

Chapter 8 Risk and Uncertainty Analyses

Stochastic Analysis

With the exception of the portfolios with Compressed Air Energy Storage or Pump Storage resource (Portfolios 42-46), all the portfolios were examined in the stochastic analysis using the PCI GenTrader model. The stochastic runs differ from the intrinsic runs in that the volatility of energy prices is incorporated. Price volatility is modeled as a distribution and sampling function defined by the expected price and the price volatility. Each of the portfolios is run repeatedly. In each pass, the prices are selected from the price distribution. By running a number of iterations, a probability distribution of financial outcomes is derived, allowing the reviewer the opportunity to explore and better understand the range of financial risk a portfolio is exposed to as a result of the uncertain forward wholesale energy markets. These results then lend themselves to a comparison of the unique cost and risk trade offs embodied in each of the portfolios. Since the price volatility only captures shorter-term price movements, the various scenarios for different longer-term trends in energy prices and potential carbon emission adders still need to be reviewed stochastically. Therefore, stochastic runs were performed for High Market-Medium Carbon Tax, Low Market-Medium Carbon Tax, Medium Market-Medium Carbon Tax, Medium Market-Low Carbon Tax, and Medium Market-High Carbon Tax. The results of the stochastic analysis are statistical, producing a range of financial outcomes, a mean, standard deviation, and confidence intervals. The numerical stochastic output has been provided to graphically and quantitatively evaluate cost and risk.

Efficiency Frontier

The Efficiency Frontier is a graphical display of the model output that quantifies the expected financial outcomes of the portfolios along the x-axis and the risk factor (\$/MWh) along the y-axis. The expected financial outcome is computed as the 20-year levelized cost of the supply portfolio in \$/MWh. The risk factor is the 20-year levelized value for the 95% confidence annual costs. Ninety-five

percent confidence annual costs means that 95% of the annual costs derived from the stochastic model for the portfolio are equal to or less than the reported value. The Efficiency Frontier is the leading edge of the scatter plot that is closest to the x- and y-axes, and therefore represents the portfolios that minimize costs and risk. The resulting scatter plots with the efficiency frontiers are shown below for all 5 scenarios:

Figure 8-1, Medium Scenario Efficiency Frontier

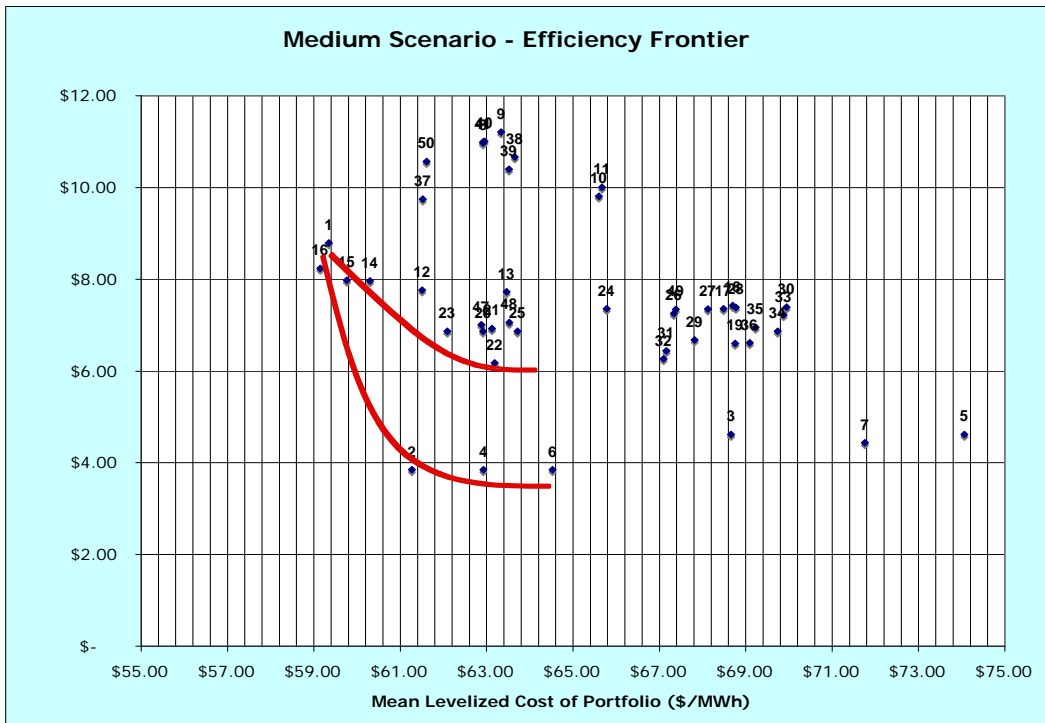


Figure 8-2, Low Carbon Scenario Efficiency Frontier

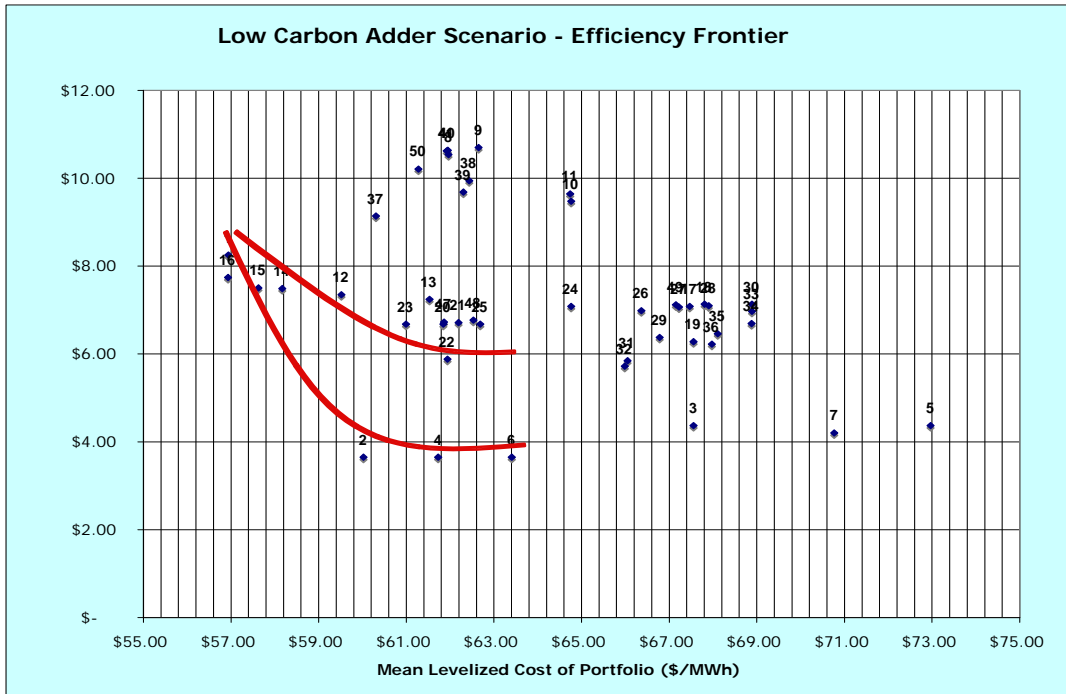


Figure 8-3, High Carbon Scenario Efficiency Frontier

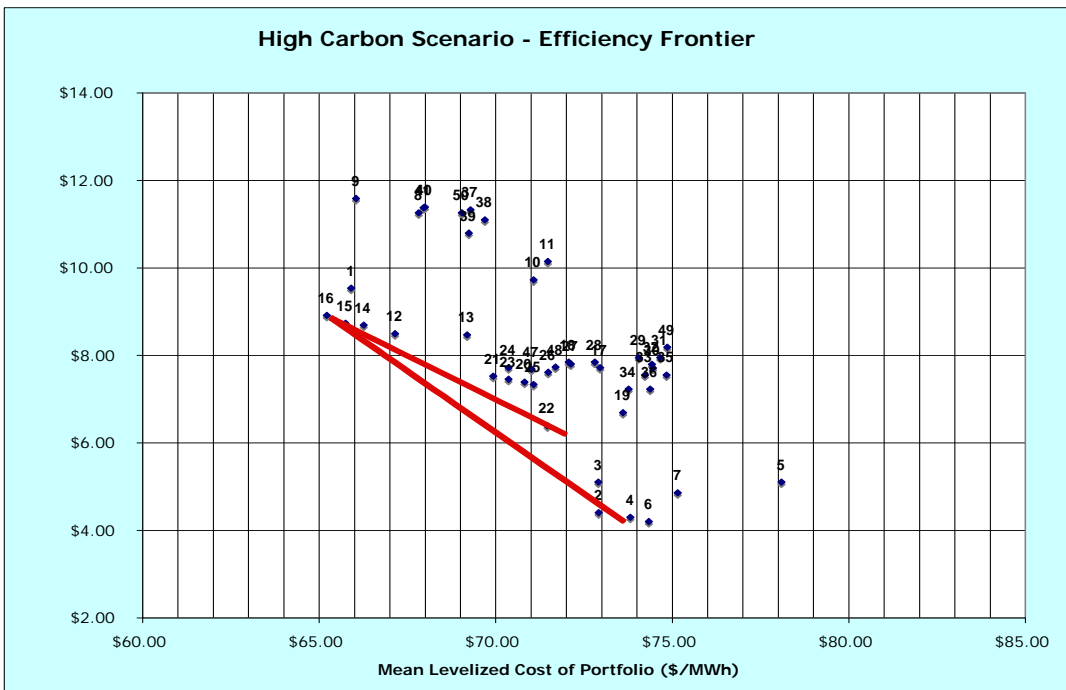


Figure 8-4, Low Market Scenario Efficiency Frontier

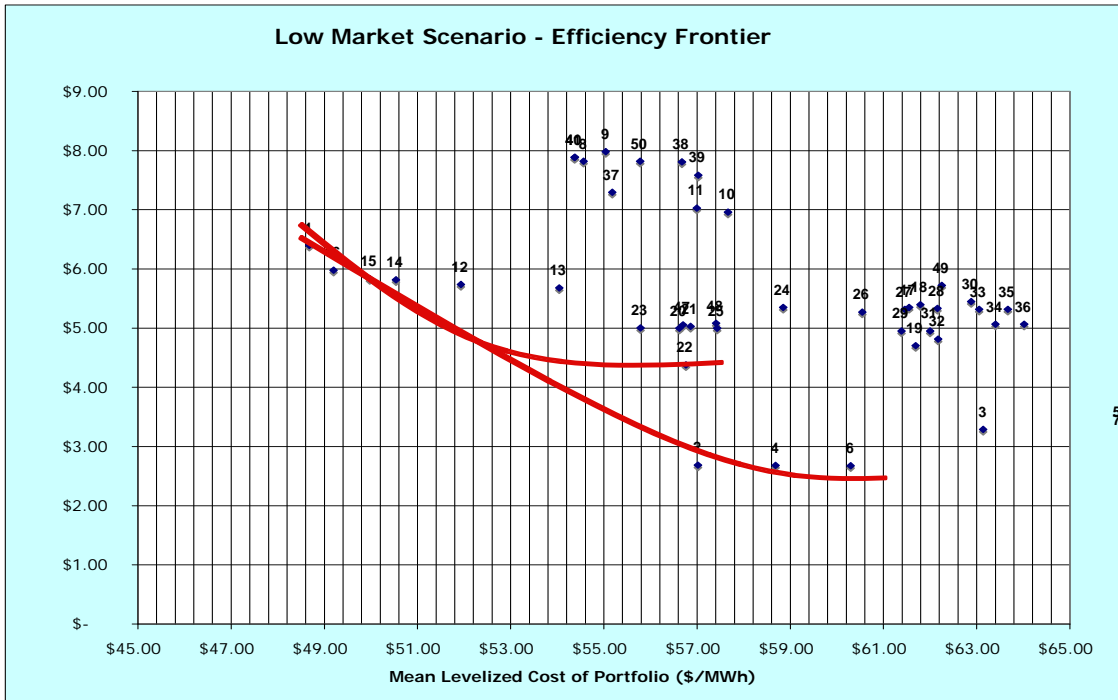
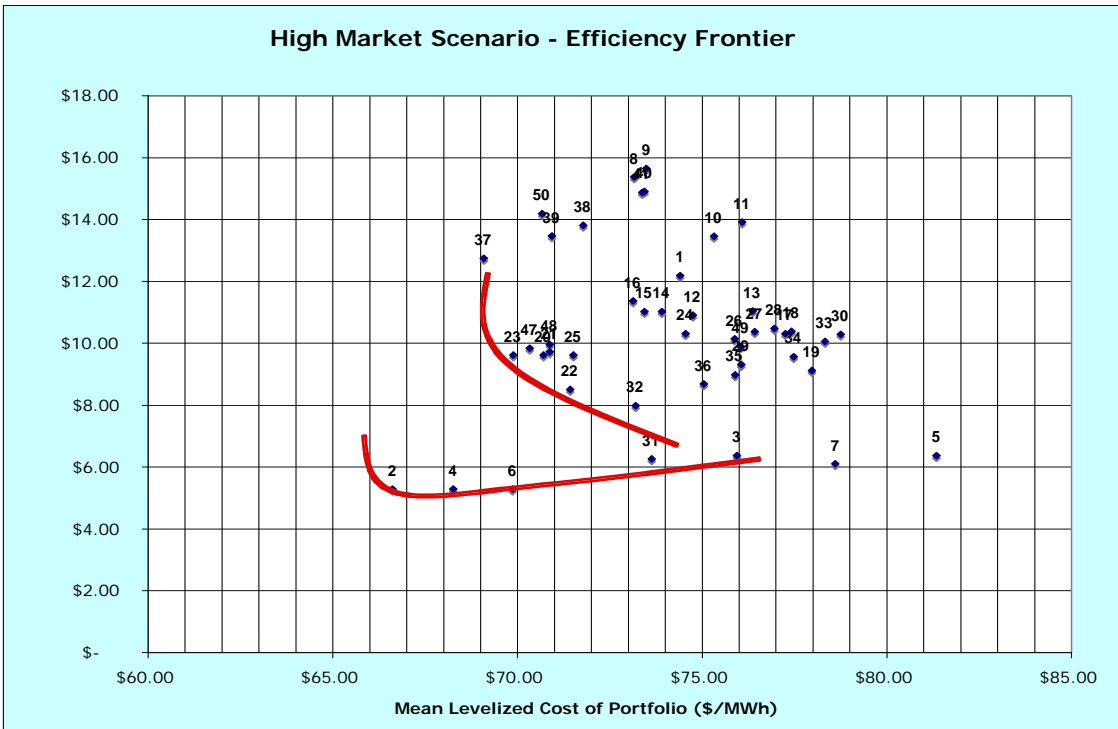


Figure 8-5, High Market Scenario Efficiency Frontier



In the charts, two efficiency frontiers are shown. The lower of the two represents the frontier if the coal-only portfolios (portfolios 2-7 inclusive) are incorporated into the leading edge of the scatter plot. Given the high degree of uncertainty surrounding the potential construction of new coal plants, a second line is shown indicating where the leading edge would be ignoring the coal-dominant portfolios. Note that mixed fuel portfolios – those that combine coal with natural gas resources – were still considered when determining this second line. These two efficiency frontiers show the benefit of the baseload coal resources to mitigate market risk, but the results of the High Carbon Adder scenario make it clear that these coal portfolios, not surprisingly, do not mitigate future carbon adder risk very effectively.

