Evaluating the Financial Performance of Power Generation Assets II

Cash Flow Risk Analysis and Portfolio Optimization

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Four Questions, Two Today

1. Can a methodology be developed that "speeds up" the production cost models?
2. Given such a technology, how can the simulation be made efficient?

3. Given a simulation platform, how can asset values be examined?
4. Given asset values, how can portfolios of assets be optimized?

Diverse Research Applications

- Today's discussion is meant to illustrate the breadth and diversity of research questions
  - Corporate Finance: Merger and Acquisition Analysis
  - Policy Analysis: Regulatory Impact Assessment
  - Managerial Economics and Organizational Behavior: Internal Incentives and Compensation Structure
  - Financial Risk Management: Integration of risk management for real *and* financial assets (more efficient exploitation of "balance sheet" hedges)
  - Strategic Management: Optimization and Strategic Planning

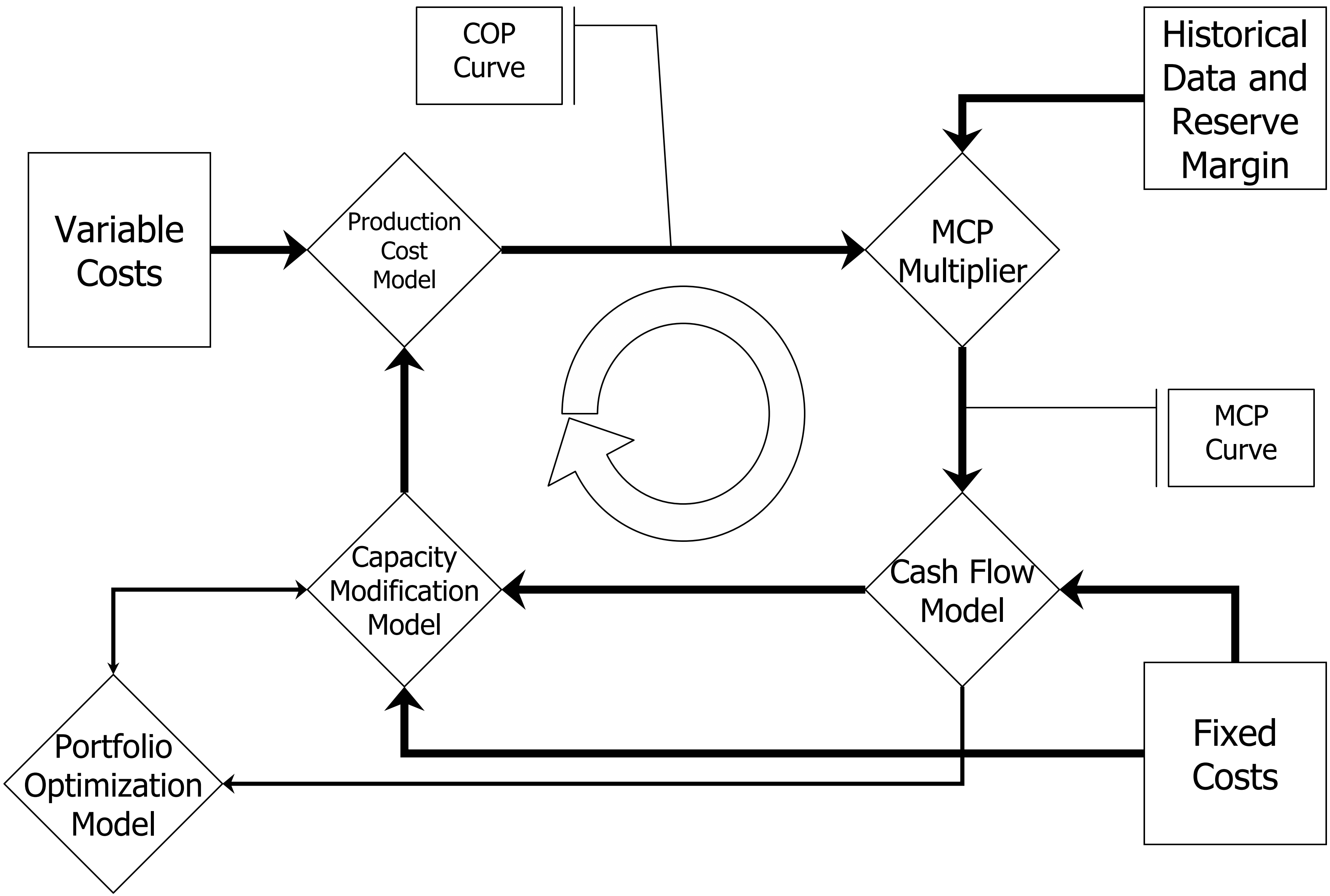
Valuing Generating Assets

- The Discounted Cash Flows (DCF) method for power projects requires:
  - Operating Performance of Plant vs Market
    - Capacity Factor
    - Additions and Retirements
    - Network Factors
  - Expense Projections (Costs of Production)
  - Revenues (Market Clearing Prices)
  - Financial Structure (selection of discount rate)

