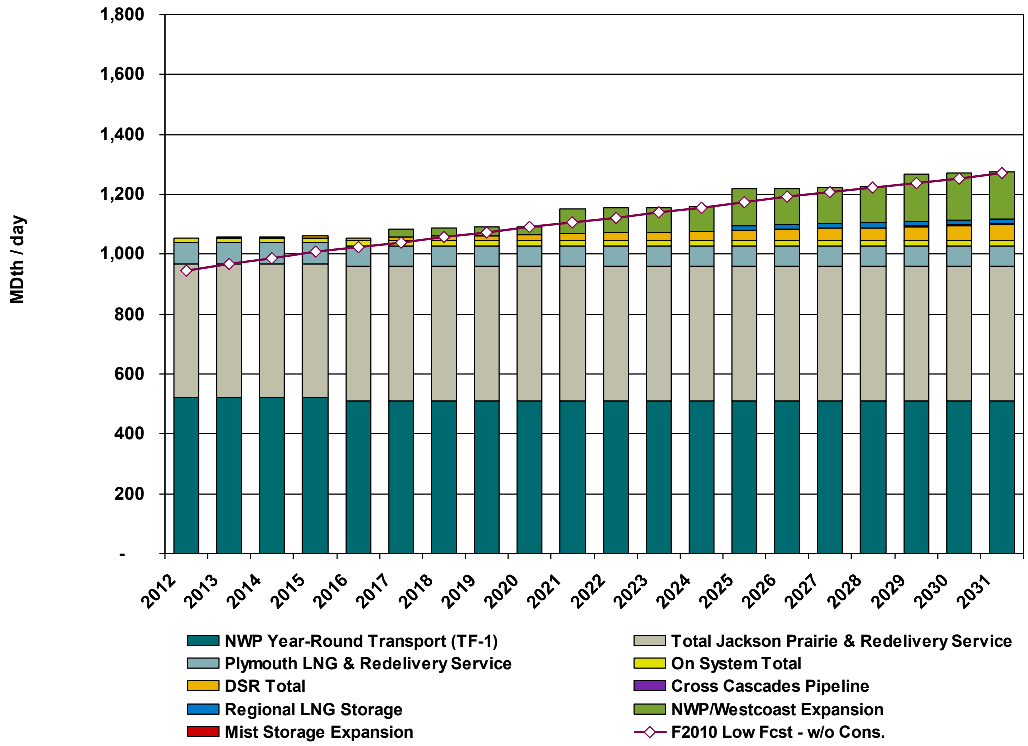


Figure J-7
High Growth Optimal Portfolio – Gas Sales

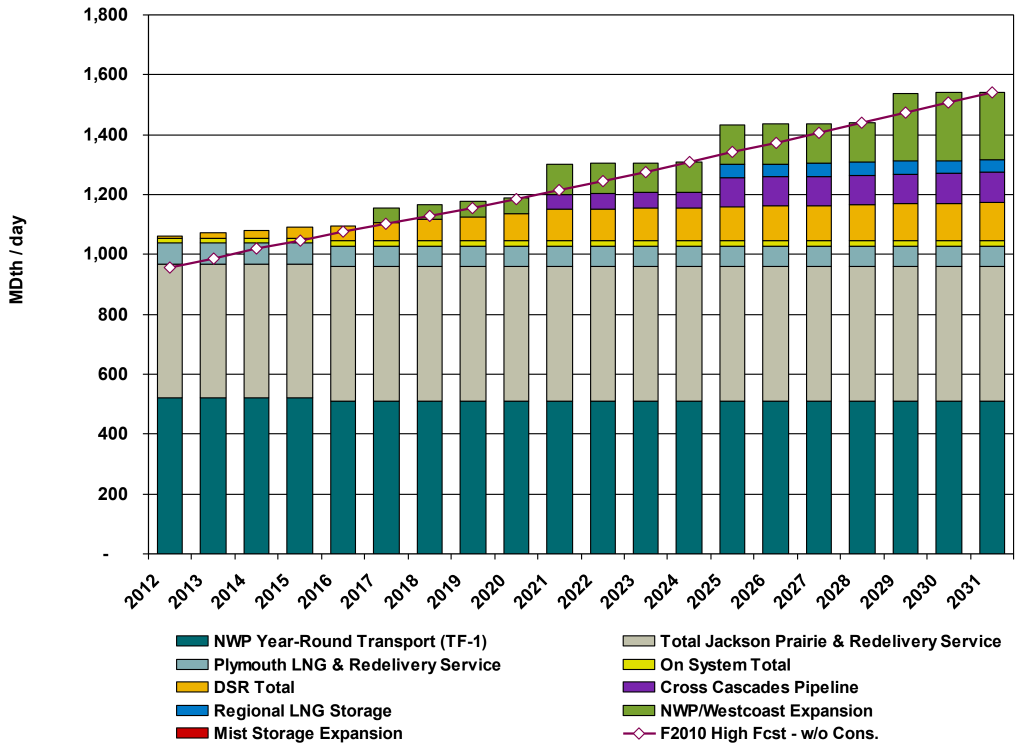


Figure J-8