One other approach is to draw the scatter plot and the associated efficiency frontier excluding all portfolios that include any new coal resource that does not employ carbon capture and sequestration technology (Portfolios 1, 4, 6, 20-23, 25, 47, 48). These charts are displayed on the following pages.

Figure 8-6, Medium No Coal Scenario Efficiency Frontier

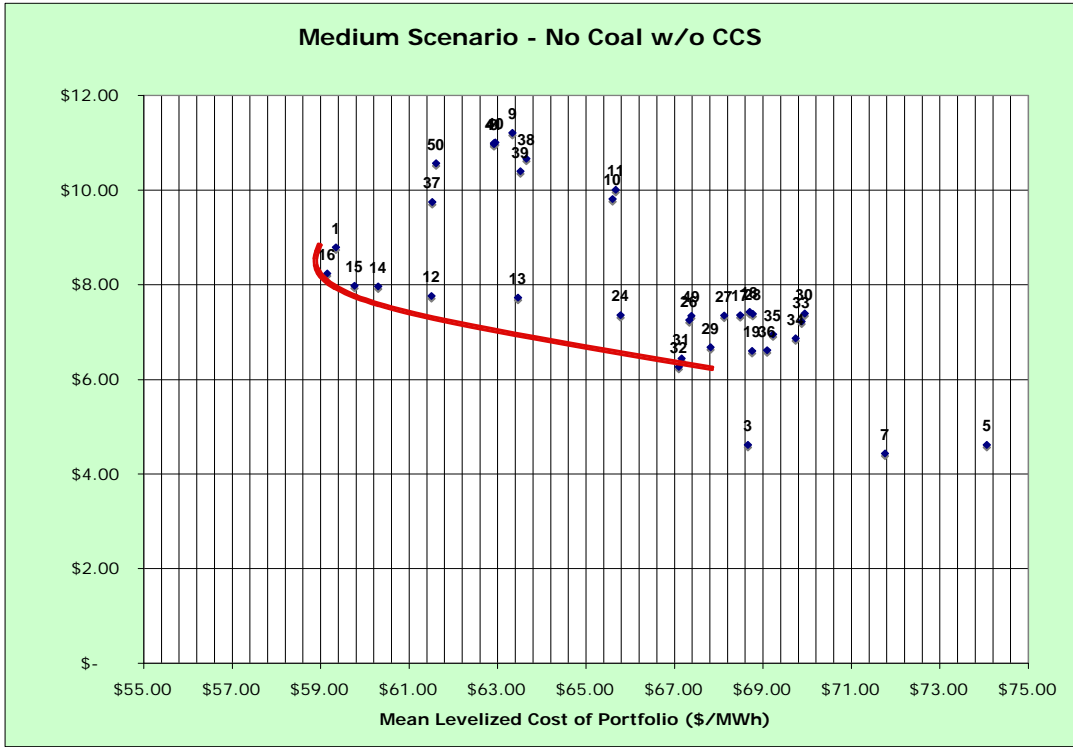


Figure 8-7, Low Carbon No Coal Scenario

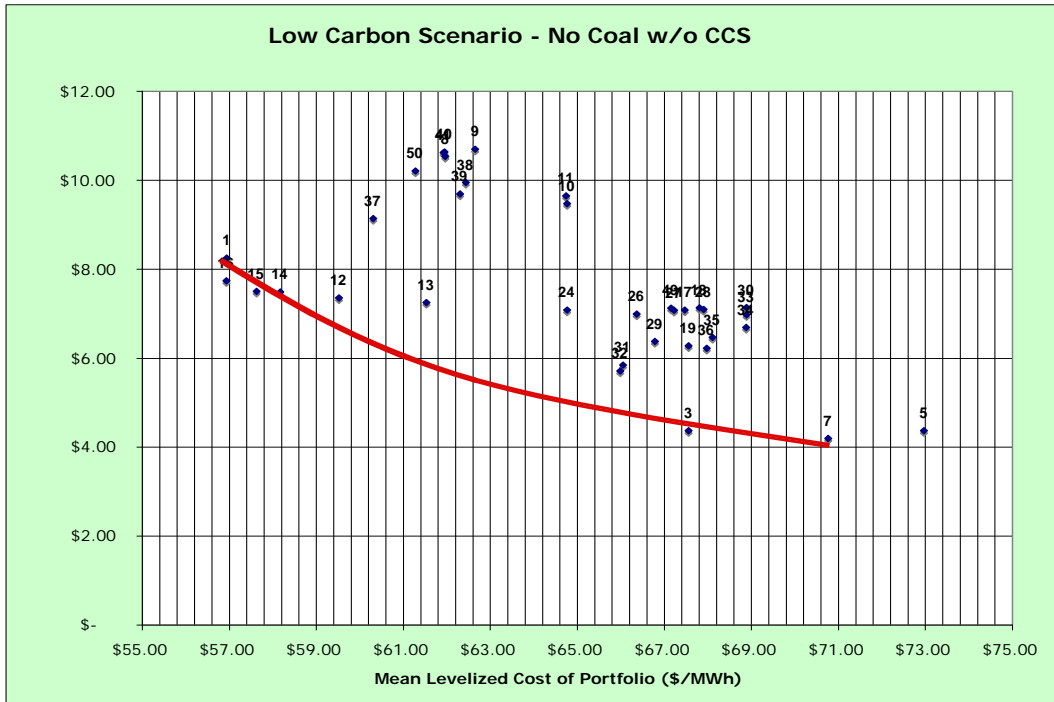


Figure 8-8, High Carbon No Coal Scenario

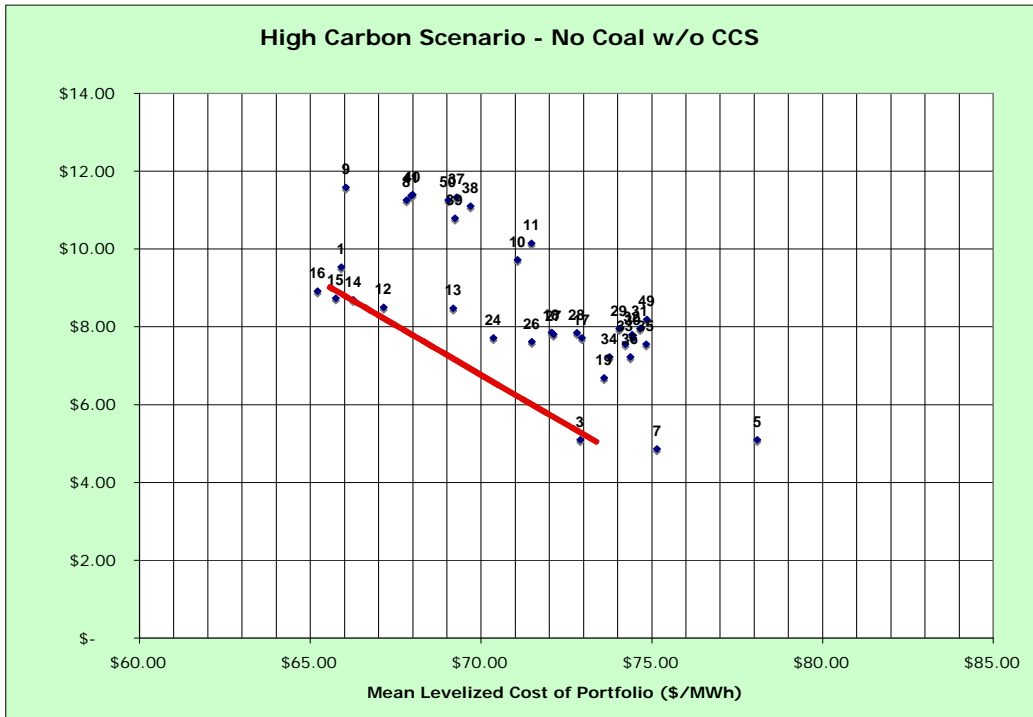


Figure 8-9, Low Market No Coal

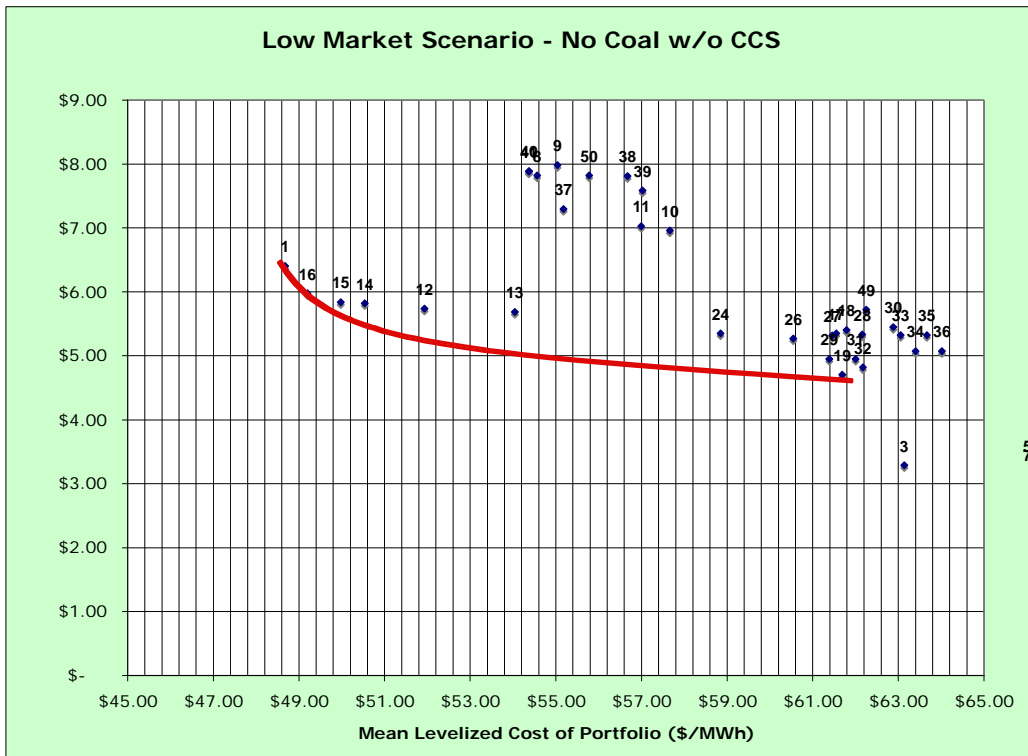
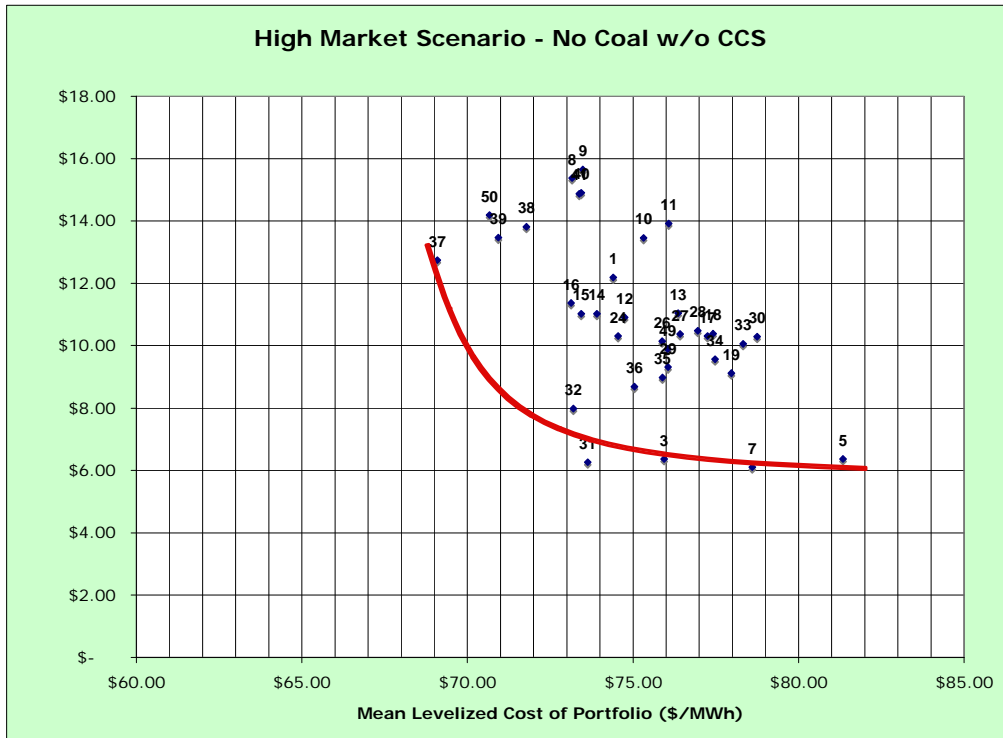


Figure 8-10, High Market No Coal



Stochastic Results

In reviewing these portfolio results, it is helpful to summarize the results in a table displaying the portfolios on the efficiency frontiers in the various scenarios. The table below displays the lowest cost portfolios (upper left), and the lowest risk portfolios (lower right) on the efficiency frontier in each case:

Table 8-1, Lowest Cost Portfolios

Scenario	All Portfolios		<u>Exclude PF using only Coal⁴</u>		<u>Exclude all Coal w/o Capture⁵</u>	
	Low Cost	Low Risk	Low Cost	Low Risk	Low Cost	Low Risk
Basecase	16, 1, 15	2, 4, 6	16, 1, 15	22, 23, 20	16,1,15	3, 32
Low Carbon	16, 1, 15	2, 4, 6	16, 1, 15	23, 22	1, 16, 15	3
High Carbon	16, 15, 1	2, 3, 4	16, 15, 1	22	16, 15, 1	3
Low Market	1, 16, 15, 14	2, 4, 6	1, 16, 15, 14	22, 23, 20	1, 16, 15, 14	3
High Market	2, 4, 6	2, 4, 6	37, 23, 47, 22	31, 32, 22	37	31, 32, 3

In general, there is a cost/risk tradeoff that favors the lower cost portfolios with a moderate amount of increased risk in all these cases. When considering the trade-off of cost vs. risk between the upper left end of the efficiency frontier and the lower right, and the slope of the efficiency frontier in between, it seems that the supply portfolio costs would be better managed by driving down the expected cost for a moderate increase in risk exposure.

As an example of this consideration, note the comparative results for portfolios 16 and 23. Both portfolios have wind and a generic regulating resource. In addition, portfolio 23 has 250 MW of conventional coal and 200 MW of combined cycle CT, while portfolio 16 relies strictly on market to meet the balance of the default load. In the base case scenario, there is nearly a \$3.00/MWh increase in cost between portfolios 16 and 23, while there is only a \$1.40/MWh decrease in risk. What this means is that portfolio 16 is subject to price swings resulting from market volatility that can add as much as \$1.40/MWh in a year more than would result in portfolio 23, but the overall cost is \$3.00/MWh lower. As long as the

⁴ Excluding PF using only Coal – This efficiency frontier ignored the results for portfolios 2-7 that only added coal resources to the resource mix.

