

Valuing New Technology: The Case of Photovoltaics and Other Capital Intensive Renewables

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OVERVIEW: TRADITIONAL COST MODELS NO LONGER WORK

	Just as Investors Understand That....	Energy Planners/Policy Makers Must Also Recognize That....
Cost and Risk	Expected returns (profits) cannot be separated from expected investment risks	A technology's cost, unadjusted for its market risk, is meaningless
Portfolios	A diversified portfolio is the only effective risk-hedging strategy	"Least-cost" analysis is no substitute for energy portfolio diversification
Accounting Measurement	Accounting profits are not a good predictor of a firm's future potential, strategic options and market share	Traditional cost analysis may not fully capture all dimensions of a new technology's value

PRINCIPAL ANALYTIC RESULTS– TWELVE YEARS OF RESEARCH IN THREE MINUTES:

- **Standard, finance-oriented valuation models show that the kWh-cost for most renewables is less than gas-fired electricity**
 - Reflects market risk and the effect of taxes
 - Excludes environmental externality, flexibility and other additional values
- **Adding renewables to a fossil generating portfolio *reduces* overall generating cost as well as risk**
 - This result derives from basic portfolio theory
 - Most renewables are *zero-beta* or “systematically riskless” assets
- **Experience in other industries suggests that exploitation of *broadly-applicable* technologies requires changes in organizations, supporting systems and infra-structure and can produce benefits not easily conceived in advance**
 - Renewables/DG: changes in network organization, regulation & pricing
 - Modernization focus: “Informed” networks
 - Basis for re-conceptualized electricity production/delivery system

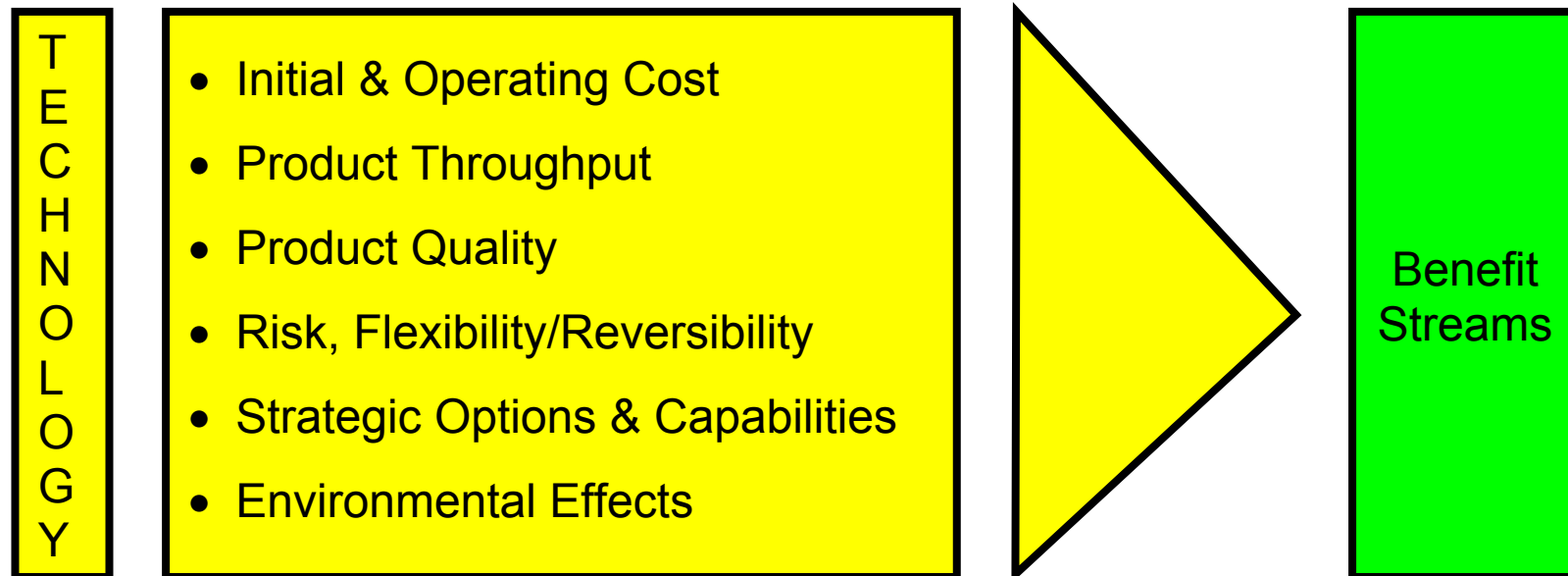
TRADITIONAL COST MODELS NO LONGER WORK:

Difficulty Conceptualizing/Quantifying Benefits and Reflecting Market Risk

- **Engineering Cost Models often fail to identify promising innovations**
 - Legacy of American Manufacturing:
 - Steel mini-mills, CAD, CIM, robotics...
- **They Were conceived in a different technological era**
 - Do not work well for DG/renewables and other passive, capital-intensive technologies— e.g. fax machines
- **They produce “rule-of-thumb” valuations that ignore taxes and risk differentials...**
 - But, fossil prices vary *systematically* – non-diversifiable risk
 - Costs of passive/capital-intensive renewables are systematically riskless
 - Financial properties mimic US Treasury obligations

EVALUATING NEW TECHNOLOGY

Technologies Provide a Bundle of Benefit-Cost Attributes



Most Attributes Have No Direct Accounting Measure

TRADITIONAL COST APPROACHES NO LONGER WORK

The Legacy of Manufacturing:

- Traditional accounting-based benefit-cost techniques fail to identify promising innovations
- These techniques have a dismal record for picking winners:

1960's:	<i>Computers</i>	"Armies of Clerks are Cheaper"
1980's:	<i>Robotics</i>	"Human Workers are Cheaper"
1980's:	<i>CAD</i>	"Engineers Are Cheaper"

In each case, cash-flow based valuations failed to consider Risk, Complementarities, new Capabilities and Strategic Options

***These same Techniques say Renewables are
"Not Yet Cost-Effective"***

TRADITIONAL COST APPROACHES NO LONGER WORK

EXAMPLE: VALUING COMPUTER-AIDED-DESIGN (CAD)×

- **Analyses Based on Naive Benefit-Cost:**

- Engineering Salaries Saved Vs. CAD-Station Outlays
- Did Not Value CAD's "Intangible" Benefits: Complementarities and Capability Attributes

Frequent product redesign	→	No obsolete product/inventory
Rapid response/throughput	→	More varied product line
Complementary benefits	→	Reduce CIM set-up costs

CAD helps firm retain customers— Not save engineering salaries

Renewables reduce financial risk and provide the basis for reconceptualizing the electricity production/delivery process