Green World Optimal Portfolio – Gas Sales

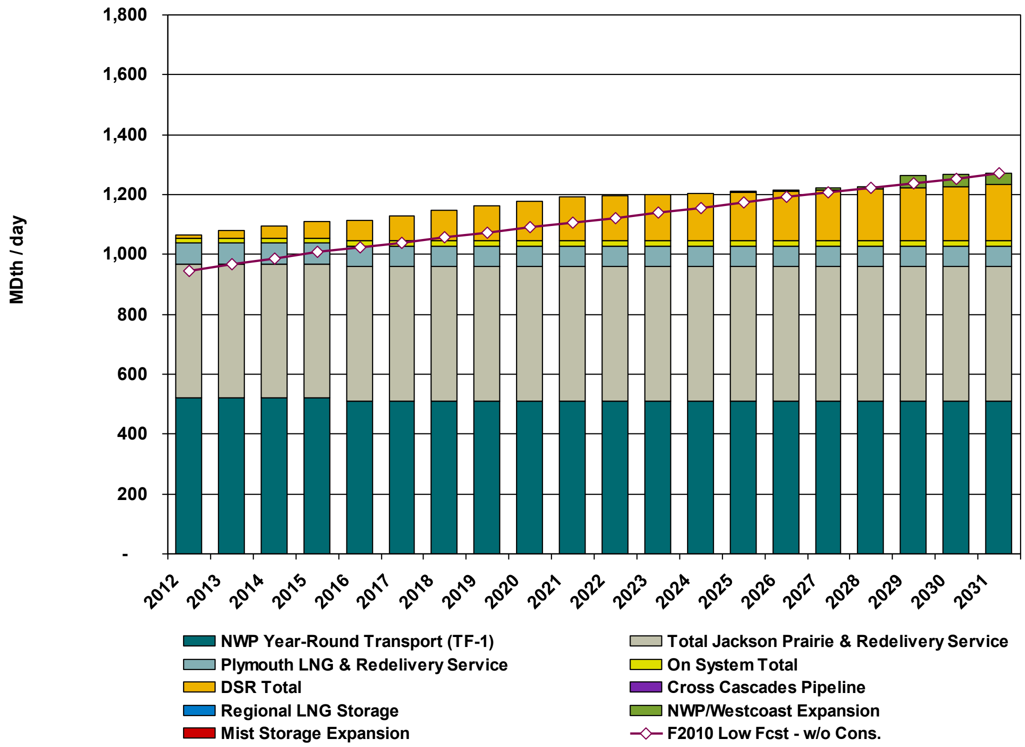


Figure J-9
Very Low Gas Prices Optimal Portfolio – Gas Sales

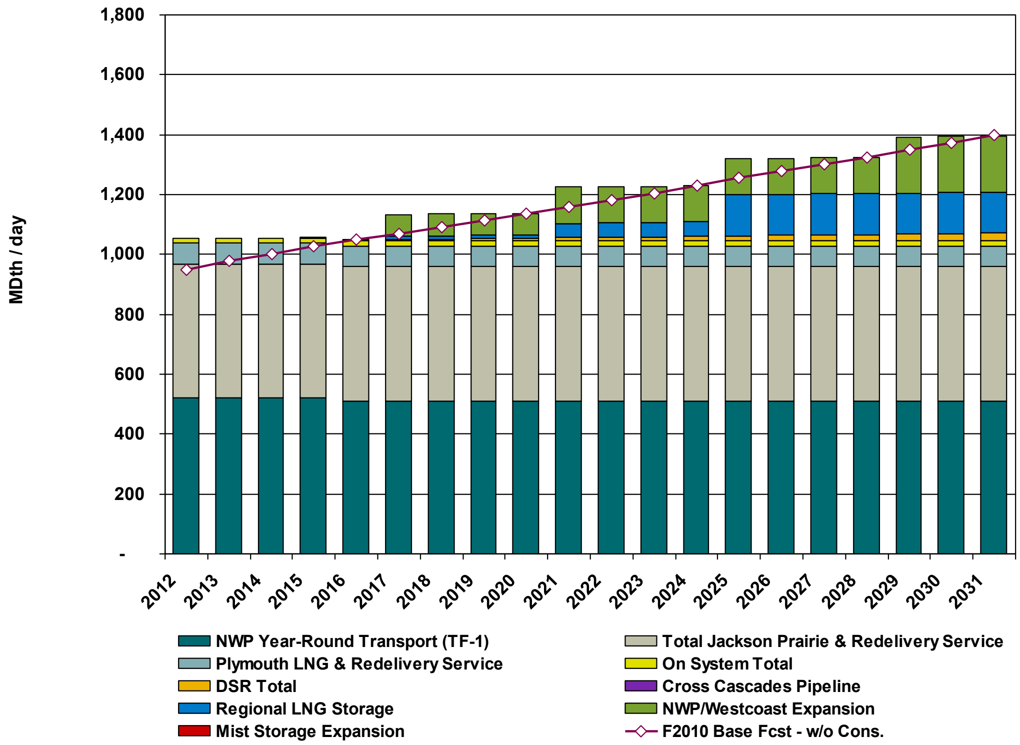


