

CANDIDATE PORTFOLIO ANALYSIS

ANALYSIS OF CANDIDATE RESOURCE PORTFOLIOS

This appendix presents the IRP analysis leading to the selection of a preferred IRP portfolio. Nine optimized candidate portfolios were constructed to meet resource adequacy requirements, RPS requirements, and Seattle City Council policies. Candidate portfolios were tested under different scenarios (stress testing) to identify the top performing portfolios measured by cost and financial risk. Similar to previous IRPs, the higher cost and risk portfolios were eliminated from further consideration and the three top performing portfolios identified as lowest cost and risk underwent additional testing. The top three portfolios were subjected to probabilistic risk analysis that varied key assumptions. After review of the top performing portfolios and consideration of how each meets the objectives for reliability, cost, and environmental responsibility, a preferred portfolio was selected.

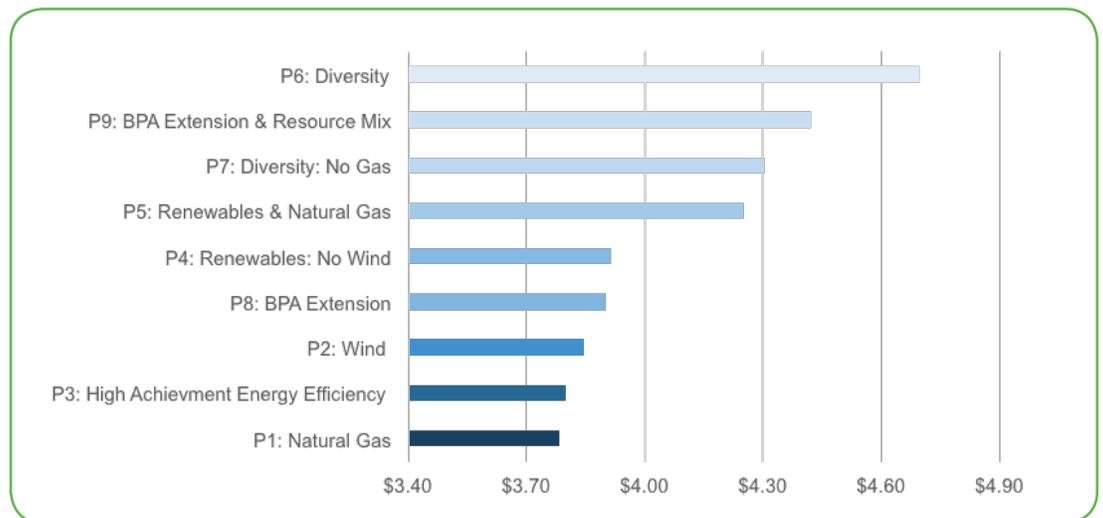
PERFORMANCE MEASURES OF PORTFOLIOS

The quantitative performance of each of the portfolios was evaluated based upon two metrics: cost and financial risk. Cost is measured as the net present value (NPV) of the net power costs (NPC) of the portfolios over the 20-year study period. The net power costs are the total costs of the portfolio, minus the revenues received from any surplus power sales. The net power costs of the portfolio include costs for emissions (if applicable) of carbon dioxide, sulfur dioxide, mercury, and particulates. Financial risk is measured based on the coefficient of variation (CV). CV measures the degree of deviation from the mean and is used to measure the annual volatility cost.

DETERMINISTIC ANALYSIS OF CANDIDATE PORTFOLIOS

First deterministic analyses were conducted on candidate resource portfolios for the years 2016 through 2035 under the expected demand, hydro conditions, fuel prices, and operating constraints. The net present values of the net power costs for each candidate portfolio are illustrated in Figure 1. Details about the resources included in each portfolio are in the Candidate Resource Portfolio Development Appendix. The descriptions in Figure 1 identify unique attributes about the candidate portfolio identified.

Figure 1: Net Present Value of the Net Power Cost by Candidate Resource Portfolios' Expected Conditions