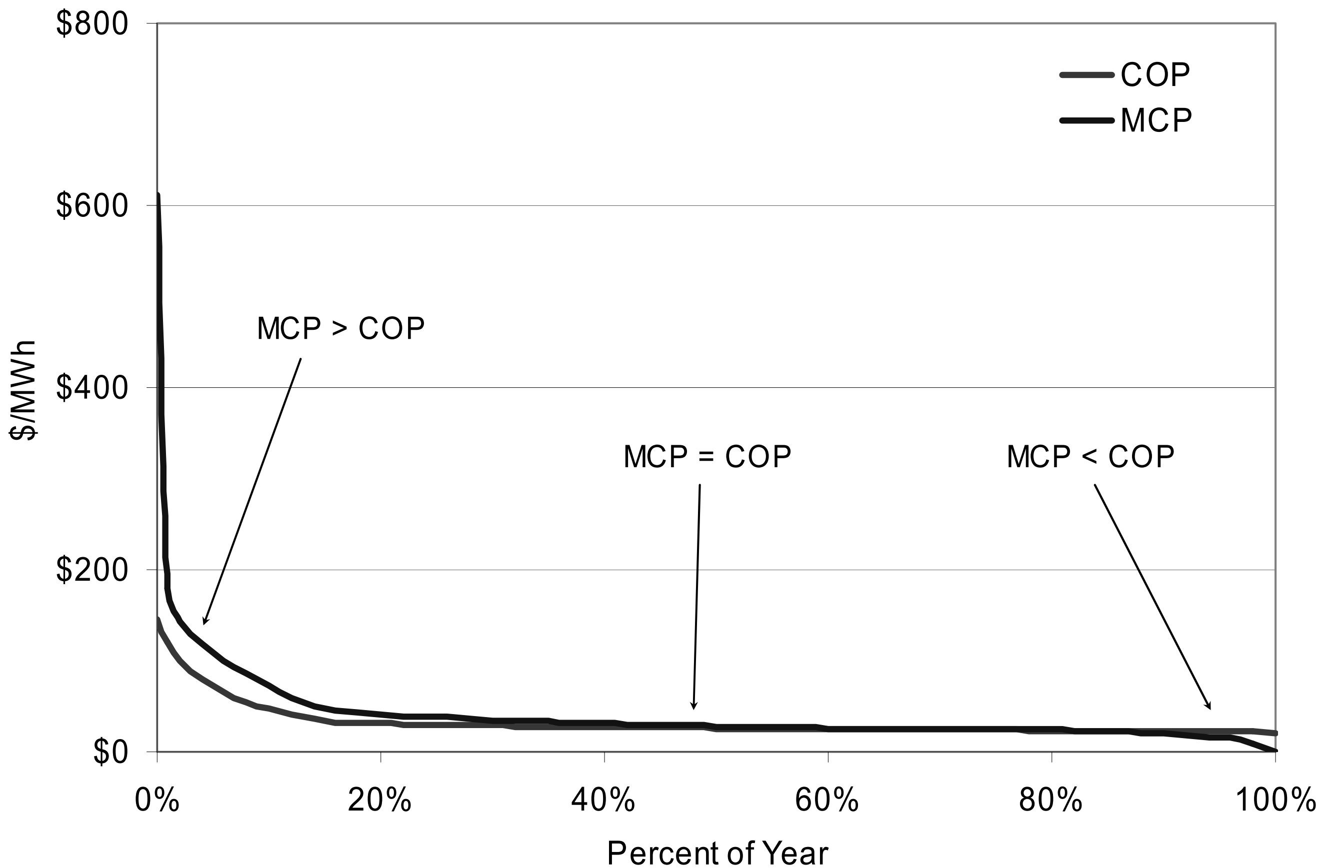
Review of First Presentation

- Neural networks used to model cost-of-production curves
- Market clearing price curves estimated from limited historical data and expert judgment
- Embedded decision makers used to incorporate capacity planning (and other) decisions
- End Result: annual cash flow simulation model for every network plant in a NERC region

Reduced-Form Production Cost Model Flow Chart



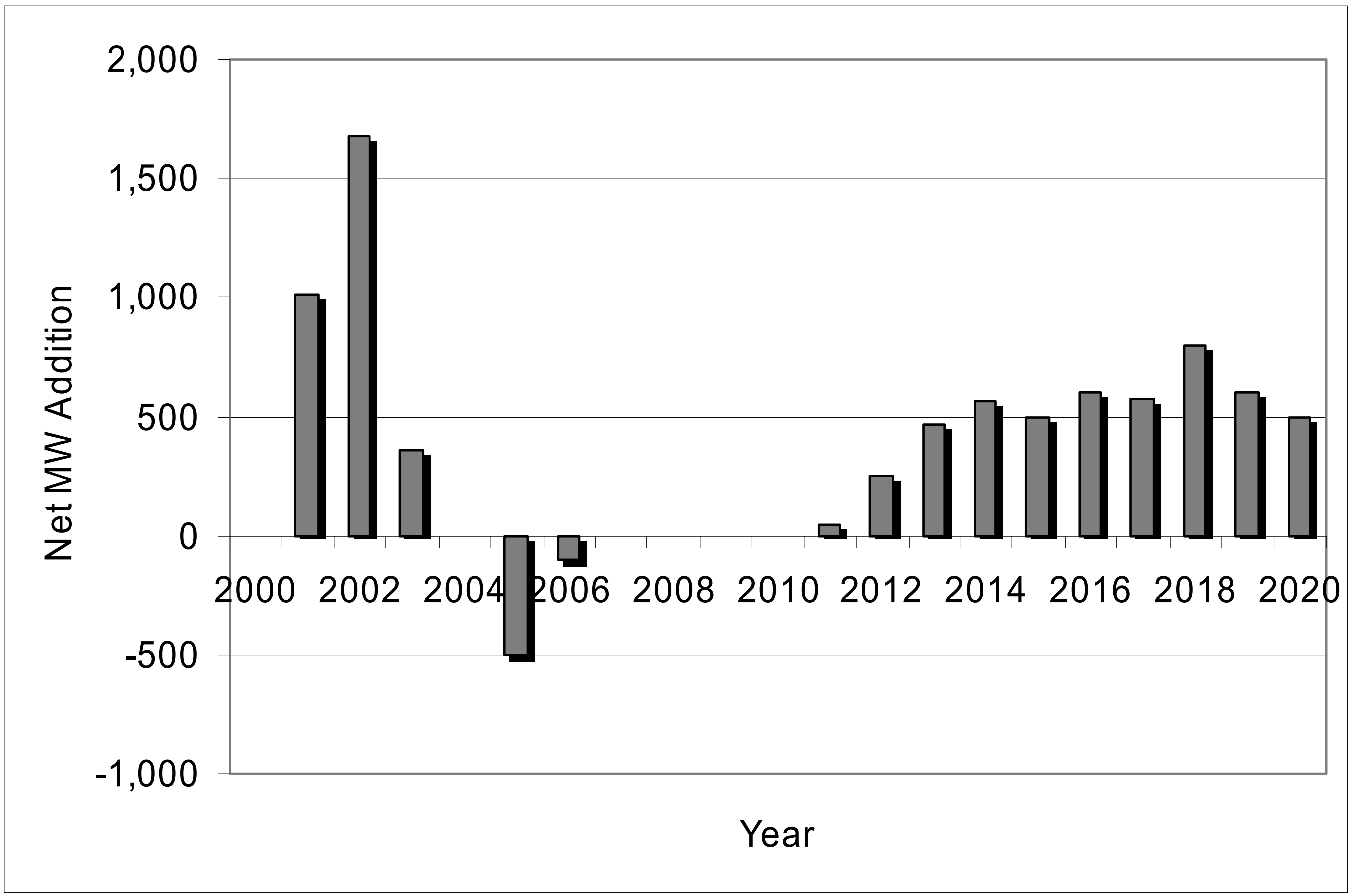
COP and Market Clearing Prices



Cash Flow Analysis

- Incorporation of:
  - Fixed costs
  - Discount rates
  - Salvage values
  - Capital costs
- Performance Metrics
  - Cash flows are generated for every year for every power plant in the region
  - NPVs (or IRRs) are then calculated from estimated cash flows for each multiple year scenario

Single Iteration of Capacity Modification Model



Answering an Open Question

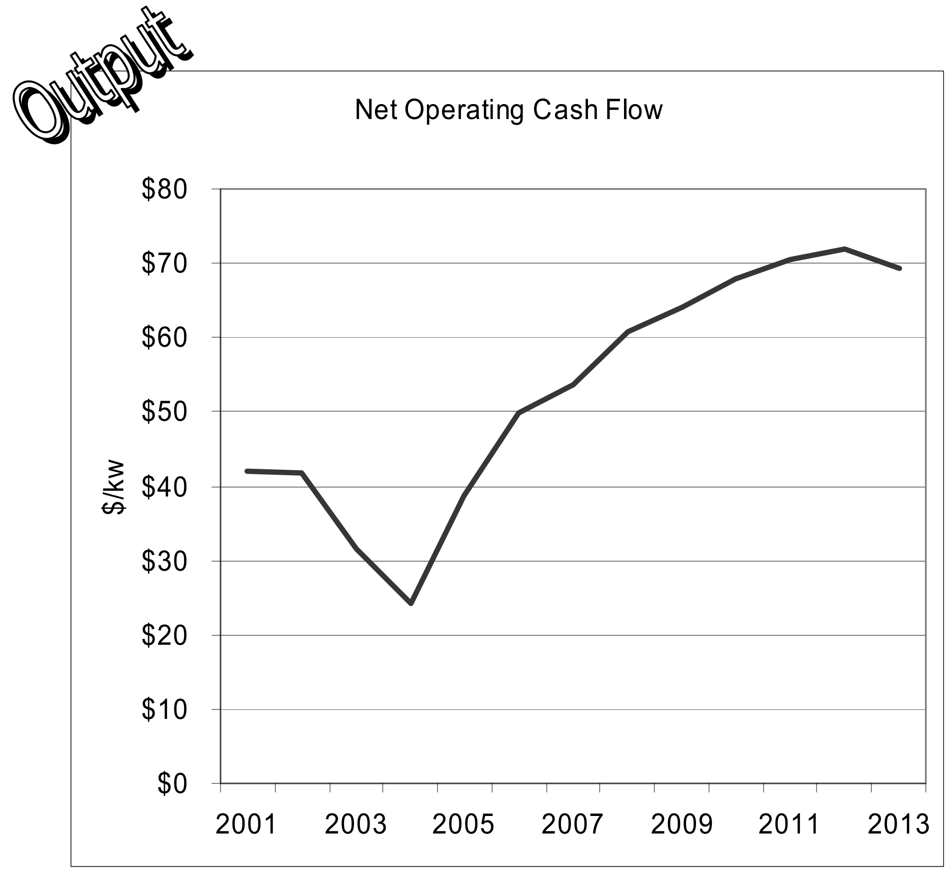
- Would two identical plants at different locations on the network perform differently?
- Our model *does* include network effects, but…
- Finding a test case and "self-selection" bias
  - For example, would a gas plant in the Florida Keys perform differently than one at the northern border (Henry Hub)?
  - Yes, but who would build a gas plant in the Keys?
  - In general, plants are not located in such a way that this hypothesis is easily testable