Figure J-10
Very High Gas Prices Optimal Portfolio – Gas Sales

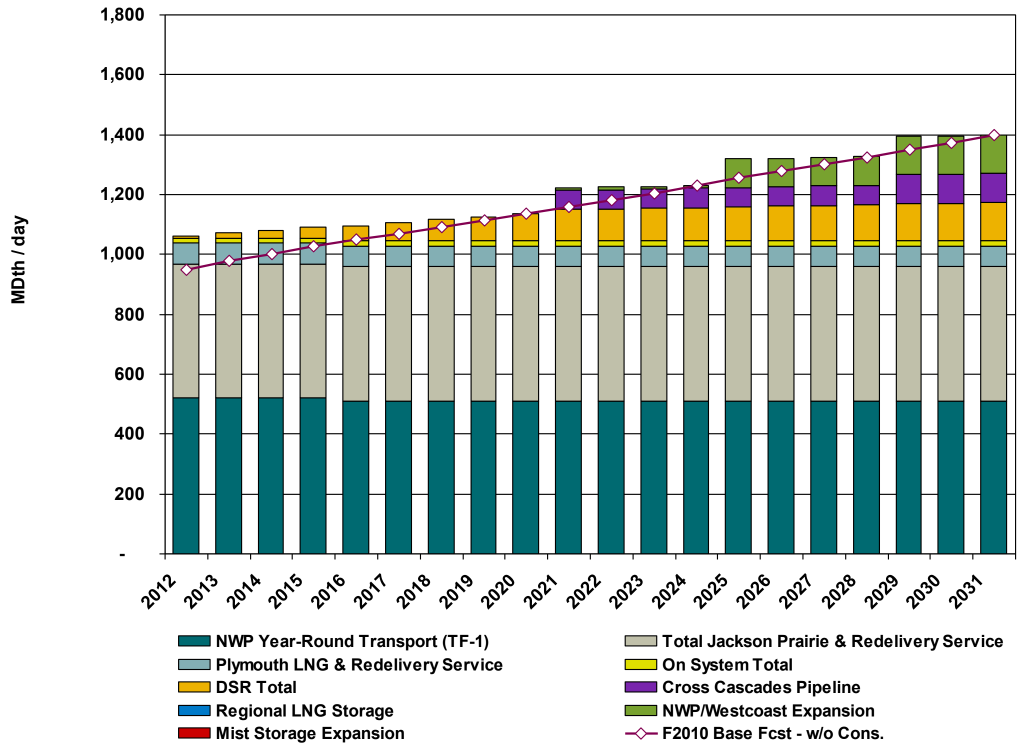


Figure J-11
Base Optimal Portfolio – Combined