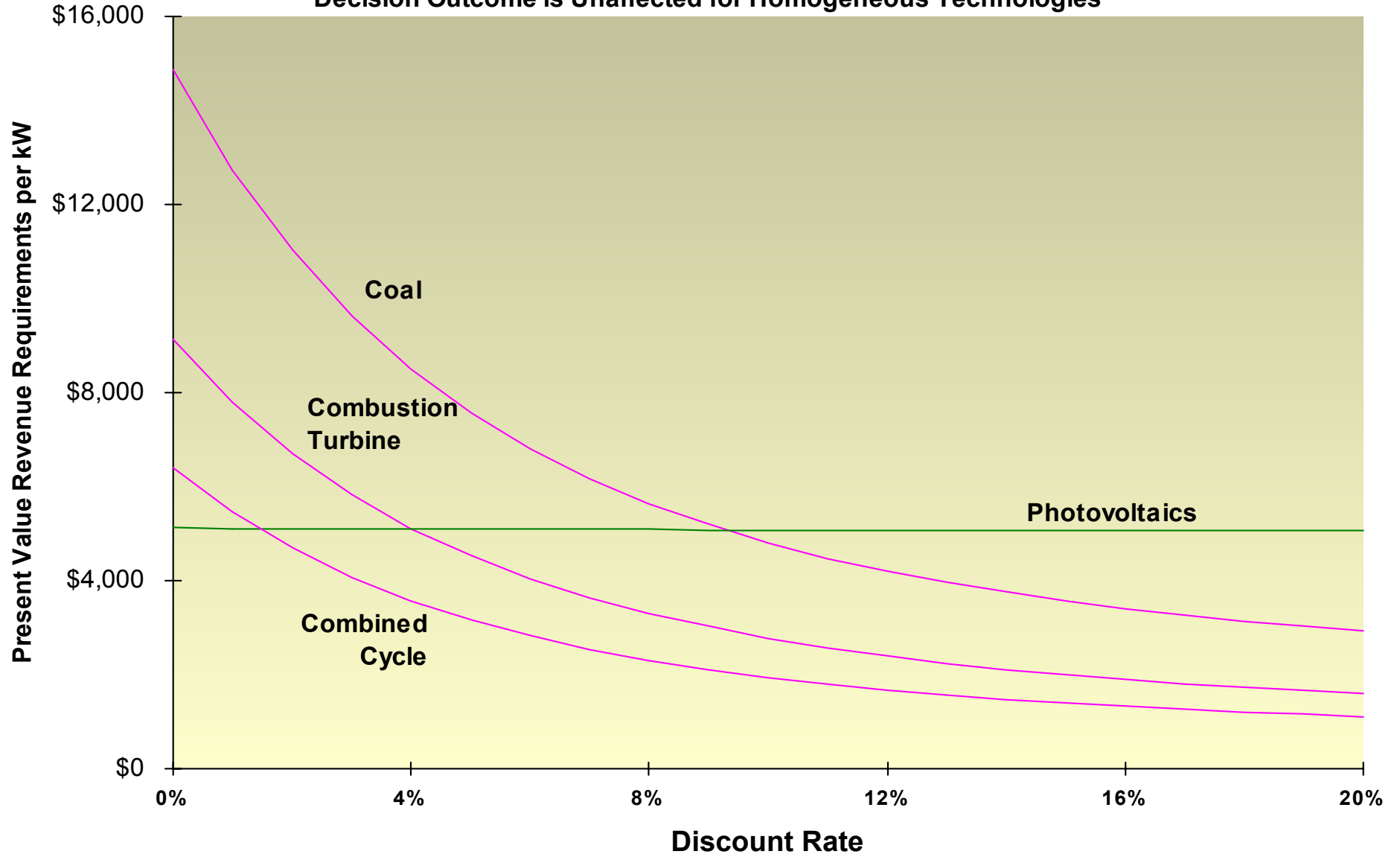
Valuing Energy Technologies Necessarily Involves an assessment of Financial Risk

- **Traditional cost-of-electricity estimates, based on Engineering Economics approaches, yield “rule of thumb” valuations**
 - Ignores risk differentials among technologies and processes *xx*
 - Probably sufficed until very recently *xx*
 - Ignores the effects of corporate taxes and depreciation tax shelters *xx*
- **Fossil Fuel Prices Vary Systematically**
- **The costs of Passive/Capital-Intensive Technologies (e.g.: PV, wind) are Essentially Systematically Riskless (beta ≈ 0)**