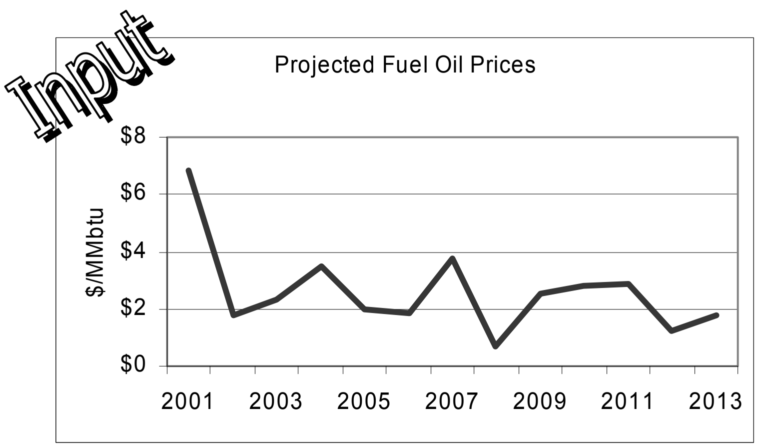
Today's Focus: Going Beyond NPV

- The level of detail in cash flow information we can generate for an entire region enables several paths of analysis that extend far beyond just NPV/IRR
  - Influence of various sources of input uncertainty
  - Ranking of relative performance
  - Portfolio-level analysis of risk factors
  - Portfolio optimization
- Keep in mind that having a cash flow model of *every* power generating asset in a region facilities a unique degree of analysis
- Emissions? Other-than-financial performance measures?
  - Inclusion of 3P
  - Real Options

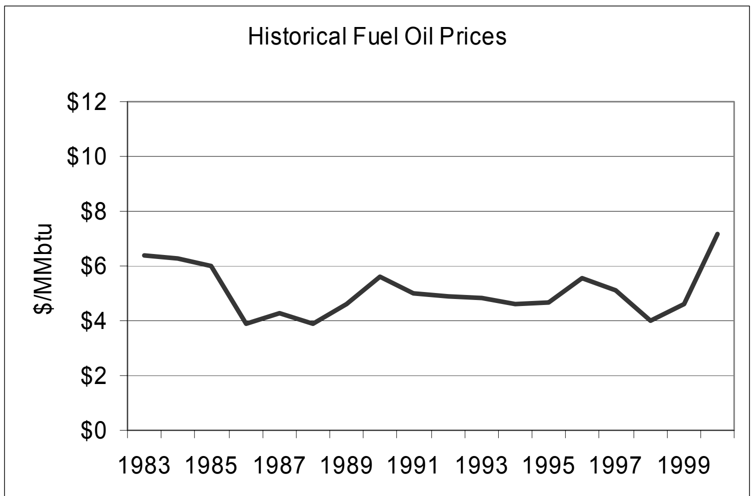
A Single 13-Year Cash Flow Scenario

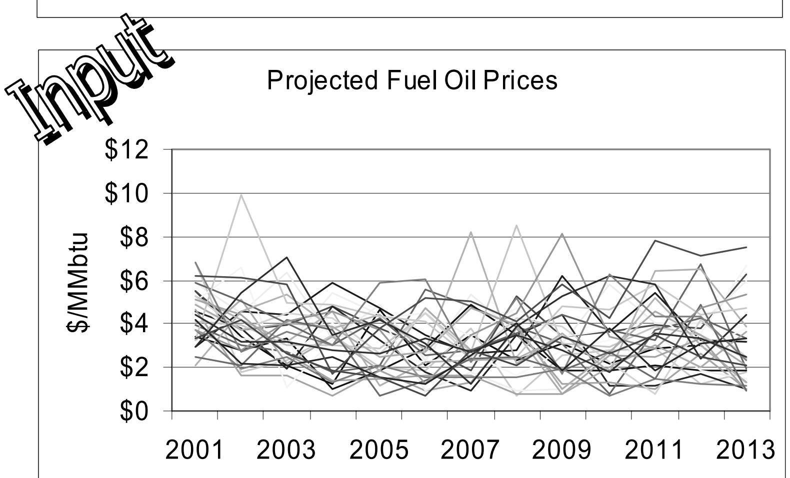
- Unit 1, Intercession City (Osceola, S. Central Florida)
- 56.7 MW Fuel Oil Plant
- Operational in 1974

