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The Cost of Geothermal Energy in the Western US Region: A Portfolio-Based Approach

A Mean-Variance Portfolio Optimization of the Region's Generating Mix to 2013

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Abstract

Energy planning represents an investment-decision problem. Investors commonly evaluate such problems using portfolio theory to manage risk and maximize portfolio performance under a variety of unpredictable economic outcomes. Energy planners need to similarly abandon their reliance on traditional, "least-cost" *stand-alone* technology cost estimates and instead evaluate conventional and renewable energy sources on the basis of their *portfolio cost*— their cost contribution relative to their risk contribution to a mix of generating assets.

This report describes essential portfolio-theory ideas and discusses their application in the Western US region. The memo illustrates how electricity-generating mixes can benefit from additional shares of geothermal and other renewables. Compared to fossil-dominated mixes, *efficient* portfolios reduce generating cost while including greater renewables shares in the mix. This enhances energy security. Though counter-intuitive, the idea that adding more costly geothermal can actually reduce portfolio-generating cost is consistent with basic finance theory. An important implication is that in dynamic and uncertain environments, the relative value of generating technologies must be determined not by evaluating alternative *resources*, but by evaluating alternative *resource portfolios*.

The optimal results for the Western US Region indicate that compared to the EIA target mixes, there exist generating mixes with larger geothermal shares at equal-or-lower expected cost and risk.

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"Least-Cost" Versus Portfolio-Based Approaches in Generation Planning

Geothermal and other renewables provide clean generating alternatives, and hence offer effective mechanisms to help climate change mitigation but policy makers are concerned because of the widespread perception that increasing their deployment will raise the overall cost of generating electricity.

In the US, electricity capacity expansion planning, though conducted under Integrated Resource Planning procedures, is still largely based on *least-cost* principles, under which planners evaluate generating alternatives using their stand-alone costs.[1] Least-cost may have worked sufficiently well in previous technological eras, marked by relative cost certainty, low rates of technological progress, technologically homogeneous generating alternatives and stable energy prices [Awerbuch, 1995a]. Today's electricity planner faces a broadly diverse range of resource options and a dynamic, complex, and uncertain future. Attempting to identify least-cost alternatives in this environment is virtually impossible [Awerbuch, 1996].

Financial investors are used to dealing with uncertainty. They have learned that a diversified asset portfolio provides the best means of hedging future risk and therefore evaluate individual investments in terms of their portfolio effects. Given today's uncertainty about future technology cost and performance, it makes sense to also shift electricity planning from its current emphasis of evaluating alternative technologies, to evaluating alternative generating portfolios and strategies. Mean-variance portfolio (MVP) theory is highly suited to the problem of planning and evaluating US electricity portfolios and strategies.[2]

MVP principles evaluate conventional and renewable alternatives not on the basis of their *stand-alone* cost, but on the basis of their portfolio cost— i.e.: their contribution to overall portfolio generating cost relative to their contribution to overall portfolio risk. At any given time, some alternatives in the portfolio may have higher costs while others have lower costs, yet over time, the astute combination of resources serves to minimize overall expected generation cost relative to the risk.

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[1] IRP filings increasingly claim to use a "portfolio approach" (e.g.: Pacificorp *2003 Integrated Resource Plan,* http://www.pacificorp.com/File/File25682.pdf). However, while these filings evaluate alternative sets of arbitrarily constructed expansion *portfolios*, they do not incorporate the important mean-variance portfolio risk elements described here. Rather, they perform the traditional sensitivity-based risk analyses, which can be quite misleading as I have discussed elsewhere (e.g. Awerbuch 1993, 1995, 1995a).

[2] MVP, an established part of modern finance theory, is based on the pioneering work of Nobel Laureate Harry Markowitz 50 years ago (Fabozzi, Gupta and Markowitz [2002] and Varian [1993]). In addition to its widespread use for financial portfolio optimization, MVP has been applied to capital budgeting and project valuation [Seitz and Ellison, 1995], valuing offshore oil leases [Helfat, 1988], energy planning [Awerbuch and Berger 2003; Berger 2003; Awerbuch 2000a, Humphreys and McLain 1998, Awerbuch 1995, Bar-Lev and Katz 1976] quantifying climate change mitigation risks [Springer, 2003, Springer and Laurikka (undated)] and optimizing real (physical) and derivative electricity trading options (Kleindorfer and Li 2002).

This report describes a portfolio-based analysis that examines the effect of increasing the share of geothermal generation in the US Western Region generating portfolio. The analysis suggests that the region's electricity-generating mix will benefit from additional shares of geothermal, even under the assumption that it costs more than other alternatives on a *stand-alone* basis.

Although counter-intuitive, the idea that adding more costly geothermal can actually reduce portfolio generating cost is consistent with basic finance theory and derives from the statistical independence of geothermal costs, which do not correlate (or covary) with fossil price movements. Adding geothermal increases portfolio diversification and yields lower expected generating costs.

Portfolio-Based Planning For Electricity Generation

Portfolio optimization locates generating mixes with lowest-expected cost at every level of risk, where risk is defined in the usual finance fashion as the year-to-year variability (standard deviation) of technology generating costs. The US-EIA (NEMS) projected generating mixes serve as a benchmark or starting point for the analysis. Detailed decommissioning date assumptions are made on the basis of existing plant age as given in the *World Electricity Power Plant Database*. The optimal results indicate that compared to EIA target mixes, there exist generating mixes with larger geothermal shares that exhibit equal or lower cost and risk.