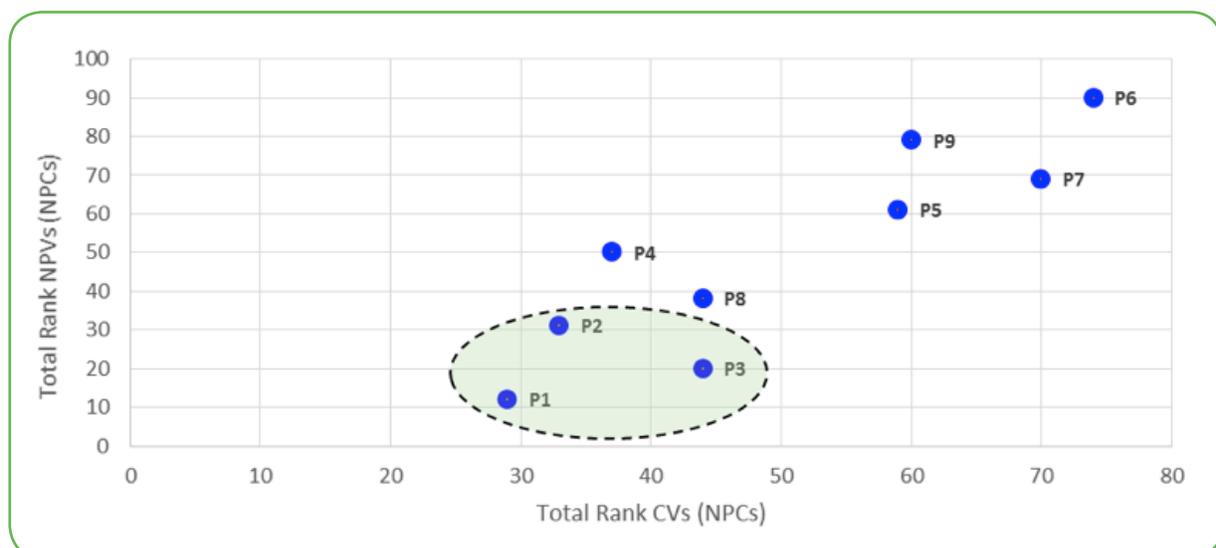


The candidate resource portfolios were further examined under different scenarios to evaluate their performance based on costs and risk measures. This process has resulted in the identification of the top performing portfolios. By performing scenario analysis, further stress testing was performed, analyzing the following nine individual changes from expected conditions:

- Low Demand Growth
- High Demand Growth
- Low Natural Gas Prices
- High Natural Gas Prices
- Low CO2 Prices
- Base CO2 Prices
- High CO2 Prices
- Low Water Conditions
- High Water Conditions

Since City Light's portfolio is 90% hydro, one of the most impactful scenario is low (dry) water conditions. Under such a scenario, Natural Gas (P1), Wind (P2), and High Achievement (P3) portfolios performed the best in comparison with other portfolios in terms of costs and risks. To identify the top performing portfolios, the results of the deterministic runs were ranked based on cost performance and separately ranked based on financial risk performance. The rank order is representative of how well the portfolio performed from a cost perspective (or financial risk perspective) in the 10 deterministic scenarios. If a portfolio was the lowest cost in all ten scenarios, its rank order would equal 10. If a portfolio was highest cost in all ten scenarios, its rank order would be 100. Figure 2 shows the cost vs financial risk performance using the total rank order of the candidate resource portfolios. Taking into consideration the expected results and the scenario analysis, the portfolios that performed the best were Natural Gas (P1), Wind (P2), and High Achievement of Energy Efficiency (P3). P1 having both the least cost and risk, P3 having the second least cost, and P2 having the second least risk.

Figure 2: Total Rank Order of Candidate Resource Portfolios (Cost and Risk)



Based on the preceding analyses, the top three portfolios were identified for further evaluation:

1. P1: Natural Gas
2. P2: Wind
3. P3: High Achievement of Energy Efficiency

All three top portfolios include a new BPA Hydro contract with a modest reduction in the energy purchased compared to the existing BPA contract. Each has similar amounts of reliable and cost-effective market purchase flexibility. At this point, the other portfolios were eliminated.