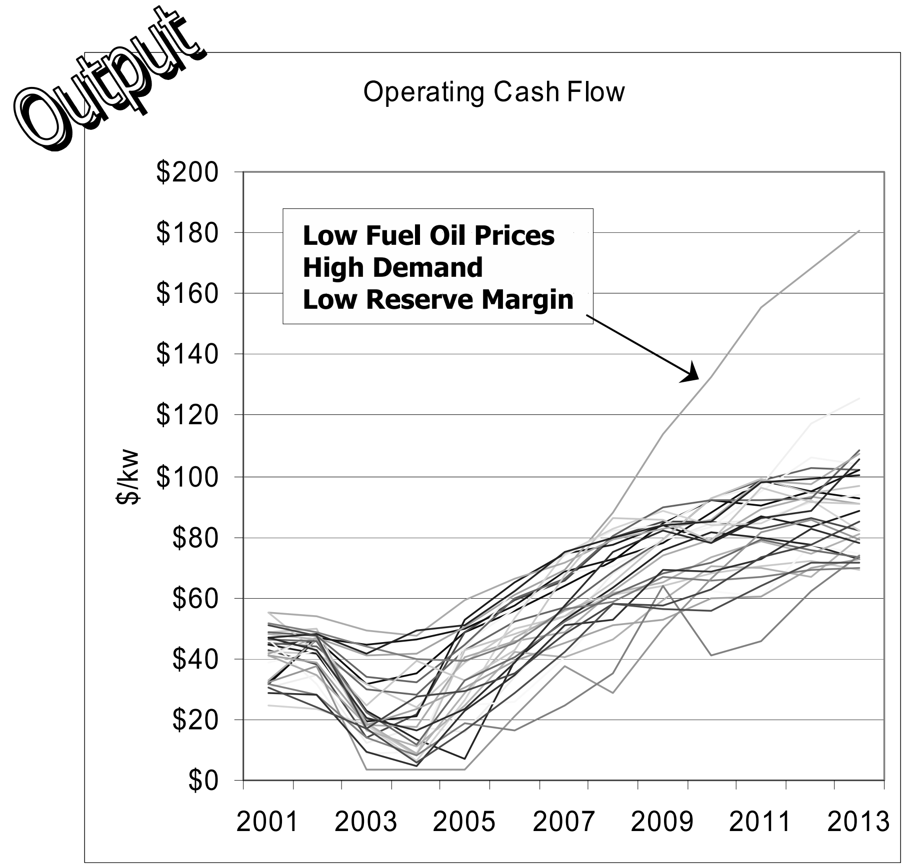




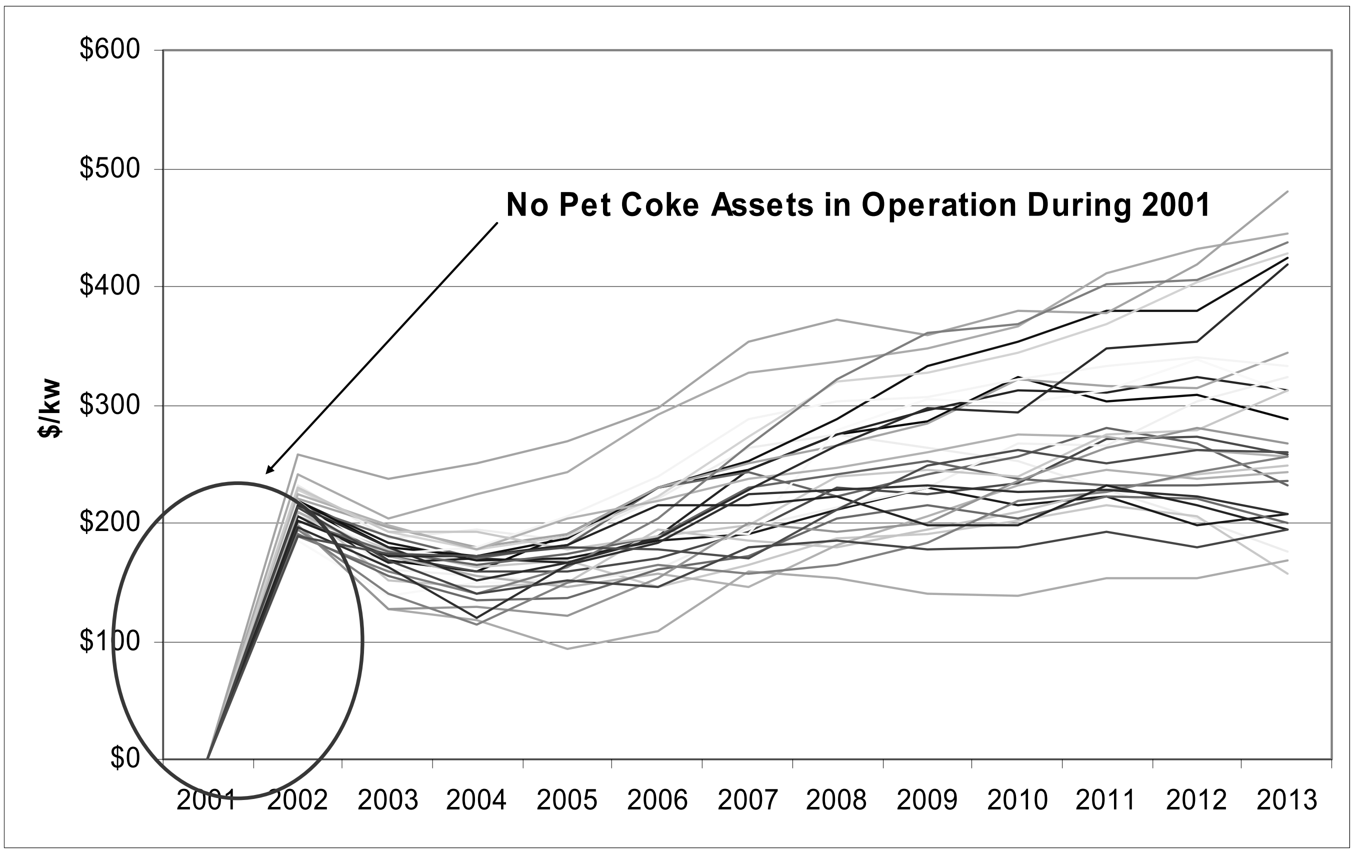
Multiple Cash Flow Paths by Plant Unit 1, Intercession City