Portfolio optimization

Portfolio theory was initially conceived in the context of financial portfolios, where it relates $E(r_p)$, the *expected* portfolio return, to σ_p, the total portfolio risk, defined as the standard deviation of periodic portfolio returns.[3] The following discussion of portfolio theory is based on a simple, two-asset portfolio, presented in the context of portfolio *cost*, which can be interpreted as the inverse of return.

Portfolio Optimization locates minimum cost generating portfolios at every level of risk. These optimal or *efficient* mixes lie along the Efficient Frontier (EF), shown as a pink line on the subsequent graphs. Portfolio cost is the weighted average cost of the generating mix components. For a two-technology generating mix, expected portfolio cost is the weighted average of the individual expected costs of the two technologies:

$$\text{Expected Portfolio Cost} = E(Cp) = X1 \bullet E(C1) + X2 \bullet E(C2) \qquad \text{(Eq.1)}$$

Where: X_1, X_2 are the proportional shares of the two technologies in the mix and $E(C_1)$ and $E(C_2)$ are the expected generating costs for those technologies.

Expected Portfolio risk, σ_p, is also a weighted average of the individual technology cost variances, as tempered by their co-variances:

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[3] See: Brealey and Myers, McGraw Hill or any other finance text.

$$\text{Expected Portfolio risk} = \sigma_p = \sqrt{X_1^{\,2}\sigma_1^{\,2} + X_2^{\,2}\sigma_2^{\,2} + 2X_1X_2\rho_{12}\sigma_1\sigma_2} \qquad \text{(Eq. 2)}$$

Where:

- X_1 and X_2 are the proportional shares of the two technologies in the mix
- σ_1 and σ_2 are the standard deviations of the holding period returns (HPR)[4] of the annual costs of technologies *1* and *2*
- ρ_{12} is their correlation coefficient

This leads to the following technology risk estimates, where the standard deviations apply to the HPRs. For example, in the case of gas, the standard deviation for fuel price is σ = 30%, implying that the standard deviation of the annual HPRs (the year-to-year rates of change) is 30%. In the case of Renewable technologies, which require no fuel outlays, the fuel standard deviation is zero.

Technology Risk Estimates (Standard Deviation) [a/]

	Construction Period [b/]	Fuel [c/]	Variable O&M	Fixed O&M
Coal	**0.20**	**0.020**	**0.2**	**0.087**
Gas	**0.15**	**0.300**	**0.2**	**0.087**
Nuclear	**0.20**	**0.194**	**0.2**	**0.087**
Wind	**0.05**	**-**	**0.2**	**0.087**
Hydro	**0.20**	**-**	**0.2**	**0.087**
Geothermal [d/]	**0.15**	**-**	**0.2**	**0.087**

a. Estimation procedures developed in Awerbuch and Berger (Paris, IEA, 2003)

b. Construction period costs for existing (embedded) technologies is 0.0

c. Empirical estimate based on 1994-2003 data

d. Four geothermal categories are used in the analysis. While exploration and other costs increase, construction period risk is assumed to remain constant.

cost_variance_correlation_fuel_tech.xls

Construction period risks vary by technology type and are generally related to complexity and length of the construction period.[5] Fixed O&M implies an annual obligation that will be undertaken by an investor as long as sufficient income exists, which makes this risk similar to the risk of payments on the firm's debt. Fixed O&M is therefore a *debt-equivalent* obligation (e.g. Brealey and Myers) whose year-to-year standard deviation is approximated by the standard deviation of an investment grade bond (Awerbuch and Berger, 2003).

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[4] The *Holding Period Return* is defined as HPR = (EV – BV)/BV, where *EV* is the ending value and *BV* the beginning value, e.g. see: Seitz and Ellison, (1995), Brealey and Myers, (1994) or any finance text. A detailed discussion of its relevance to portfolios is given in Awerbuch and Berger (2003).

[5] Construction period risks are based on the proxy procedures developed in Awerbuch and Berger (2003)

The correlation coefficient, ρ, is a measure of diversity. Lower correlation among portfolio components creates greater diversity, which serves to reduce portfolio risk. More generally, portfolio risk *falls* with increasing diversity, as measured by an absence of correlation (covariance) between portfolio components. Adding a fixed-cost technology to a risky generating mix serves to *lower* expected portfolio cost at any level of risk, even if the fixed-cost technology costs *more* (Awerbuch, 2005). A pure fixed-cost technology, has $\sigma_i = 0$. This lowers portfolio risk (since two terms in the above equation reduce to zero), which in turn allows other higher-risk/lower-cost technologies into the optimal mix.[6] In the case of fuel-less renewable technologies, fuel risk is zero and its correlation with fossil fuel costs is also taken as zero.

Historic Fuel Correlation Factors
US Western Region

	Coal	Gas	Uranium
Coal	1.00	0.09	0.13
Gas	0.09	1.00	0.02
Uranium	0.13	0.02	1.00

Based on 1994 - 2003 fuel price data

Portfolio optimization locates generating mixes with minimum expected cost and year-to-year risk. For each technology, risk is the year-to-year standard deviation of the HPRs for three generating cost inputs: fuel, O&M and capital or construction period risk. Fossil fuel standard deviations are estimated from historic US data.[7] Standard deviations for capital and O&M are estimated using proxy procedures as discussed above. Construction period risk for embedded technologies is 0.0. 'New' technologies are therefore riskier than embedded ones— e.g. new coal is riskier than 'old' coal. New technologies are often more efficient than older ones or have lower capital costs per MW of capacity. 'New' technologies, especially wind and gas, therefore exhibit lower kWh costs.