RISK MEASURE

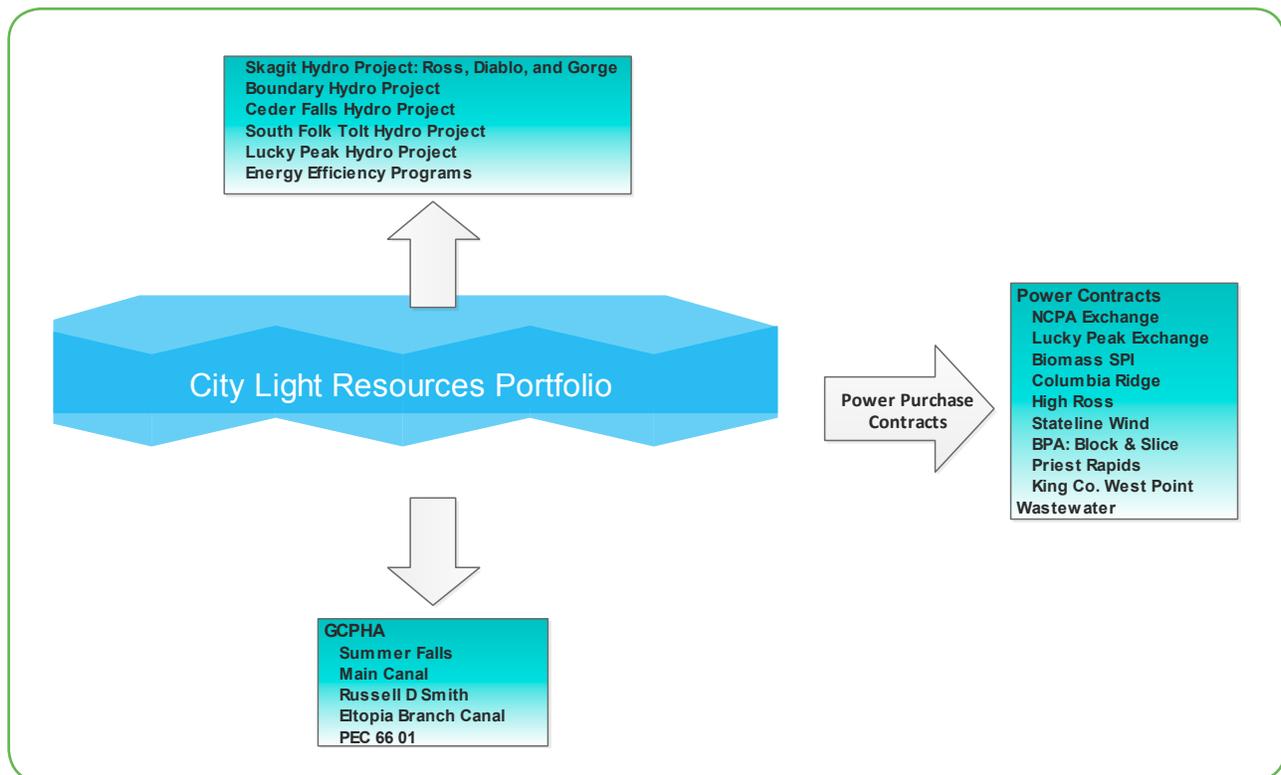
Volumetric risk analysis

Risk refers to the existence of volatilities that can result in adverse events. For Seattle City Light, risk refers to volatilities in supply resources and system load (demand). Volatility can affect City Light's ability to meet customer demand with cost-effective and environmentally-friendly generating resources at all times.

In general, risk analysis uses techniques to identify and assess the factors that cause these volatilities in supply and demand and help to design preventive measures to hedge against possible adverse events, increasing the reliability of City Light's power system.

A resource portfolio is a collection of power generating resources which is owned totally or partially by an entity or an organization. Figure 3 illustrates the elements of City Light's resource portfolio (existing resources).

FIGURE 3: SEATTLE CITY LIGHT RESOURCE PORTFOLIO (EXISTING RESOURCES)



City Light faces two main sources of risk that affect the reliability of its power system:

1. Demand risk is the volatility in customer demand (system load) which challenges City Light's ability to meet these changes in real-time, all the time, and
2. Supply risk is the volatility in the generation capabilities of City Light's power generating resources, which can affect its ability to meet customer demand.

Both of these sources of risk can change the reliability of City Light's power system. If adverse events for supply and demand are encountered singly or simultaneously, countermeasures need to be identified to successfully deal with these events.

City Light has elected to use a 90 percent reliability level of supply resources as the risk measure for meeting customer demand for the 2016 IRP. The volatility of supply and demand is incorporated into the probabilistic analysis for calculating this measure. For each portfolio, the expected net present value of annual net power costs corresponding to the 90 percent level of reliability has been calculated for purposes of evaluating the candidate portfolios.¹