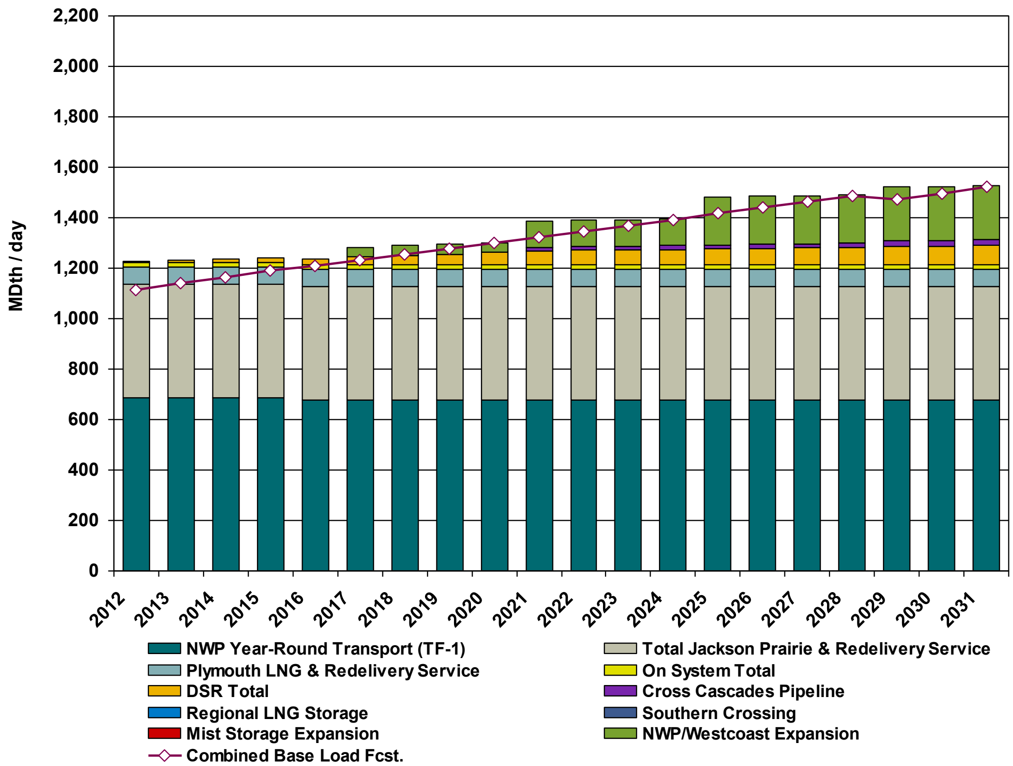


Figure J-12

Base + Thermal Mix Optimal Portfolio – Combined

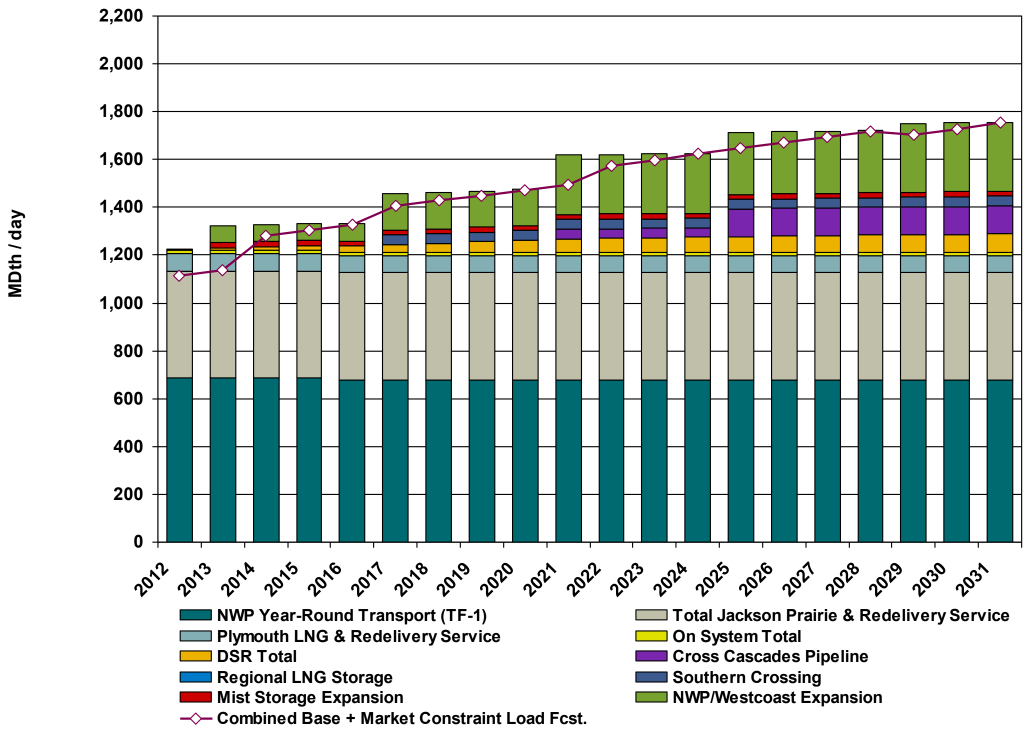
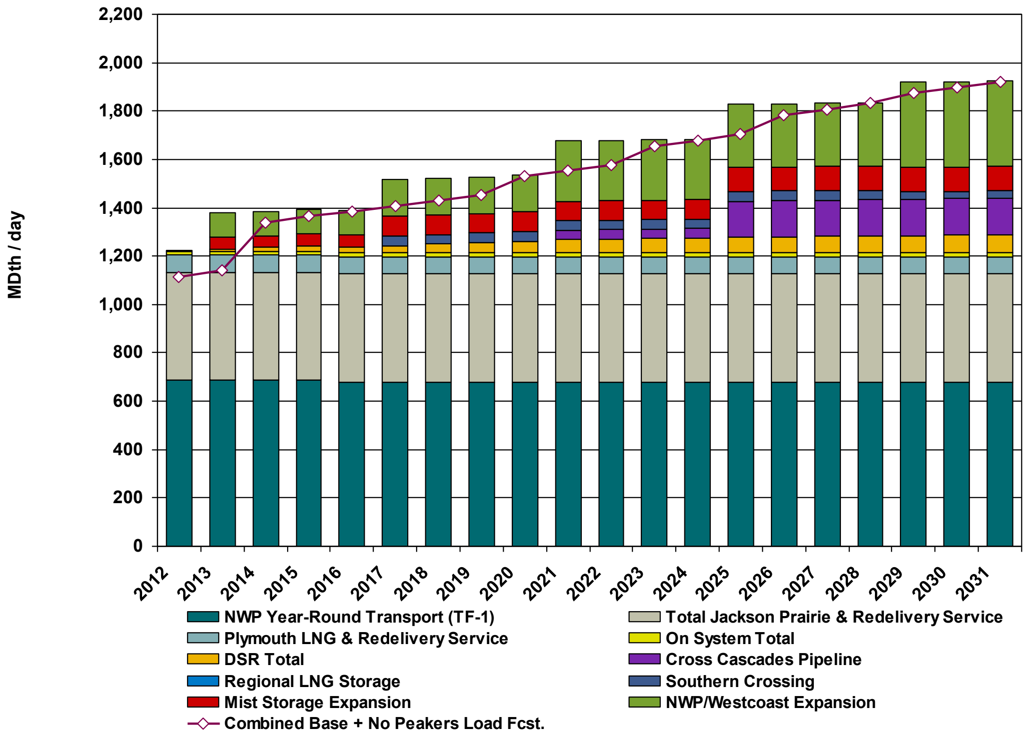