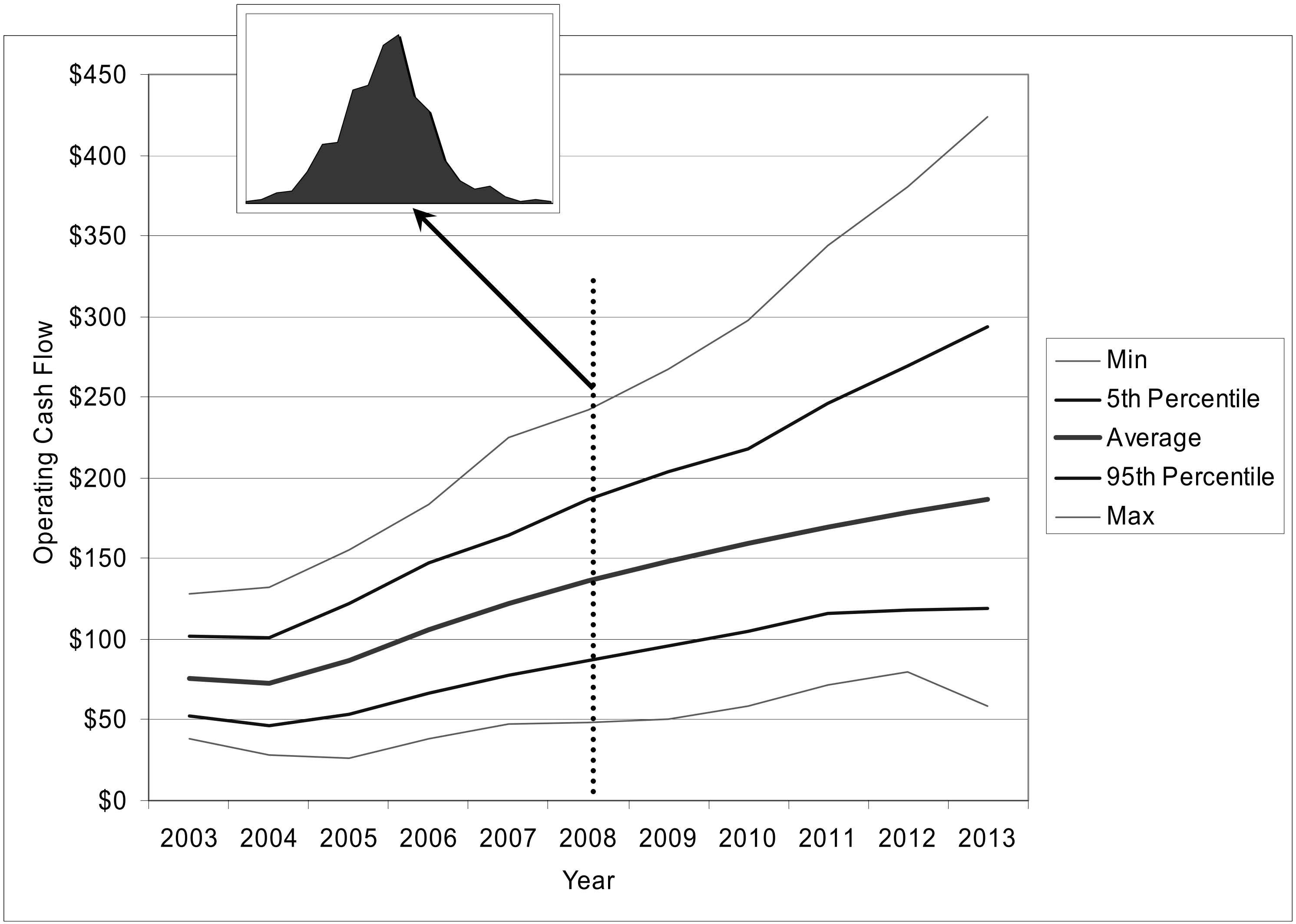




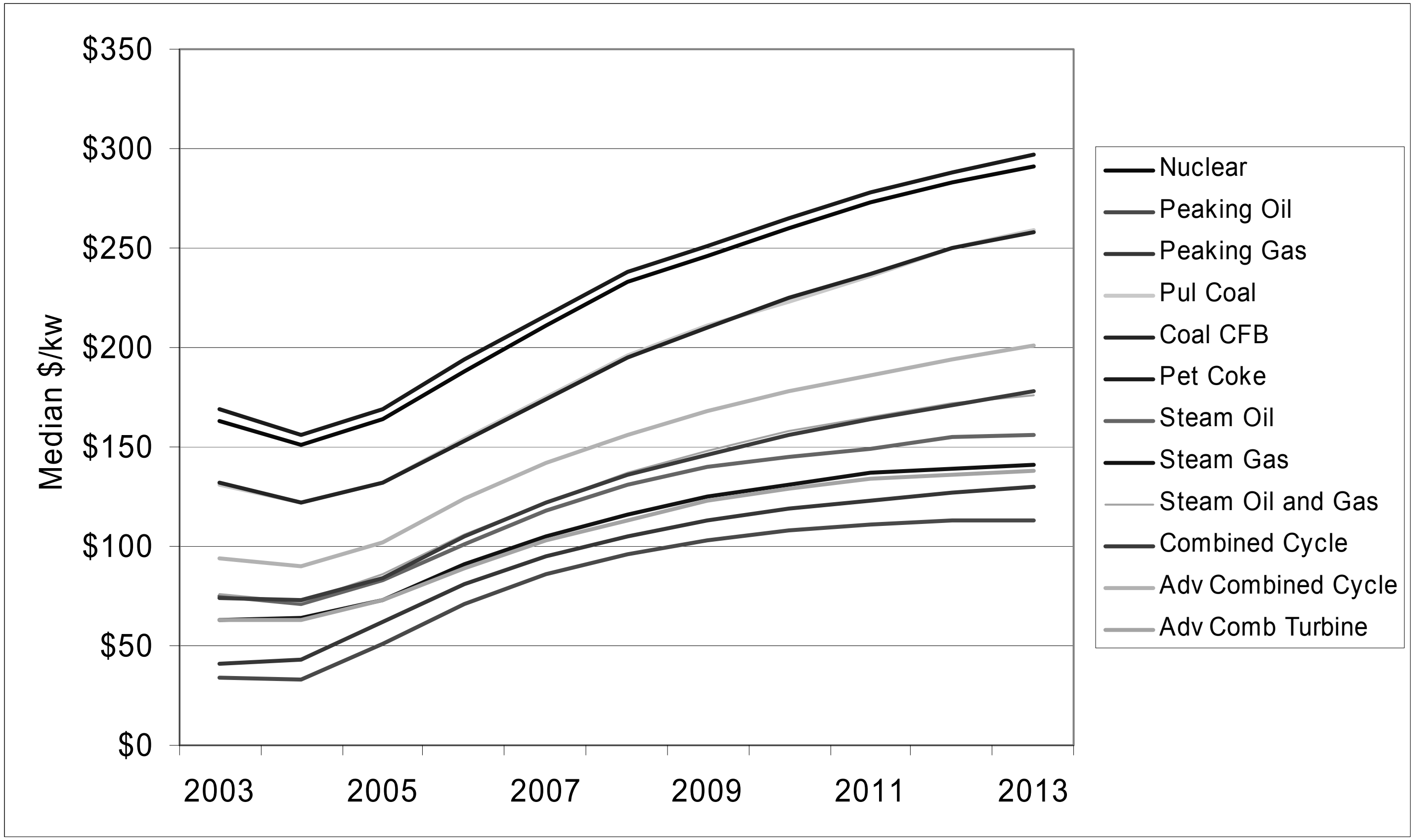
Multiple Cash Flow Paths by Class Pet Coke