RISK ANALYSIS FOR SEATTLE CITY LIGHT

Developing Risk Metrics for City Light Resource Portfolios

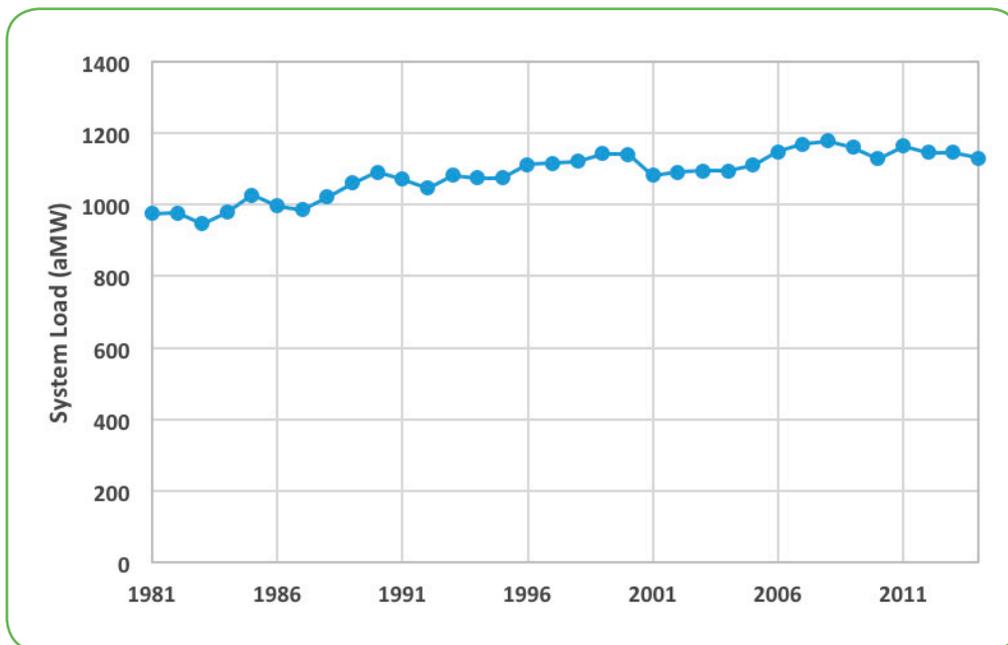
1. Demand, Supply and the Aggregate

a. Demand Risk

Demand volatility is one of the main sources of uncertainty for City Light's power system. On a yearly level, the most significant factor that causes this uncertainty is economic upturns and downturns.²

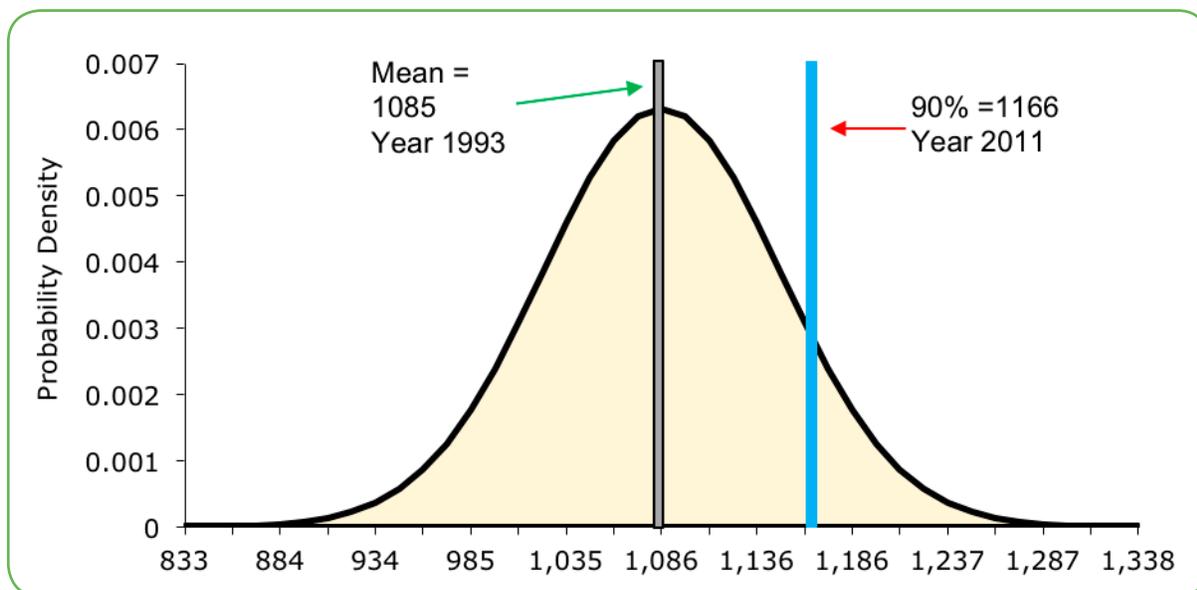
Figure 4 illustrates historical yearly demand data. As demand data moves progressively into more discrete time periods (e.g. annual to monthly to hourly), demand volatility becomes progressively higher.

FIGURE 4: Average yearly system load: 1981-2014



Our analysis concludes that City Light's yearly historical demand approximately follows a normal distribution pattern. A normal distribution, mean, and standard deviation are used for the purpose of simulation. Figure 5 illustrates the normal distribution fitted to the historical yearly demand.