Figure J-13
Base + No Peakers Optimal Portfolio – Combined



3. Portfolio Delivered Gas Costs – Avoided Costs

The average delivered portfolio cost for the gas sales scenarios are shown graphically in Chapter 6. They are presented below in tabular form in Figure J-14. These costs represent the avoided portfolio gas costs. Note however, these costs represent the avoided cost of gas delivered to PSE's system. They do not include the avoided gas distribution system costs.

Figure J-14

Avoided Portfolio Gas Costs ($/Dth)

Year	Base	Base + CO2	Low Growth	High Growth	Green World	Very Low Gas Prices	Very High Gas Prices
2010	7.17	7.71	5.77	8.46	11.27	5.68	8.48
2011	7.67	9.04	6.00	9.22	12.20	5.66	9.52
2012	7.85	9.30	6.27	9.89	13.16	5.64	10.42
2013	8.24	9.85	6.63	10.67	14.21	5.62	11.73
2014	8.62	10.33	6.84	11.44	14.90	5.69	12.54
2015	9.04	10.82	7.20	11.41	15.28	5.77	12.82
2016	9.45	11.48	7.37	11.49	15.84	5.75	13.19
2017	10.11	11.99	7.58	12.03	16.47	5.74	13.80
2018	10.60	12.80	7.72	12.47	17.11	5.82	14.31
2019	11.46	13.81	8.00	13.36	18.26	5.93	15.34
2020	11.77	13.74	8.14	13.52	18.35	5.90	15.68
2021	12.07	14.35	8.29	14.10	18.93	5.88	16.19
2022	11.05	13.57	8.50	14.65	20.23	6.04	16.97
2023	11.72	14.35	8.69	15.21	20.84	6.04	17.70
2024	11.88	14.65	8.92	15.86	22.18	6.09	18.46
2025	12.42	15.72	9.09	16.69	23.02	6.07	19.52
2026	12.82	16.03	9.28	17.05	24.00	6.08	20.06
2027	13.78	17.18	9.56	17.48	25.51	6.21	20.64
2028	14.10	17.65	9.72	17.93	26.22	6.19	21.22
2029	14.44	18.50	9.91	18.46	26.69	6.17	21.97