The effects of improved technology efficiency are mitigated by the effects of the utility ratemaking formula. This study assumes a rate-base regulated environment, under which a utility's annual capital charges (depreciation and allowed earnings) reflect the original asset cost less accumulated depreciation. For each type of embedded technology we estimated the average age of existing plant and adjusted the original capital costs for accumulated depreciation. This has the effect of reducing kWh costs, especially for older existing capacity, e.g. nuclear and to a lesser extent, coal.

Capital-intensive renewable technologies such as geothermal have cost structures that are nearly fixed over time.[8] They might cost a little more on a *stand-alone* basis, but their costs are fixed or essentially *riskless* and, more importantly, are uncorrelated to fossil price risk. The operating costs of a generating mix containing 25% geothermal will fluctuate a lot less than one with no geothermal.

---

[6] Note that for a fixed-cost technology $\sigma_j = 0$ or nearly so. This reduces σ_p, since two of the three terms in Equation 2 are reduced to zero. It is also easy to see that σ_p declines as $\rho_{i,j}$ falls below 1.0.

[7] For example, standard deviation of annual natural gas price HPR's over the last 10 years is 0.30.

[8] The finance theory aspects of this idea are further developed in Awerbuch, (2000).

The portfolio analysis focuses on the risk of generating *costs* only. We ignore year-to-year fluctuations in electricity output from wind or geothermal plants, taking the approach that a properly managed geothermal resource can produce constant annual output. On an accounting or regulatory basis, estimated kWh cost is calculated by dividing the annual capital charge by the kWh output. Annual output variability will therefore cause year-to-estimated kWh costs to vary as well. Finance theory does not necessarily support this view. However, since we take a regulatory-based approach, it may make sense to re-visit this issue in future work, if annual geothermal and wind output varies significantly.

Future fossil fuel costs and other generating outlays are random statistical variables. While their historic *averages* and standard deviations are known, they move unpredictably over time. No one knows for sure what the price of gas will be next month, just like nobody knows what the stock markets will do. Estimating the generating cost of a particular portfolio presents the same problems as estimating the expected return to a financial portfolio. It involves estimating cost from the perspective of its market risk.

Current approaches for evaluating and planning national energy mixes consistently bias in favor of risky fossil alternatives while understating the true value of geothermal, wind, PV, and similar fixed-cost, low-risk, passive, capital-intensive technologies. The evidence indicates that such technologies offer a unique cost-risk menu along with other valuable attributes that traditional valuation models cannot "see" [Awerbuch, 1993, 1995, 1995a]. The evidence further suggests that fixed-cost renewables cost-effectively hedge the fossil price risk as compared to standard financial hedging mechanisms [Bolinger, Wiser and Golove, 2004].

Portfolio optimization for the Western US Region

Figure 1 shows the EIA energy mixes for the western Region for the base year, 2003, and for the target year, 2013. During that period, kWh demand in the region is projected to rise 32%. EIA forecasts indicate that this increased demand will be met primarily through capacity increases in gas and coal. Hydro output is also larger in 2013, but this is not the result of greater capacity. The move to larger gas and coal shares by 2013 increases portfolio risk—the year-to-year expected generating cost volatility—as discussed subsequently.

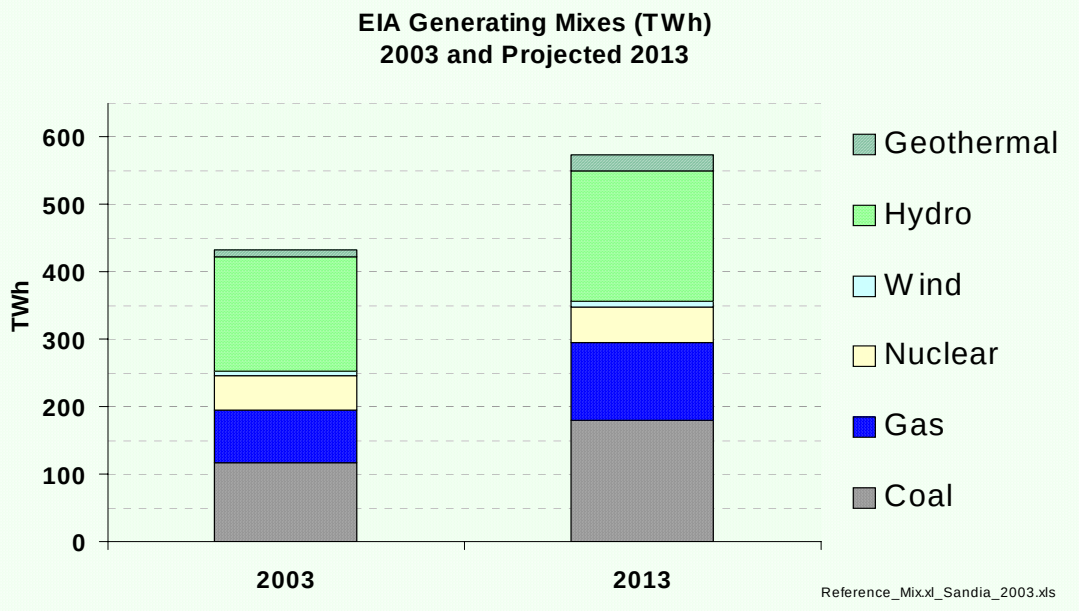


Figure 1

Table 1 shows the EIA (NEMS) real (Constant 2002$) technology costs for the base and target years. Table 2 gives the same information using nominal costs, based on assumed 3% inflation rate. All costs are taken on a pre-tax basis.