FIGURE 5: Normal (Gaussian) distribution of average yearly historical Seattle City Light demand: 1981-2014

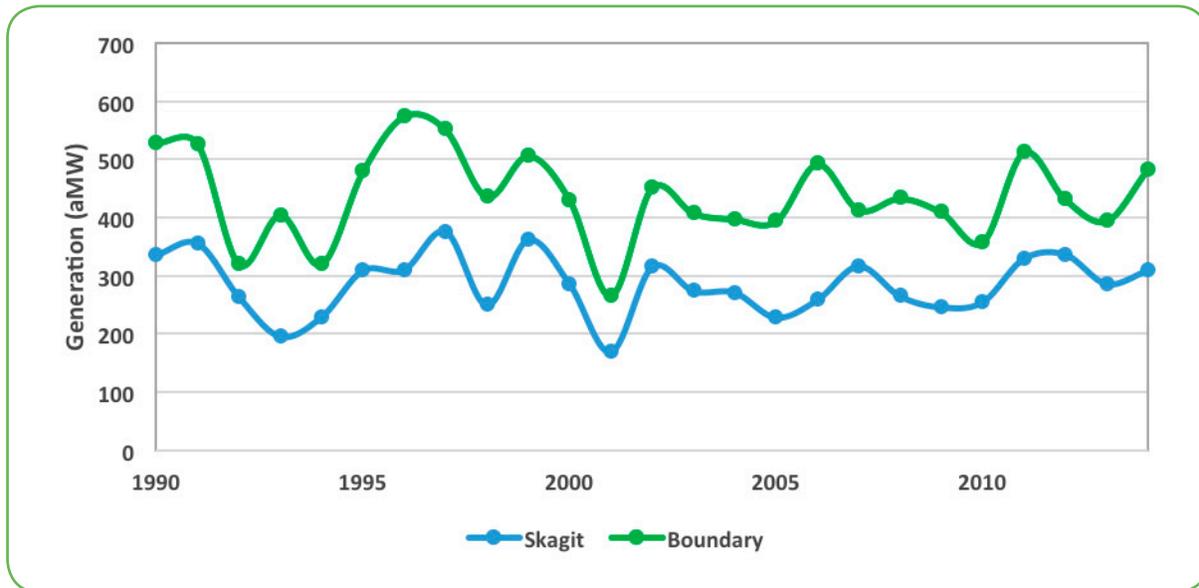


Economic expansions and contractions significantly affect the pattern of electric consumption in all three sectors of City Light customers (industrial, commercial and residential), which causes demand to deviate from expected consumption patterns. City Light completed statistical analyses on historical yearly demand data, 1981 to 2014, and demand volatility (historical variations) has been incorporated into the probability distribution analysis for simulation.

b. Supply Risk

About 90 percent of City Light's electric supply comes from hydro generation in a typical year. Yearly hydro generation capability is highly correlated to water conditions. Water conditions are very uncertain, thus hydro generation capability is very uncertain. This uncertainty in the supply of City Light's power system significantly affects its ability to respond to demand volatility and can affect resource reliability. Figure 6 illustrates historical yearly generation and the associated volatility of City Light's two main hydro projects, Skagit and Boundary, from 1990 to 2014.

FIGURE 6: Average yearly historical generation of Skagit and Boundary: 1990-2014



City Light has completed statistical analyses on yearly historical hydro generation, hydro volatility, and their cross-sectional correlations for Skagit, Boundary, and BPA's hydro resources (Appendix 4 - Resource Adequacy). As with demand, it is assumed that yearly historical hydro generation approximately follows a normal distribution. This assumption is supported by our statistical analysis. The historical mean of hydro generation and the associated standard deviation of each hydro project are taken into account in the probability distribution analysis. Yearly cross-sectional correlations between hydro projects are also taken into account for the total probability distribution analysis. These are incorporated into the probability distribution analysis for the purpose of simulation.