Distributions Both Ways



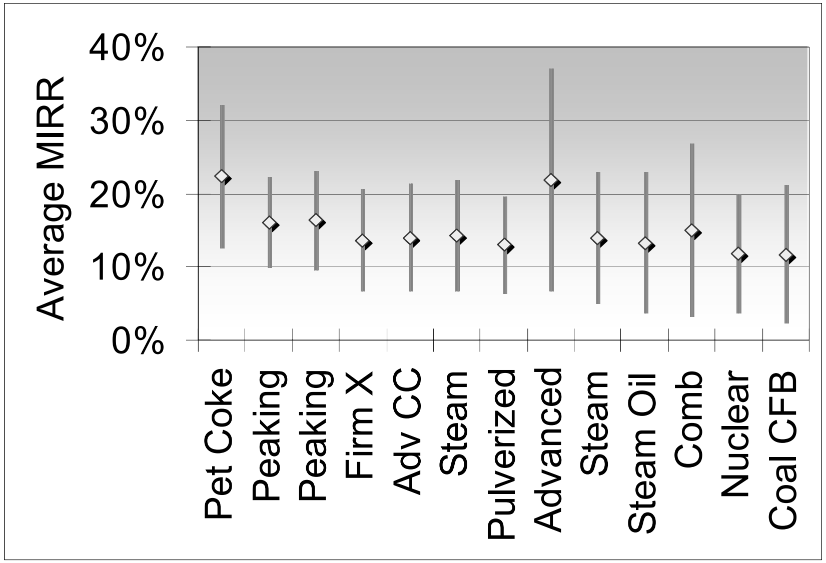
Median Cash Flow Paths

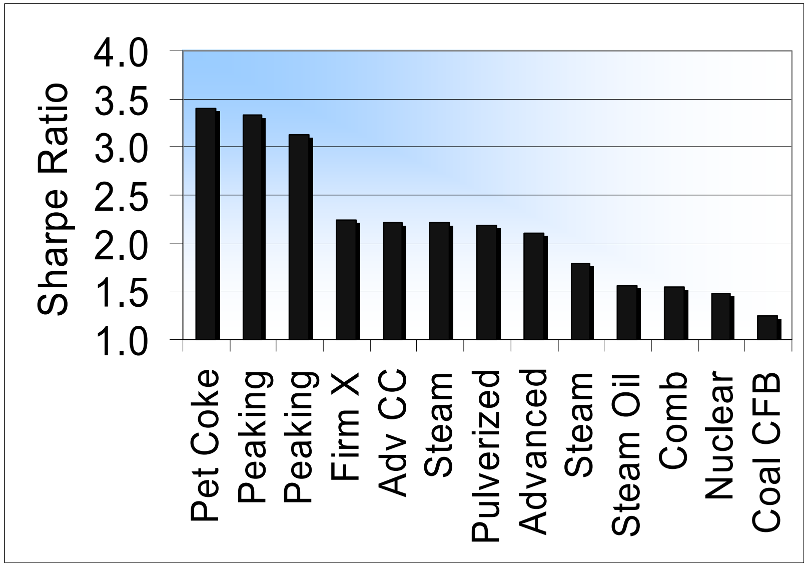


Performance Measures

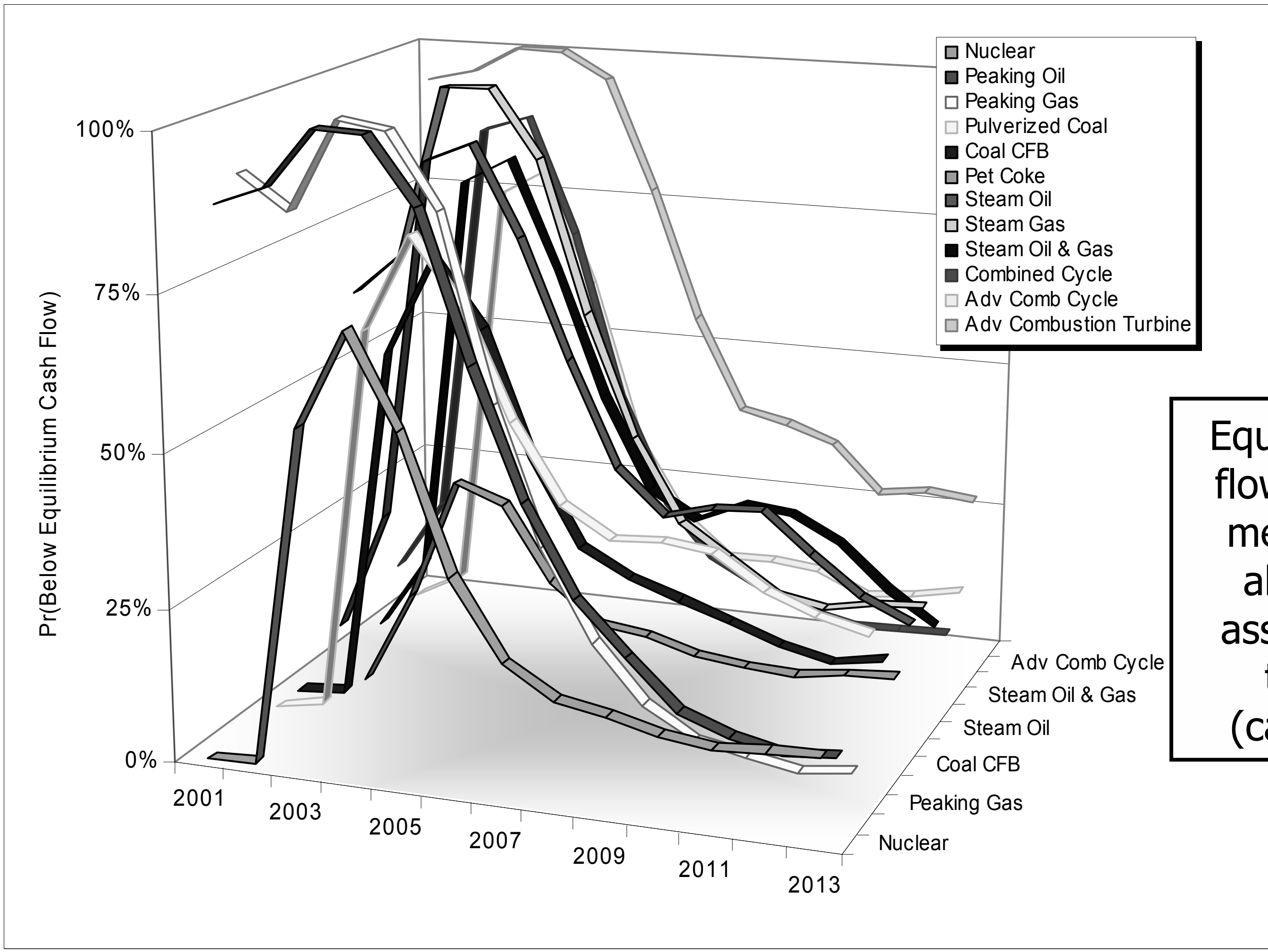
Net Present Value/kw

	Nuclear	Peaking - Oil	Peaking - Gas	Coal - Pulverized	Coal - CFB	Coal - Pet Coke	Steam - Oil	Steam - Gas	Steam - Oil/Gas	Combined Cycle	Adv Combined Cycle	Adv CT - Simple Cycle
Minimum	$ (186)	$ 64	$ 116	$ (30)	$ 93	$ 117	$ 68	$ 127	$ 81	$ 151	$ 199	$ 141
5th Percentile	$ 139	$ 153	$ 177	$ 244	$ 304	$ 405	$ 203	$ 222	$ 238	$ 268	$ 314	$ 222
Average	$ 527	$ 258	$ 284	$ 615	$ 685	$ 826	$ 366	$ 359	$ 399	$ 437	$ 530	$ 344
95th Percentile	$ 919	$ 366	$ 377	$1,008	$1,071	$1,236	$ 567	$ 480	$ 580	$ 576	$ 704	$ 443
Maximum	$1,544	$ 565	$ 501	$1,652	$1,725	$1,897	$ 819	$ 537	$ 808	$ 653	$ 797	$ 481
Standard Deviation	$ 240	$ 69	$ 62	$ 240	$ 236	$ 253	$ 114	$ 78	$ 105	$ 91	$ 114	$ 66





Probability of "Losing Money" and "Equilibrium" Cash Flows



Equilibrium cash flow is a way of measuring the ability of the assets to cover their fixed (capital) costs

Applications of Loss Probabilities

- The obvious use is in risk assessment
  - Value-at-Risk (VaR)
  - Conditional VaR (average loss conditional on loss occurring)
  - XLoss (average maximum loss)
- Loss probabilities can be used beyond risk assessment
- Projected loss probabilities can be used to structure financing arrangements
  - Defer payments during years in which probability of loss is high
  - Accelerate payments during years in which probability of loss is low
- Careful structuring of financing can lower the likelihood of financial distress for both investors and lenders
  - Proper financial structure design can generate Pareto improvements for *both* equity and debt holders

Beta and Market-Relative Performance

- The Capital Asset Pricing Model (CAPM) beta measures the risk of an asset relative to the whole market (for a well-diversified investor)
- Typically, the "market" is unobservable
- Our model is unique in that we actually do have the cash flow performance of the entire market (every plant in the NERC region)
- We can compile a "market index" that measures all assets in the region and therefore compute power generation asset betas

Asset Class NPV Correlations

	Nuclear	Peaking - Oil	Peaking - Gas	Coal - Pulverized	Coal - CFB	Coal - Pet Coke	Steam - Oil	Steam - Gas	Steam - Oil/Gas	Combined Cycle	Advanced Combined Cycle	Advanced CT - Simple Cycle
Nuclear	1.00											
Peaking - Oil	0.48	1.00										
Peaking - Gas	0.52	0.62	1.00									
Coal - Pulverized	0.99	0.46	0.51	1.00								
Coal - CFB	1.00	0.46	0.51	0.99	1.00							
Coal - Pet Coke	1.00	0.47	0.51	0.99	1.00	1.00						
Steam - Oil	0.72	0.86	0.52	0.73	0.71	0.72	1.00					
Steam - Gas	0.60	0.27	0.82	0.61	0.61	0.60	0.27	1.00				
Steam - Oil/Gas	0.75	0.80	0.68	0.77	0.75	0.75	0.96	0.45	1.00			
Combined Cycle	0.82	0.50	0.88	0.82	0.82	0.82	0.59	0.88	0.74	1.00		
Advanced Combined Cycle	0.85	0.36	0.76	0.85	0.85	0.85	0.48	0.92	0.62	0.95	1.00	
Advanced CT - Simple Cycle	0.66	0.36	0.85	0.66	0.66	0.66	0.35	0.99	0.52	0.91	0.94	1.00

Implications of the Correlations

- Baseload vs Peaking
- Fuel Relationships

- Should diversification priority be:
  - To fuel type first?
  - To operational status first?
  - To technology first?
  - To emissions characteristics first?
- What drives correlation structure?