⁵ Exclude all Coal w/o Capture - This efficiency frontier disregarded any portfolio that had any new coal generation without capture and sequestration technology. This includes Portfolios 2, 4, 6, 20-23, 25, and 47-48.

utility can absorb occasional higher cost variability of portfolio 16, it would be least costly in the long run. Of course, there are some other risk factors to consider in selecting Portfolio 16. Since this Portfolio relies almost entirely on market – only adding enough renewable and regulating resources to reliably meet the Montana RPS standard, it is vulnerable to scenarios where energy prices turn out to be significantly higher in the long-term than are projected in the basecase scenario. In reviewing the High Market scenario, Portfolio 16 is now on average \$3.00/MWh higher than Portfolio 23, and Portfolio 23 retains its lower risk profile at the same time – again by about \$1.00/MWh. Basically, when considering portfolio 23 against 16, portfolio 16 is significantly lower in cost in all the scenarios with a moderate increase in risk, except that portfolio 16 leaves a larger risk exposure to longer-term high cost market trends.

It is also helpful to summarize the results into the RiskVAR90 variable used in the last plan. The RiskVar90 combines the expected financial results and the risk variable into a single score by weighting the mean expected outcome at 70% weighting and the 95% confidence outcome at 30% weighting. These single scores can then be reviewed a little easier than considering the two-dimensional display of the efficiency frontiers. The results are shown on the following page:

Figure 8-11: Risk VAR90 for Stochastic Results:

PF Description	Base Case	Low Carbon	High Carbon	Low Market	High Market	Weighted Avg.	Range
1 No Resources	\$ 61.98	\$ 59.41	\$ 68.76	\$ 50.59	\$ 78.06	\$ 65.84	\$ 27.47
2 PV Sub	\$ 62.43	\$ 61.12	\$ 74.24	\$ 57.82	\$ 68.20	\$ 66.53	\$ 16.41
3 PV Sub w/ CCS	\$ 70.05	\$ 68.86	\$ 74.43	\$ 64.13	\$ 77.85	\$ 72.21	\$ 13.72
4 PV Super	\$ 64.08	\$ 62.82	\$ 75.10	\$ 59.49	\$ 69.85	\$ 67.95	\$ 15.62
5 PV Super w/ CCS	\$ 75.45	\$ 74.28	\$ 79.62	\$ 69.53	\$ 83.26	\$ 77.55	\$ 13.72
6 IGCC	\$ 65.68	\$ 64.50	\$ 75.60	\$ 61.09	\$ 71.45	\$ 69.23	\$ 14.50
7 IGCC s/ CCS	\$ 73.09	\$ 72.02	\$ 76.61	\$ 67.47	\$ 80.44	\$ 74.95	\$ 12.96
8 CCCT	\$ 66.21	\$ 65.13	\$ 71.19	\$ 56.91	\$ 77.77	\$ 68.98	\$ 20.87
9 CCCT w/ CCS	\$ 66.70	\$ 65.86	\$ 69.52	\$ 57.43	\$ 78.18	\$ 68.83	\$ 20.74
10 CHP	\$ 68.55	\$ 67.61	\$ 73.99	\$ 59.75	\$ 79.35	\$ 71.37	\$ 19.60
11 Oil Sands	\$ 68.67	\$ 67.63	\$ 74.52	\$ 59.10	\$ 80.26	\$ 71.68	\$ 21.16
12 SCCT Frame	\$ 63.84	\$ 61.72	\$ 69.70	\$ 53.65	\$ 78.02	\$ 67.20	\$ 24.36
13 Aero	\$ 65.78	\$ 63.71	\$ 71.73	\$ 55.75	\$ 79.67	\$ 69.13	\$ 23.92
14 IC	\$ 62.68	\$ 60.42	\$ 68.87	\$ 52.28	\$ 77.22	\$ 66.18	\$ 24.94
15 LM	\$ 62.16	\$ 59.87	\$ 68.37	\$ 51.73	\$ 76.74	\$ 65.66	\$ 25.01
16 Renewable for RPS only	\$ 61.62	\$ 59.25	\$ 67.89	\$ 50.99	\$ 76.54	\$ 65.19	\$ 25.55
17 Super w/ CCS,CCCT	\$ 70.69	\$ 69.59	\$ 75.27	\$ 63.16	\$ 80.35	\$ 73.13	\$ 17.19
18 Super w/ CCS, CCCT w/ CCS	\$ 70.92	\$ 69.95	\$ 74.42	\$ 63.41	\$ 80.53	\$ 73.05	\$ 17.12
19 Super w/ CCS, CHP	\$ 70.73	\$ 69.44	\$ 75.61	\$ 63.10	\$ 80.70	\$ 73.30	\$ 17.60
20 Super, CCCT	\$ 64.97	\$ 63.85	\$ 73.03	\$ 58.12	\$ 73.60	\$ 68.32	\$ 15.48
21 Super, CCCT w/ CCS	\$ 65.20	\$ 64.20	\$ 72.18	\$ 58.37	\$ 73.79	\$ 68.23	\$ 15.42
22 Super, CHP	\$ 65.03	\$ 63.71	\$ 73.38	\$ 58.08	\$ 73.98	\$ 68.50	\$ 15.90
23 PV Sub, CCCT	\$ 64.15	\$ 63.00	\$ 72.60	\$ 57.29	\$ 72.77	\$ 67.61	\$ 15.48
24 PV Sub w/ CCS, CCCT	\$ 67.99	\$ 66.88	\$ 72.67	\$ 60.45	\$ 77.64	\$ 70.46	\$ 17.19
25 IGCC, CCCT	\$ 65.78	\$ 64.69	\$ 73.28	\$ 58.93	\$ 74.40	\$ 68.96	\$ 15.47
26 IGCC w/ CCS, CCCT	\$ 69.51	\$ 68.46	\$ 73.77	\$ 62.13	\$ 78.92	\$ 71.83	\$ 16.80
27 IGCC w/ CCS, CCCT, Fram	\$ 70.32	\$ 69.35	\$ 74.47	\$ 63.05	\$ 79.53	\$ 72.58	\$ 16.48
28 IGCC w/ CCS, CCCT, Aero	\$ 70.99	\$ 70.03	\$ 75.16	\$ 63.76	\$ 80.10	\$ 73.24	\$ 16.34
29 Biomass, Super w/ CCS, CCCT	\$ 69.81	\$ 68.69	\$ 76.43	\$ 62.87	\$ 78.85	\$ 72.80	\$ 15.98
30 Biomass, Super w/ CCS, CCCT	\$ 72.16	\$ 71.03	\$ 76.76	\$ 64.51	\$ 81.84	\$ 74.60	\$ 17.33
31 Bio, Geo, Super w/ CCS, CCCT	\$ 69.09	\$ 67.81	\$ 77.04	\$ 63.48	\$ 75.51	\$ 72.07	\$ 13.56
32 Bio, Geo, Wind, Super w/ CCS, CCCT	\$ 68.97	\$ 67.70	\$ 76.77	\$ 63.62	\$ 75.60	\$ 71.97	\$ 13.15
33 Bio, Wind, Super w/ CCS, CCCT	\$ 72.04	\$ 70.98	\$ 76.49	\$ 64.65	\$ 81.35	\$ 74.39	\$ 16.70
34 Bio, Wind, Super w/ CCS, CCCT	\$ 71.80	\$ 70.89	\$ 75.94	\$ 64.93	\$ 80.35	\$ 73.97	\$ 15.42
35 Bio, Geo, Wind, Super w/ CCS, CCCT	\$ 71.31	\$ 70.05	\$ 77.10	\$ 65.26	\$ 78.59	\$ 73.77	\$ 13.33
36 Bio, Geo, Wind, Super w/ CCS, CCCT	\$ 71.08	\$ 69.84	\$ 76.55	\$ 65.54	\$ 77.65	\$ 73.35	\$ 12.11
37 Bio, Geo, Wind, CCCT	\$ 64.45	\$ 63.05	\$ 72.69	\$ 57.37	\$ 72.91	\$ 67.76	\$ 15.54
38 Bio, Geo, Wind, CCCT	\$ 66.85	\$ 65.42	\$ 73.02	\$ 59.02	\$ 75.93	\$ 69.59	\$ 16.91
39 Bio, Geo, Wind, CCCT	\$ 66.63	\$ 65.21	\$ 72.48	\$ 59.30	\$ 74.97	\$ 69.18	\$ 15.67
40 Wind, Solar, CCCT	\$ 66.25	\$ 65.14	\$ 71.42	\$ 56.75	\$ 77.91	\$ 69.07	\$ 21.16
41 Wind, Solar, CCCT	\$ 66.22	\$ 65.11	\$ 71.37	\$ 56.74	\$ 77.84	\$ 69.03	\$ 21.10
47 PV Sub, CCCT, Fram	\$ 64.98	\$ 63.88	\$ 73.31	\$ 58.22	\$ 73.28	\$ 68.35	\$ 15.10
48 PV Sub, CCCT, Aero	\$ 65.64	\$ 64.56	\$ 74.01	\$ 58.93	\$ 73.86	\$ 69.02	\$ 15.08
49 Geo, Super w/ CCS, CCCT	\$ 69.59	\$ 69.29	\$ 77.31	\$ 63.96	\$ 79.02	\$ 73.20	\$ 15.05
50 Geo, Wind, CCCT	\$ 64.78	\$ 64.34	\$ 72.41	\$ 58.13	\$ 74.92	\$ 68.39	\$ 16.79
<i>Weighting</i>	<i>30%</i>	<i>10%</i>	<i>30%</i>	<i>10%</i>	<i>20%</i>		

The RiskVAR90 results clearly show some of the various trade-offs between the portfolios in the different scenarios evaluated. Generally, the portfolios with a significant amount of new conventional coal generation are cost effective compared with other alternatives, except when the high carbon costs-adder scenario is considered. The costs to mitigate carbon emissions pushes these resources into the higher end of the cost range and highlights the risks associated with these portfolios given the current uncertainty regarding coal emission regulations and potential for new taxes or caps on emissions.

From NorthWestern's perspective, it appears that while the addition of new coal generation could help to stabilize cost volatility of the default supply portfolio resulting from short-term market volatility, the overriding and larger risk exposure presented by likely eminent government regulation of carbon emissions makes the inclusion of additional coal resources in the preferred portfolio untenable. NorthWestern has made a policy judgment to not pursue coal development absent further policy guidance. NorthWestern believes that Montana policy-makers should play a significant role and can expedite resource decisions even in advance of the likely federally mandated carbon adder requirements.