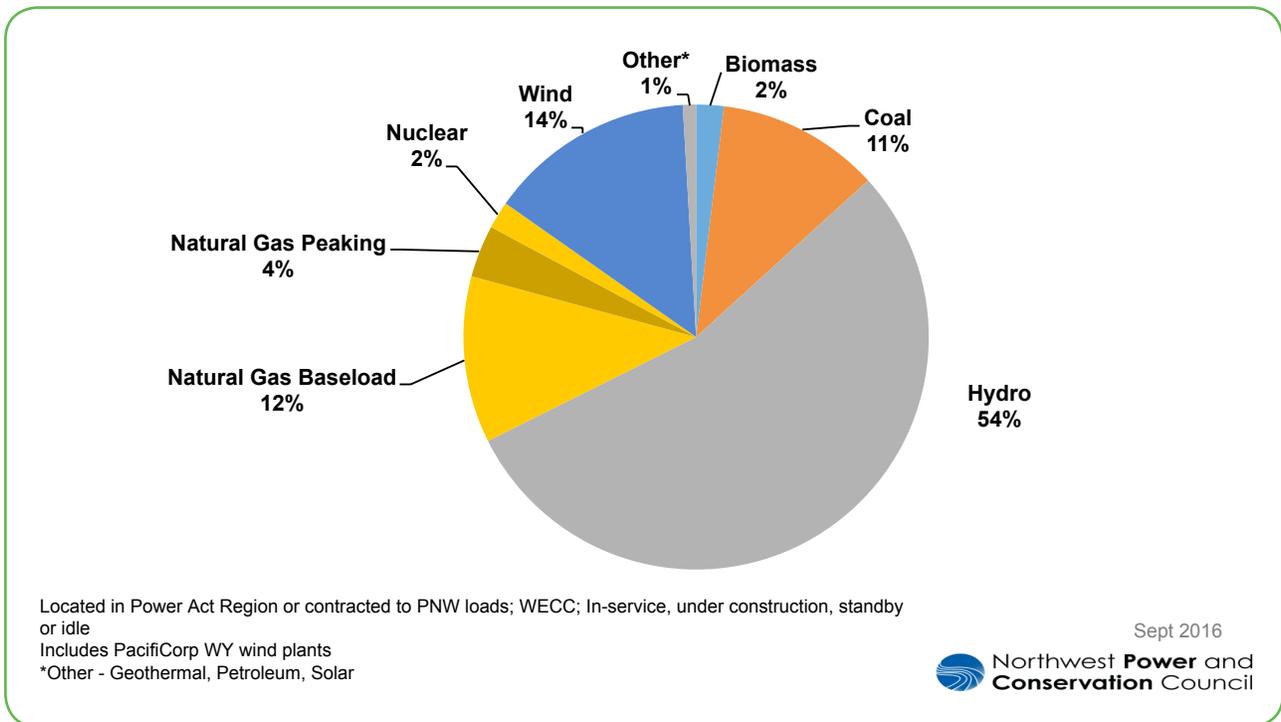
c. The Aggregate of Supply and Demand Uncertainties

If the uncertainties of demand and supply were highly correlated, it would be much easier to manage a balance between demand and supply for City Light's power system (load-resource balance). However, there is almost no correlation between these uncertainties. The simultaneous compositions of these uncertainties cause significant variation in the load-resource balance such that City Light's portfolio changes from surplus to deficit. ($S_T < D_T$) in some hours. The net deficits are associated with financial costs for City Light that accrues when power needs to be acquired from the wholesale market.

2. Fuel

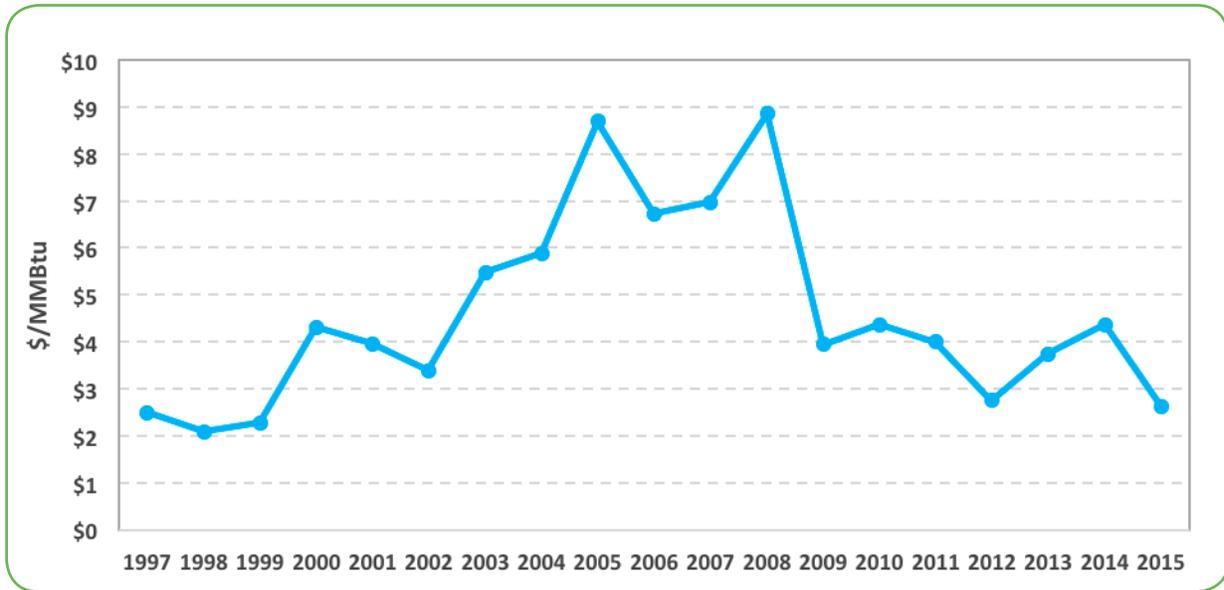
Approximately 50 percent of electric generation capacity in the Pacific Northwest is hydropower (Figure 7). Under current power market conditions, it is assumed that the market price of power is equal to the marginal cost. When market supply is less than market demand, the power prices equal the marginal costs of the incremental generating units that meet demand at any given time. The generic marginal units that are called on to meet demand are most often gas-fired generators such as combustion turbines. Given an average heat rate in the Pacific Northwest, fuel prices determine the average power prices when market supply is less than market demand. Therefore, natural gas prices are a determining factor for the financial costs associated with the net deficits for City Light’s portfolio.