Basics of Portfolio Analysis

- Portfolio return is a linear function of individual asset returns
- Portfolio risk is a <u>non</u>linear function
  - Less-than-perfect correlation can reduce risks
  - Covariance, not variance, is what drives portfolio risks
- The (Finance) Goal: maximum return for minimum risk (variance minimization)
  - Are other portfolios possible?
  - What adjustments on the finance side must be made to accommodate engineering-specific goals?
  - Can this model provide a dialogue between finance and engineering?

The Efficient Frontier

Return

Efficient Frontier

Asset B

Asset C

Asset A

Riskless
Rate

Risk

Measuring Efficiency: The Sharpe Ratio

- The Sharpe ratio is a ratio of return per unit of risk (standard deviation)
- "Efficient" portfolios have high Sharpe ratios, and the portfolio problem can be converted from variance minimization to Sharpe ratio maximization
- Other Measures:
  - **Treynor's Measure** (excess return per unit of *systematic* risk – Sharpe ratio is per unit *total* risk – is a better measure than Sharpe for large portfolios)
  - **Modigliani^2 risk-adjusted performance** (Sharpe ratio-analog in percent return terms)
  - **Jensen's Alpha** (non-equilibrium returns)

Capital Costs and Residual Values

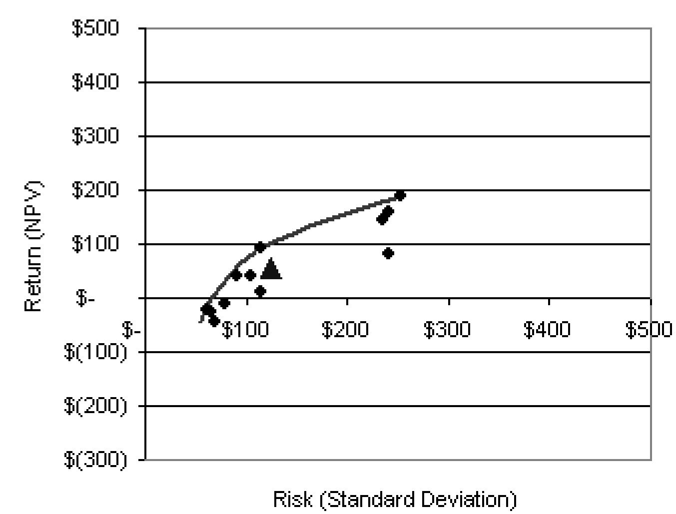
- The cash flows, by themselves, don't tell the whole story
  - Nuclear cash flows are substantial, but the asset class also has very high capital costs, so returns are low
- Analysis *must* take into account both the capital cost of an asset and any residual value at the end of the analysis period
- Unfortunately, it's often difficult to obtain this data, or even estimate it
- Still, we must be able to understand its influence on portfolio performance

9	11.8%
10	10.6%
11	10.6%
12	14.4%

Avg Sales Proceeds (000s) $ -

Re-Calculate Frontier

ID	Plant	Capital Cost		Residual Value		Std.
1	Nuclear	$	400	$	-	1000	$
2	Peaking - Oil	$	300	$	-	1000	$
3	Peaking - Gas	$	300	$	-	1000	$
4	Coal - Pulverized	$	650	$	250	1250	$
5	Coal - CFB	$	650	$	250	1250	$
6	Coal - Pet Coke	$	650	$	250	1250	$
7	Steam - Oil	$	400	$	100	1100	$
8	Steam - Gas	$	400	$	100	1100	$
9	Steam - Oil/Gas	$	400	$	100		
10	Combined Cycle	$	435	$	100		
11	Advanced Combined C	$	520	$	260		
12	Advanced CT - Simple	$	400	$	150		
13		$	-	$	-		
14		$	-	$	-		
15		$	-	$	-		
16		$	-	$	-		



MIRR	Plant	In Use?	Avg NOI	Cumulative NOI	Sales Proceeds (000s)	Sold
13.8%	1	1	$ 96	$ 1,242	$ -	0
13.1%	2	1	$ 55	$ 712	$ -	0

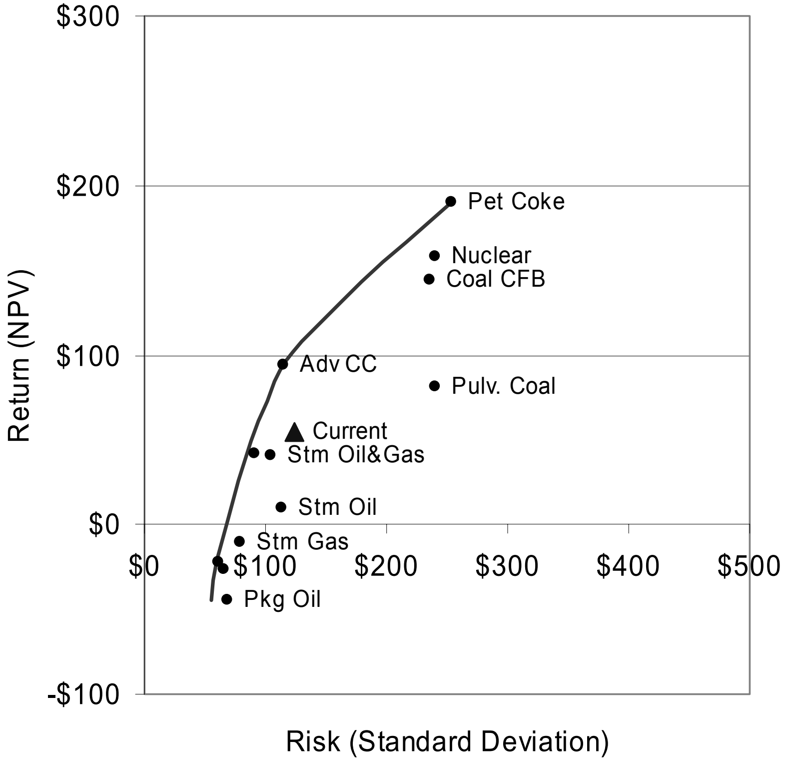
Does it matter?

What is the net effect on portfolio performance?