Table 1

US Western Region Portfolio Analysis
Real Technology Cost Inputs
(2002 $/kWh)

Technology	2003 Existing	2003 New	2013 Existing	2013 New
Coal	$0.036	$0.047	$0.037	$0.051
Gas	$0.047	$0.036	$0.056	$0.050
Nuclear	$0.014	$0.060	$0.014	$0.060
Wind	$0.042	$0.046	$0.042	$0.046
Hydro	$0.045	$0.045	$0.045	$0.045
Geothermal	$0.062		$0.062	
New Geo 1		$0.047		$0.045
New Geo 2		$0.052		$0.049
New Geo 3		$0.057		$0.054
New Geo 4		$0.071		$0.067

Source: US-EIA and Sandia National Laboratories

Table 2

US Western Region Portfolio analysis
Nominal Technology Cost Inputs Assuming 3% Inflation
(Nominal $/kWh)

Technology	2003 Existing	2003 New	2013 Existing	2013 New
Coal	$0.037	$0.049	$0.049	$0.068
Gas	$0.048	$0.037	$0.075	$0.067
Nuclear	$0.014	$0.062	$0.018	$0.081
Wind	$0.043	$0.047	$0.056	$0.062
Hydro	$0.046	$0.046	$0.060	$0.060
Geothermal	$0.064		$0.083	
New Geo 1		$0.049		$0.060
New Geo 2		$0.053		$0.066
New Geo 3		$0.058		$0.072
New Geo 4		$0.073		$0.090

Based on US-EIA and Sandia National Laboratories cost estimates, adjusted for 3% inflation

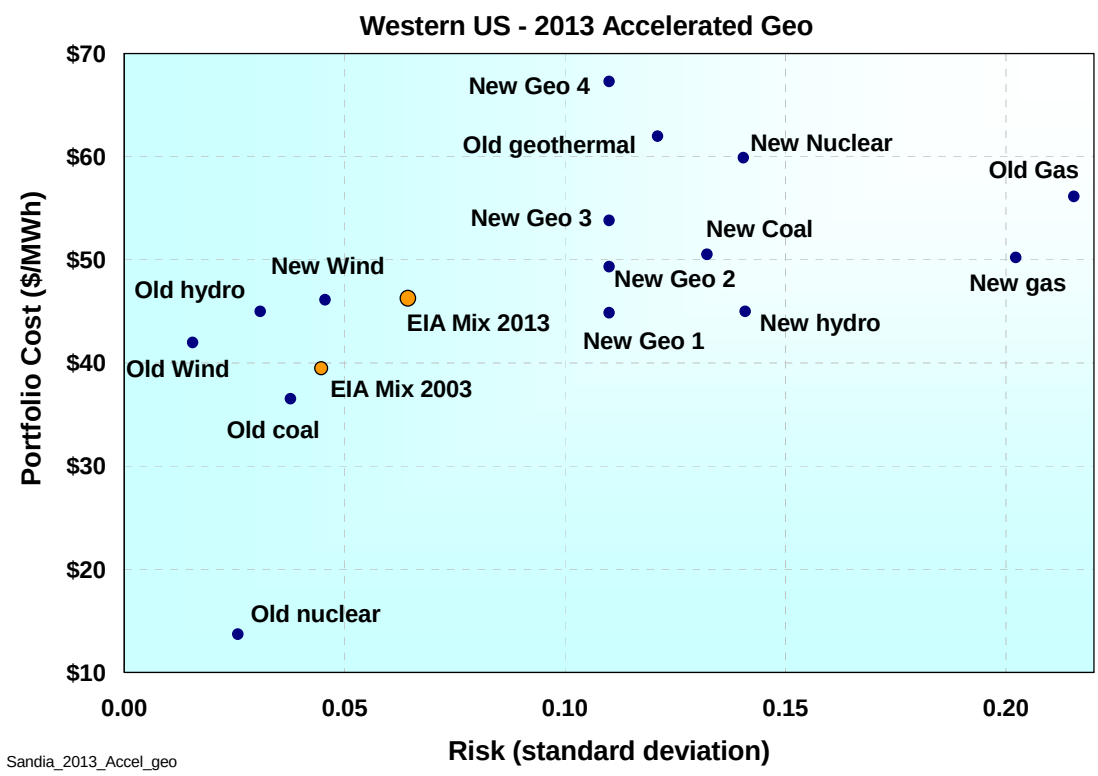
EIA provides costs for existing and "new" geothermal. However, we treat this technology in greater detail and create three additional geothermal "bands," each representing production at more difficult locations. Geothermal-4 largely represents dry-rock technology, which requires water pumping. The resource availability for each geothermal band is shown in Table 3. The expected potential for Geothermal-1, Geothermal-2 and Geothermal-3 is 2500 MW each, while the geothermal-4 potential is 20,000 MW.

Table 3: Geothermal Potential and Cost			
Band	Resource Availability	Generating Cost 2002-Constant Dollars	
	MW	2003	2013
Existing	2,543	$.062	$.062
Geothermal-	2,457	$.047	$.045
Geothermal-	2,500	$.052	$.049
Geothermal-	2,500	$.057	$.054
Geothermal-	20,000	$.071	$.067
Total	30,000	-	-

Technology Cost-Risk

Figure 2 plots the risk and the kWh cost for each of the generating technologies considered in the analysis. Total risk for a given technology is determined using Equation 2, where the weights (X_1, X_2, etc.) are given by the proportional values of the levelized cost components, capital, fuel and O&M.

Figure 2: Technology Cost and Risk



The projected 2013 EIA generating mix (Figure 2) has higher cost and risk relative to 2003. This may be driven by the 32% demand increase, as previously discussed, which occurs in the face of decommissioning of existing plants, resource shortages and possible other limitations on available options. The higher risk of the EIA 2013 target mix is primarily the result of greater reliance on gas and coal, which reduce energy diversity and security. Geothermal and other renewables are ideally positioned to diversify the 2013 generating mix and reduce its cost/risk.