FIGURE 7: NORTHWEST INSTALLED NAMEPLATE CAPACITY - 83,103 MW³



City Light has completed statistical analyses on yearly historical natural gas prices to determine fuel price volatility. Figure 8 illustrates the yearly historical natural gas prices of Henry Hub from 1997 to 2015.

FIGURE 8: Henry Hub historical yearly gas prices: 1997-2015



It is assumed that yearly historical natural gas prices approximately follow a lognormal distribution pattern. Our statistical analysis supports this assumption. A lognormal distribution with the historical mean and associated standard deviation are taken into account in the probability distribution analysis for the purpose of simulation.

The risk function, in abstract form, can be formulated as follows:

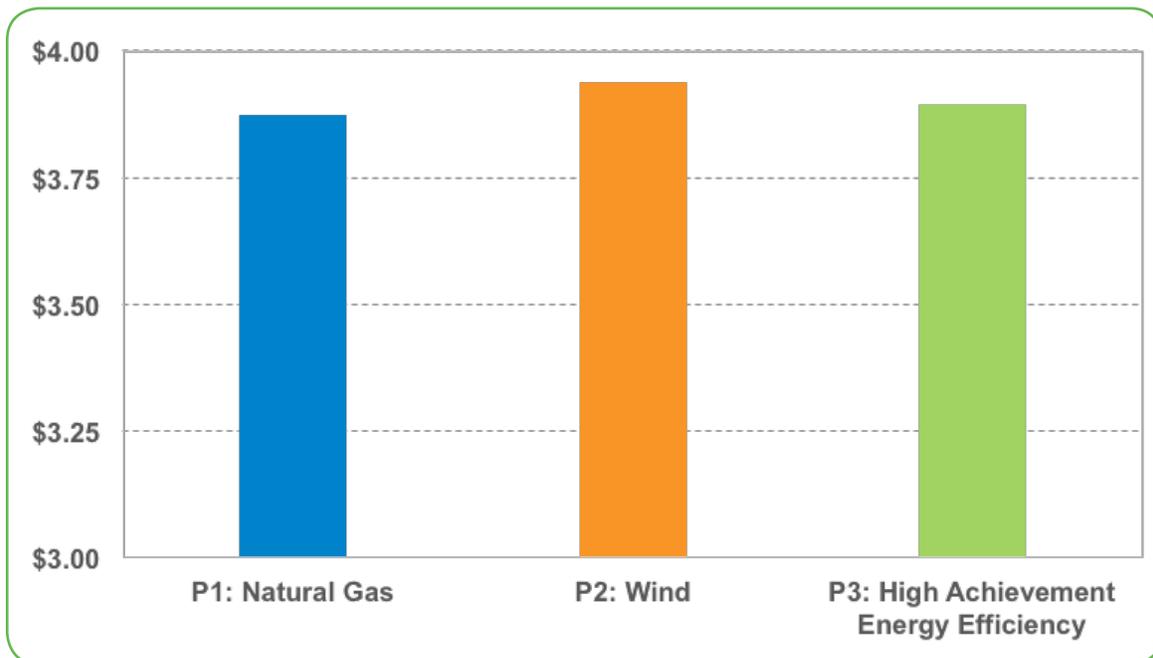
$$Risk_{T_{yr}} = \varphi(D_{T_{yr}}, H_{T_{yr}}, F_{T_{yr}})$$

This function is used to perform risk analysis on the best performing candidate portfolios.