Strategic Applications of Portfolio-Level Analysis

- “Visual Portfolio”
- Users can instantly see the portfolio-level impact of individual asset-level events
- Coordination Problems: Often, regional/divisional/local managers may make decisions that improve *their* position, but are not necessarily beneficial for the entire firm’s portfolio
- The following slides highlight some typical questions that can be addressed with our model

"Default" Portfolio



- Return: $40/kw
- Risk: $99/kw
- MIRR: 11.9%
- Sharpe: 0.40
- Size: 15,000 MW
- Weights: determined by MW size (integer-constrained)

Size Constraints (Divestiture)

- Suppose that regulators require the firm to reduce its holdings to approximately 13,000 MW
- Can the firm use this as an opportunity to improve portfolio performance?
- ***Yes!***
- Results, however, depend on how sales (and sale prices) are treated and whether or not plants are allowed to add assets as well (so long as the net result is a drop in capacity)

- The “best possible” 13,000 MW portfolio
  - Return: $75/kw
  - Risk: $123/kw
  - MIRR: 12.50%
  - Sharpe: 0.61
  - Size: 12,992 MW

- Sharpe better by 53%
- NPV better by 88%

- Further improvement (to Sharpe = 0.65) is possible by allowing the optimizer to consider repowering of assets

Merger Analysis

- Firm A
  - 7% PkgOil, 57% PkgGas, 8% StmGas, and 28% StmO&G
- Firm B
  - 31% Nuke, 45%Pkg/StmO&G, 24% Adv CC
- Firm C
  - 27% Nuke, 12% PkgOil, 29% StmO&G, 9% CC, 23% Adv CC

- Firm A is considering merging with either B or C
- Which is the better partner?

- Firm A (2,820 MW)
  - Return: $10/kw (11.7% MIRR)
  - Risk: $85/kw
  - Sharpe: 0.12
- Firm B (5,330 MW)
  - Return: $87/kw (12.7% MIRR)
  - Risk: $118/kw
  - Sharpe: 0.74
- Firm C (5,160 MW)
  - Return: $55/kw (12.7% MIRR)
  - Risk: $99/kw
  - Sharpe: 0.56

- Firm A+B (8,150 MW)
  - Return: $60/kw (12.3% MIRR)
  - Risk: $104/kw
  - Sharpe: 0.58
- Firm A+C (7,980 MW)
  - Return: $39/kw (12.3% MIRR)
  - Risk: $92/kw
  - Sharpe: 0.43

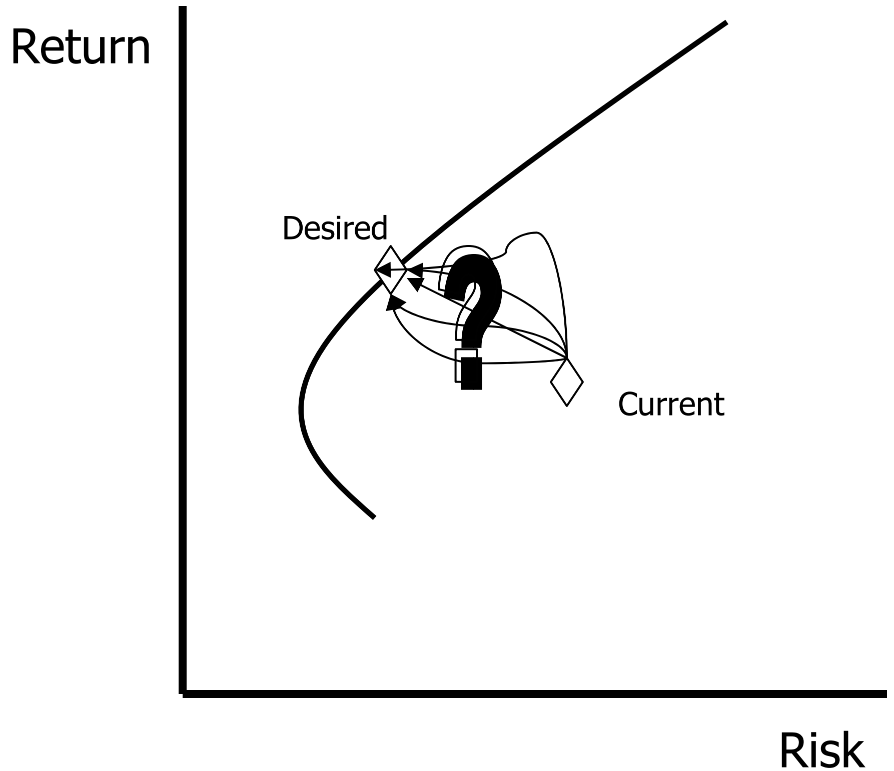
Merger Analysis

- Both B and C would improve A's position
- B and C have equal IRRs and result in post-merger portfolios with equal IRRs
  - IRR can be misleading!
- Portfolio B clearly represents the better partner for A
  - A increases its Sharpe ratio by 483%
  - A+B's Sharpe ratio is 25% higher than A+C's
- **Bottom Line:** B is the riskier partner, but that risk is well-compensated
  - Emissions limitations?

Optimal Portfolio with Cash Flow Constraints

- In the previous slides, we have used maximization of the Sharpe ratio as the objective function
- However, firms may have multiple objectives and a diverse set of constraints
- Suppose, for example, a firm wanted an efficient portfolio, but only provided that total portfolio cash flow exceeded a certain minimum level
  - Debt covenants on free cash flow
  - Debt Service Coverage Ratio

Optimal Path Analysis



- Suppose a firm wants to move from Current to Desired, a change of 3,000 MW
- However, it can't transact more than 500 MW per year
  - Other limitations could include regulatory issues, emissions caps, etc.
- How should it proceed?
  - The shape of the frontier may change over time
  - The dynamics of the market may involve an "indirect" path to Desired
- NOTE: Real options preserve paths

The "Environmental Frontier" Portfolio Optimization and 3P+CO_2

- Until now, the criteria have been exclusively finance-oriented
- However, portfolios can be constructed to satisfy any number of criteria
- The Regulator's Perspective: Emissions in the objective function
  - Minimize emissions such that risk and return are within acceptable parameters
- The Firm's Perspective: Emissions in the constraints
  - Maximize Sharpe ratio such that emissions do not exceed a certain level
- The Consumer's Perspective
  - Minimize total expenditures such that reserve margin levels are sufficient to prevent service interruptions

Emissions Uncertainty in a Portfolio Optimization Framework

- How variable is emissions output?
  - For regulators and environmental stakeholders, the goal may be to “manage” a region’s power assets to minimize the uncertainty over emissions output
  - A minimum variance emissions portfolio
- Stochastic Optimization Criteria
  - Minimize probability that emissions output is greater than cap levels
  - Maximize joint probability that emissions output is below cap and NPV is above threshold

Trading Credits and Expanding the Efficient Frontier

- In the basic model, all assets are power plants
- Suppose new assets – emissions credits – are introduced
- The introduction of these assets into the feasible set Pareto-improves market participants
- In our model, this can be seen directly by noting that the efficient environmental frontier expands "northwest"
  - More efficient combinations of assets are possible
  - On a regional level, the dollar size of the Pareto gain can be quantified

Real Asset Portfolio Applications

- Merger and Acquisition Analysis
- Regulatory Impact Assessment
- Internal Incentives and Compensation Structure
- Integration of risk management for real <u>and</u> financial assets (more efficient exploitation of “balance sheet” hedges)
- Optimization and Strategic Planning

Conclusions

- Having a detailed financial *and* operational model (incl. emissions) for all assets within a region enables a broad range of analysis previously unavailable
- One of the chief drawbacks to treating real assets like financial assets in portfolios has been the complexity of measuring risk and return in any objective fashion
  - One of the *advantages* is that engineering and regulatory issues (such as emissions control) can be treated at the same level as financial criteria
- Our neural net-enhanced simulation model, together with Visual Portfolio allows users to explore portfolio-level questions at a "desktop-level"
- Portfolio analysis of emissions is an open application in the framework