Portfolio Optimization: Interpreting Results

The charts accompanying the subsequent discussion show the portfolio generating cost and risk for each analysis. The *Efficient Frontier* (pink line) is the location of all optimal mixes. Mixes lying above the *EF* are inefficient (sub-optimal) since expected cost *and* risk can both be improved. Along the EF, cost reductions can be achieved only by accepting generating mixes with greater risk. There exist no feasible solutions below the EF. An infinite number of generating mixes exist on each chart, although we locate and show only a small set of *typical* mixes as follows:

a. **Mix *P* - High-cost Mix**: This is the feasible optimal generating mix with the highest-cost and lowest-risk for the particular set of conditions assumed. It is usually the most diverse (e.g. see: Stirling, 1996).

b. **Mix *N* - Equal-cost Mix:** This is the *Minimum-risk* mix whose cost equals that of the EIA-2013 mix.

c. **Mix *S* - Equal-risk mix:** This is the *Minimum-cost* mix whose risk equals that of the EIA-2013 mix.

d. **Mix *Q*: Low-cost Mix:** This is the lowest-cost, highest-risk feasible optimal mix. It is usually the least diverse and often consists primarily of gas generation.

The portfolio analysis does not advocate for particular generating mixes, but rather displays the risk-cost trade-offs along the efficient frontier (EF). Any solution along the EF is efficient, although it may turn out that solutions in the region of the Target EIA-2013 mix (e.g. solutions between portfolios *N* and *S*) may be the most practical and may better match the load duration curve as subsequently discussed.

The portfolio optimization takes the position of the rate paying public, to the extent that market power, fuel-adjustment clauses and other pass-throughs may not enable individual firms to fully exploit the benefits (or bear the costs) of constructing optimal mixes.

The Western Region portfolio optimization is illustrative and does not represent a specific capacity-expansion plan. Its primary purpose is to illustrate that as long as the mix can be re-shuffled over time, adding geothermal and other potentially higher-cost technologies does not necessarily raise overall generating cost as long as their costs are relatively uncorrelated to the rest of the mix. The results show the optimal geothermal shares, ignoring the requirement to optimize technologies to the load curve. In future work it may be useful to add this additional constraint.

In deregulated environments, investment decisions are made by individual power producers who evaluate only their own direct costs and risks, but do not reflect the effects their technologies may have on overall portfolio performance. Geothermal investors, for example, cannot capture the risk-mitigation benefits they produce for the overall portfolio. This leads to under-investment in geothermal relative to what is more optimal from a ratepayer or societal perspective.[9]

Finally, some investors may prefer the risk menu offered by fuel-intensive technologies such as gas–CC turbines, which have very low capital costs. With sufficient market power or regulatory pass-through, such investors may be able to externalize fuel risks onto customers. In such cases these investors do not bear the full risk effects they impose onto the generating mix, which may lead to over-investment in gas relative to what is more optimal from a total portfolio perspective.

2013 Baseline Optimization Results

This section summarizes the portfolio optimization for 2013 in the Western Region. It compares the risk-return properties of the projected EIA generating mix to a set of optimal portfolios that minimize cost and risk. These optimal portfolios include larger geothermal shares. Adding geothermal capacity does not necessarily raise cost, even if it is believed that geothermal costs more on a *stand-alone* basis.

Figure 3 gives the risk-cost results for the 2013 Baseline Optimization. It shows the location of optimal mixes along the EF. Table 4 provides the numeric details.[10]

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[9] One of the Sandia reviewers argues that geothermal investors require high rates of return because of high project risk associated with drilling and resource uncertainty. Finance theory however clearly suggests that such risks, which definitely affect project *costs*, do not affect discount rates to the extent that drilling risks are random, like a lottery (see Shyam-Sunder and Myers, 1993). In any event, our analysis begins with the plant construction phase and does not explicitly model field development and drilling.

[10] As previously discussed, portfolio risk is expressed as the standard deviation of HPRs.