RESULTS

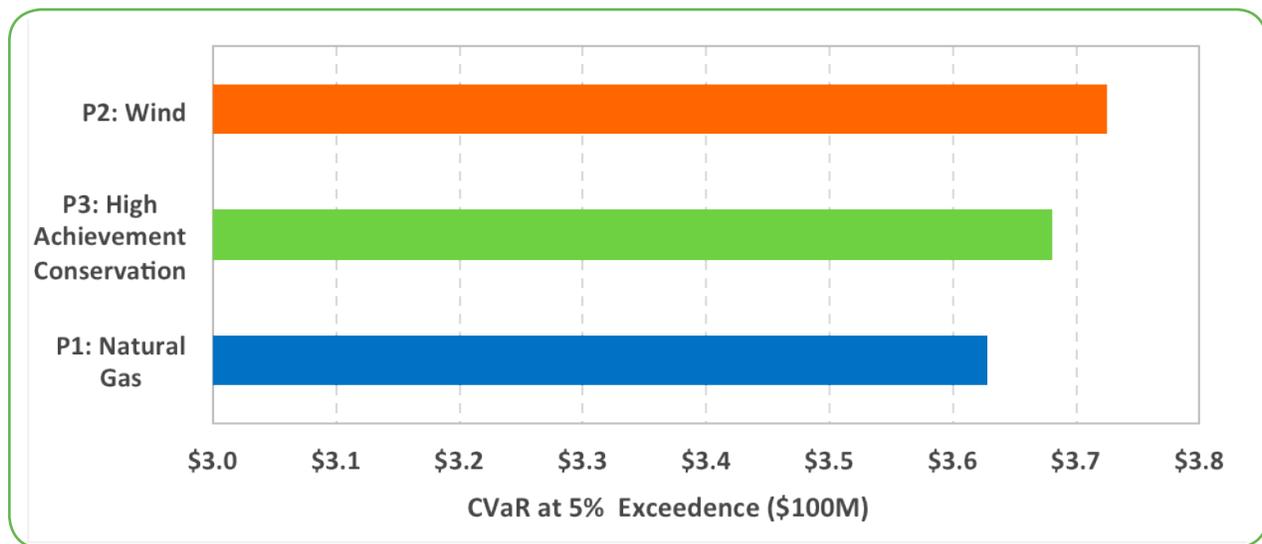
The expected cost of each portfolio is shown in Figure 9. This illustrates that portfolio 2 (Wind) has the highest expected cost.

Figure 9: Net Present Value of Net Power Cost (2016-2035)



City Light has chosen five percent (5%) conditional value at risk to measure the riskiness of the top three portfolios. The conditional value at risk measures the expected net power cost of the portfolios in the worst five percent (5%) of scenarios. It can be seen from Figure 10 that portfolio 2 (Wind) has the highest risk amongst the top three portfolios.

Figure 10: Conditional value at risk (CVaR) of net power costs at 5% exceedance



The final results of stochastic analysis show that the top three portfolios perform similarly. The portfolio that performed the best (marginally) from the cost and risk perspectives (the least cost, lowest risk) is portfolio 1 which includes natural gas fired generation. However, this portfolio is not preferred because of the inclusion of a long-term natural gas resource contract and the exclusion of additional renewable resources. City Council has been clear about its preferences for energy efficiency and renewable resources over fossil fuels and these preferences are identified in City Council Resolutions. For example, City Council Resolution 30144 establishes a preference for cost-effective energy efficiency and renewable resources, and the basis for City Light to offset all of its greenhouse gas emissions from fossil fuels. In 2016, the City Council passed Resolution 31667 includes a provision that opposes the use of fossil fuels.

The second best performing portfolio in terms of cost and risk includes High Achievement of Energy Efficiency portfolio which is also consistent with City policy and the Council resolutions stated above. By the support and approval of City Light's 2016 Integrated Resource Planning Stakeholders and Energy Committee of the City Council, City Light has selected the High Achievement of Energy Efficiency portfolio as the preferred portfolio.

¹ Net Power Cost (NPC) is the sum of the costs of owned power generating resources, power contracts and the difference between market sales and market purchases.

² Extreme weather conditions resulting in very high or low temperatures significantly affect the expected pattern of electricity usage by City Light's customers when monthly studies are done, but it is not as significant as economic conditions when a yearly study is performed.

³ Power Plants in the Pacific Northwest Installed Capacity. Northwest Power & Conservation Council, September 2016. <https://www.nwcouncil.org/energy/powersupply/home/>