Figure 3: Western Region 2013 Baseline Optimization

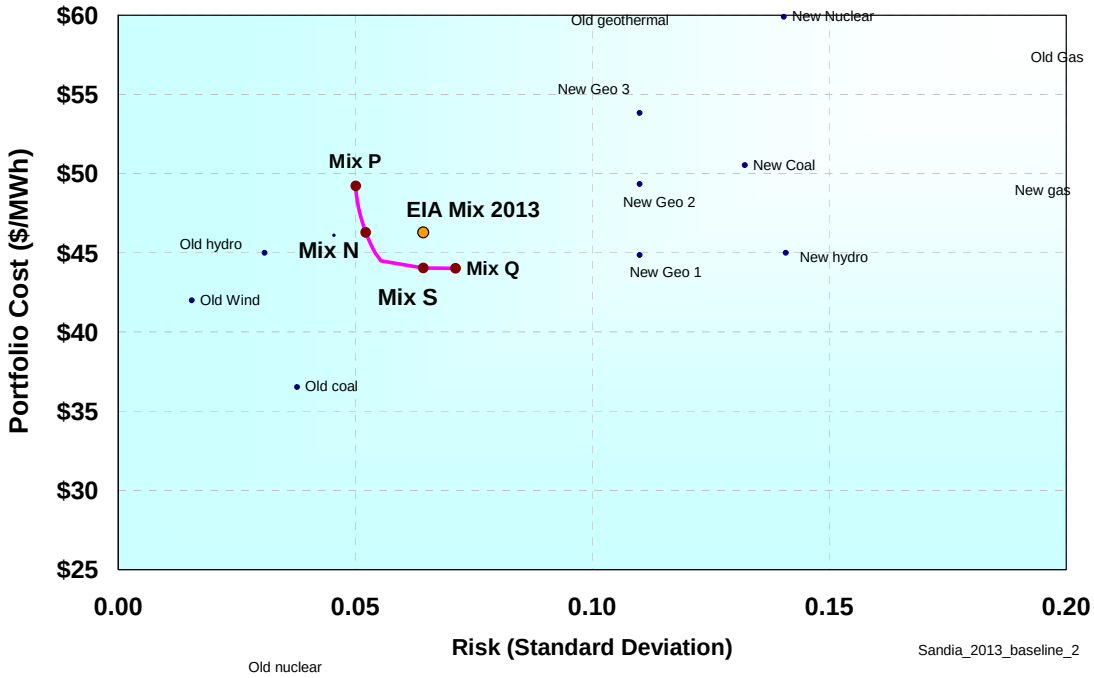

Table 4

Portfolio Risk-Cost and Technology Shares					
			EIA Mix		
	Mix P	Mix N	2013	Mix S	Mix Q
Risk	0.05	0.05	0.06	0.06	0.07
Cost	$49.21	$46.28	$46.28	$44.03	$44.02
			Technology Energy Share		
Coal	23%	31%	31%	29%	23%
Gas	9%	10%	20%	25%	30%
Nuclear	4%	4%	9%	4%	4%
Wind	3%	3%	2%	3%	3%
Hydro	27%	33%	34%	34%	34%
Geothermal	35%	20%	4%	7%	7%

Figure 3 identifies several *typical* mixes that are superior to the projected EIA-2013 Target mix. An infinite number of other such mixes exist, and could be located, given additional conditions and optimization constraints.[11]

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[11] Relative to the EIA-2013 Target Mix, the portfolio analysis allowed certain nuclear retirements so that the optimized portfolio results show a lower, 4% nuclear share. Nuclear retirements are often

The EIA-2013 target mix (orange dot) has generating cost of $0.046/kWh, and a 4% Geothermal share. The optimized typical mixes, by comparison, have the following cost (Table 4).

EIA-mix	Cost: 4.6 cents/kWh	Geothermal share: 4%
Mix *P*:	Cost: 4.9 cents/kWh	Geothermal share: 35%
Mix *N*:	Cost: 4.6 cents/kWh	Geothermal share: 20%
Mix *S:*	Cost: 4.4 cents/kWh	Geothermal share: 7%

We stress again that infinite other solutions exist. More importantly, radically different portfolio mixes can produce very similar risk-return characteristics. Indeed in any risk-return vicinity there will exist a large number of radically different feasible portfolio combinations. This enables the optimization to locate mixes with desired risk-return properties, but with higher geothermal shares.

The typical optimal mixes shown are not necessarily matched to the load duration curve, in the sense that that they may not contain sufficient flexible peaking capacity. Moreover, the optimal solutions may involve decommissioning existing plants and substituting newer, lower cost technologies. This might occur even in cases where individual plant owners may find their existing plants are still profitable and would not consider closing them. Future work could focus on these and other requirements, which will further constrain the optimal solution. Given the strength of these results, however, it is likely that even with further constraints, efficient solutions that meet additional system and political requirements do exist.[12]

2013 Portfolio Optimization Assuming Lower Natural Gas Prices

Overview:

The *Efficient Frontier* for the Western Region is constrained by high fossil and nuclear generating costs and geothermal resource limitations. This section evaluates the effects on

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more a political, as opposed to a technological issue. In future Western Region portfolio analyses, it may be useful to examine the effect of specific nuclear policy constraints, such as the shadow cost of either closing or maintaining nuclear capacity.

[12] One of the Sandia reviewers calculates the following proportion of base and dispatchable technologies for each of the optimized mixes above:

	Mix P	Mix N	EIA 2013	Mix S	Mix Q
Base	64%	55%	44%	40%	34%
Dispatchable	36%	43%	54%	59%	64%

The EIA-2013 mix is based on the NEMS model, which calculates the optimal NEMS portfolio using a linear program to simultaneously minimize cost and meet load demands. Optimized mean-variance portfolio results the lie between Mix N and Mix S may essentially meet load-duration requirements, although this is not specifically modeled.

the generating mix of increasing gas, the EIA low-cost option. We increase the gas share in the optimal mixes by arbitrarily reducing its generating cost by 15%, from $50/MWh to $42.5/MWh.

The results (Figure 4 and Table 5) suggest that an increased gas share is attained only at greatly increased risk. The effect on generating cost of the optimal portfolio is minimal. Costs for Mixes *P*, *N* and *S*, are reduced slightly reflecting primarily the assumed lower gas prices. The components of the mix change only very slightly. However, Mix *Q* changes significantly. Its gas share rises from 30% to 74% and its expected cost relative to the Mix *S* falls by about 5%. This cost reduction however is attained at the expense of a 130% increase in risk from 0.06 to 0.14.

Figure 4: Western Region 2013 Portfolio Cost-Risk With Lower Gas Prices
Adding More Gas Primarily Increases Risk

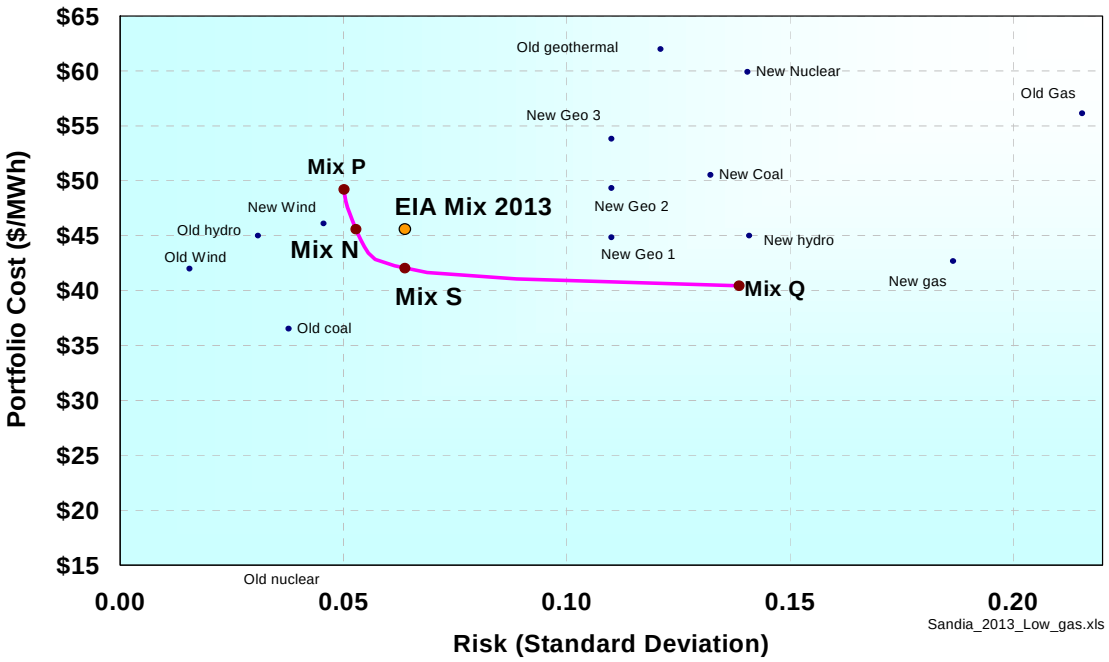

Table 5

Portfolio Risk-Cost and Technology Shares					
	Mix P	Mix N	EIA Mix 2013	Mix S	Mix Q
Risk	0.05	0.05	0.06	0.06	0.14
Cost	$49.21	$45.59	$45.59	$42.03	$40.42
			Technology Energy Share		
Coal	23%	30%	31%	27%	20%
Gas	9%	11%	20%	26%	74%
Nuclear	4%	4%	9%	4%	4%
Wind	3%	3%	2%	3%	1%
Hydro	27%	31%	34%	34%	1%
Geothermal	35%	21%	4%	7%	0%

The Effect of Accelerated Geothermal-3 and Geothermal-4 Deployment

Motivation for This Analysis

This section evaluates the shadow cost of policies that promote accelerated deployment of the higher-cost geothermal applications represented by Geo-3 and Geo-4. In the 2013 Baseline Results, the equal-risk/minimum-cost mix (Mix S) contains 7% Geothermal, which includes the maximum resource potential for Geo-1 and Geo-2. However, Geo-3, Geo-4 and Old-Geothermal do not enter Mixes *S* or *Q*.

In this Accelerated Deployment Analysis we search for optimal mixes that lie in the vicinity of Mix-S and that include Old-Geo, Geo-3 and Geo-4. We evaluate the portfolio cost-risk impact of "forcing" this additional geothermal share into the optimal mix. Specifically, we set the lower bounds for geothermal so that the optimal mixes will contain the maximum resource availability of Geo-1, Geo-2 and Geo-3, plus 25% of Geo-4. The latter is an arbitrary value. This yields the following *minimum* geothermal bounds:

Table 6: Geothermal Lower Bounds for Accelerated Deployment Analysis

Geothermal Type	Total Resource Available (MW)	Lower Bound (MW)
Old Geothermal	2,543	2,500
Geothermal 1	2,457	2,500
Geothermal 2:	2,500	2,500
Geothermal 3:	2,500	2,500
Geothermal 4	20,000	5,000
Totals	30,000 MW	15,000 (MW)

Figure 5: The Effect Of Accelerated 2013 Geo Deployment

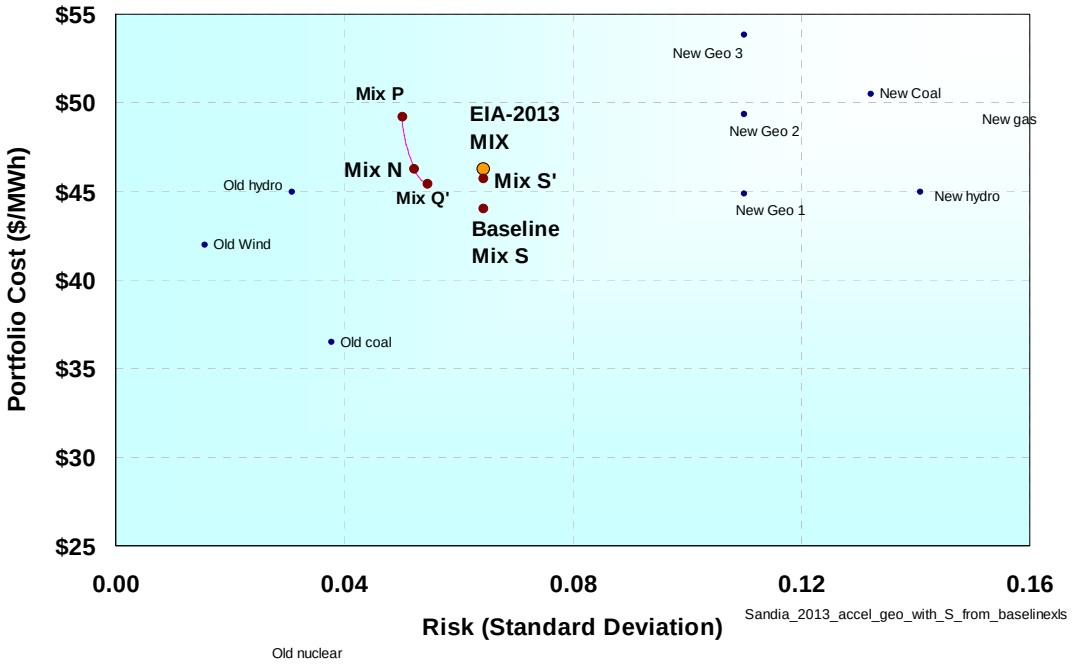

Table 7: Portfolio Details: Accelerated Deployment Analysis

Portfolio Risk-Cost and Technology Shares					
	Mix P	Mix N	EIA Mix 2013	Mix S'	Mix Q'
Risk	0.05	0.05	0.06	0.06	0.05
Cost	$49.21	$46.28	$46.28	$45.74	$45.41
			Technology Energy Share		
Coal	23%	31%	31%	48%	29%
Gas	9%	10%	20%	0%	13%
Nuclear	4%	4%	9%	4%	4%
Wind	3%	3%	2%	3%	3%
Hydro	27%	33%	34%	28%	34%
Old Geo	2%	2%	2%	2%	2%
New Geo-1	4%	4%	3%	4%	4%
New Geo-2	3%	3%	0%	3%	3%
New Geo-3	3%	3%	0%	3%	3%
New Geo-4	23%	8%	0%	6%	6%
Total Geo	35%	20%	4%	18%	18%

Discussion: Accelerated Geo Deployment Case

The 2013 EIA projected mix has a cost of $.0463/kWh as before, with a 2% share of old geothermal and 3% new Geothermal-1. (Figure 5 and Table 6).

Expected Cost of accelerated Geo-3 and Geo-4 deployment:

EIA-mix	Cost: 4.6 cents/kWh	Geothermal share: 4%
Mix *P*:	Cost: 4.9 cents/kWh	Geothermal share: 35%
Mix *N*:	Cost: 4.6 cents/kWh	Geothermal share: 20%
Mix *S:*	Cost: 4.4 cents/kWh	Geothermal share: 7%
Mix *S':*	Cost: 4.5 cents/kWh	Geothermal share: 18%
Mix *Q:*	Cost: 4.5 cents/kWh	Geothermal share: 18%

The analysis therefore suggests advanced, higher-cost geothermal technologies can be deployed without raising cost or risk relative to the EIA-2013 target mix. The expected shadow cost of deploying 15,000 MW of Geothermal, including 2500 MW of Geo-3 and 5000 MW Geo-4 can be measured as the vertical distance between S and S', which is a negligible 0.2 cents/kWh. This is the expected cost of deployment relative to the unconstrained *Baseline Mix S,* although Mix Q has lower risk and the same geothermal shares and hence represents an improvement over S'. The shadow cost of Mix Q relative to S is 0.1 cent. When viewed in terms of the EIA-2013 mix, accelerated deployment, e.g. Mix Q or Mix S' actually costs less (by –0.05 cents).

Conclusions

Today's dynamic and uncertain energy environment requires portfolio-based planning procedures that accommodate market risk and de-emphasize *stand-alone* generating costs. Portfolio analysis reflects the cost inter-relationship (covariances) among generating alternatives. Though crucial for correctly estimating overall cost, electricity-planning models universally ignore this fundamental statistical relationship and instead resort to sensitivity analysis and other ill-suited techniques to deal with risk. Sensitivity analysis cannot replicate the important cost inter-relationships that dramatically affect estimated portfolio costs and risks (Awerbuch, 1993). It is not a substitute for portfolio-based approaches.

Mean-variance portfolio theory is well tested and ideally suited to evaluating national electricity strategies.[13] The MVP framework offers solutions that enhance energy diversity and security and are therefore considerably more robust than arbitrarily mixing technology alternatives. MVP illustrates that the typical US gas-coal generating portfolio offers little diversification. While it may insulate from random risk— e.g. transportation shortages and

[13] Other techniques have also been applied, e.g. A.C. Stirling [1996, 1994], develops maximum-diversity portfolios based on a considerably broader uncertainty spectrum. Though radically different in its approach, his diversity model yields qualitatively similar results.

particular fuel flow stoppages, it provides little insulation from the systematic risk of coal and gas price movements, which have historically been highly correlated.[14]

Given the high degree of uncertainty about future energy prices, the relative value of generating technologies must be determined not by evaluating alternative resources, but by evaluating alternative resource portfolios. Energy analysts and policy makers face a future that is technologically, institutionally and politically complex and uncertain. In this environment, MVP techniques help establish renewables targets and portfolio standards that make economic and policy sense [Jansen, 2004]. They also provide the analytic basis policy-makers need to devise efficient generating mixes that maximize security and sustainability. MVP analysis shows that contrary to widespread belief, attaining these objectives need not increase cost. In the case of the Western US Region, increasing the geothermal share, even if it is believed to cost more on a stand-alone basis, reduces portfolio cost-risk and enhances energy security.

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[14] Increasing use of contracts may mitigate this historical relationship by pricing each fuel more on the basis of its costs. However, history suggests that when shortages for a particular fuel occur, the cost of alternative fossil fuels rises.

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