Engineering-Economics Valuation Can Produce Conflicting Results

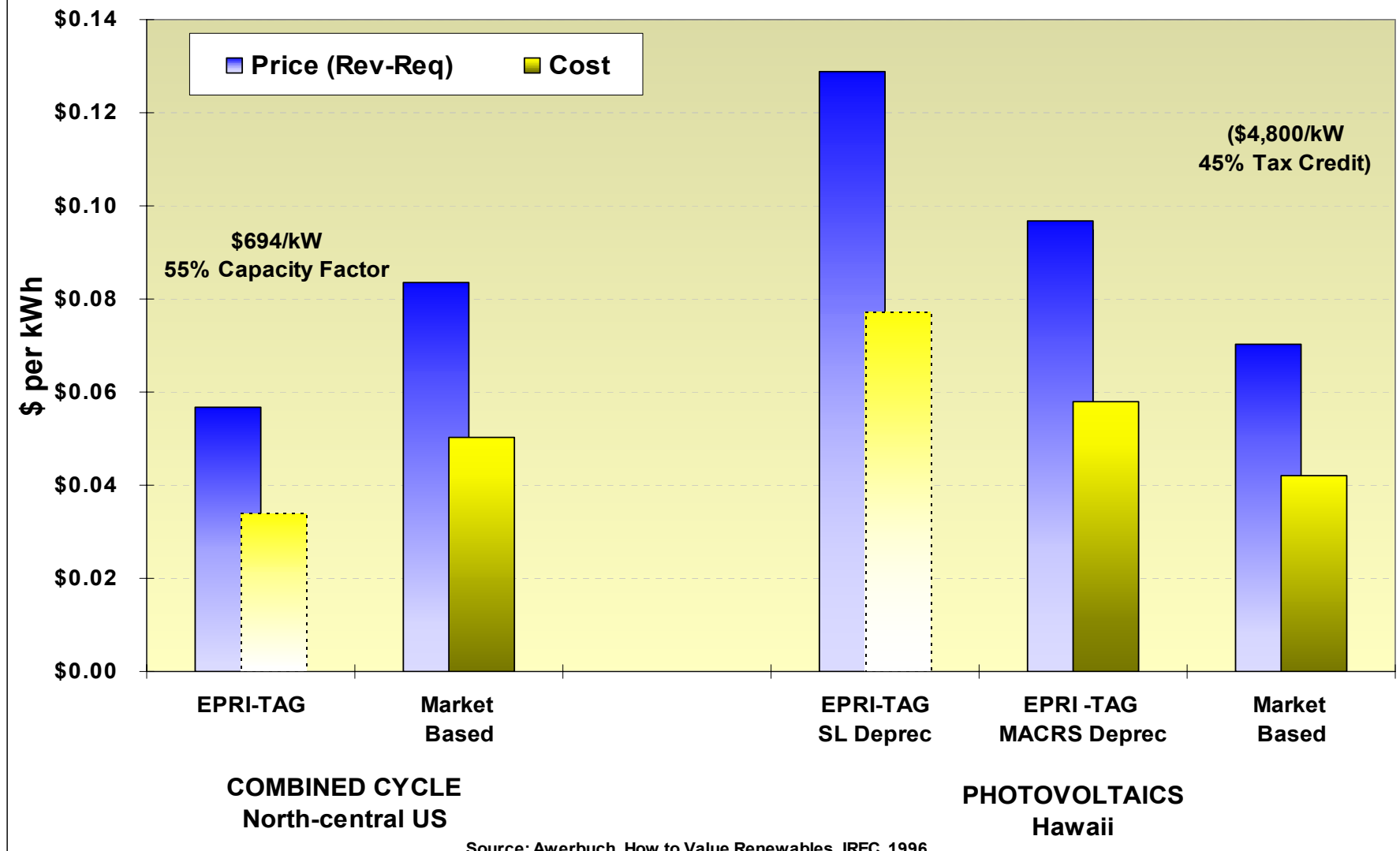
Valuing Two Bond Investments Using a Single Arbitrary Discount Rate		
	Assumed Discount = 6%	
	10% Junk Bond	4% Government Bond
YEAR	Yearly Proceeds	
1	\$100	\$40
2	\$100	\$40
3	\$100	\$40
5	\$100	\$40
Present Value of Proceeds	\$347	\$139

**Ignoring Risk in Valuation:
Present Values Using a Single Discount Rate for all Costs
Decision Outcome is Unaffected for Homogeneous Technologies**



Based on NARUC [1990] Costs

Cost and Price for Gas-CC and PV (1996) Engineering Vs. Risk-adjusted Approaches

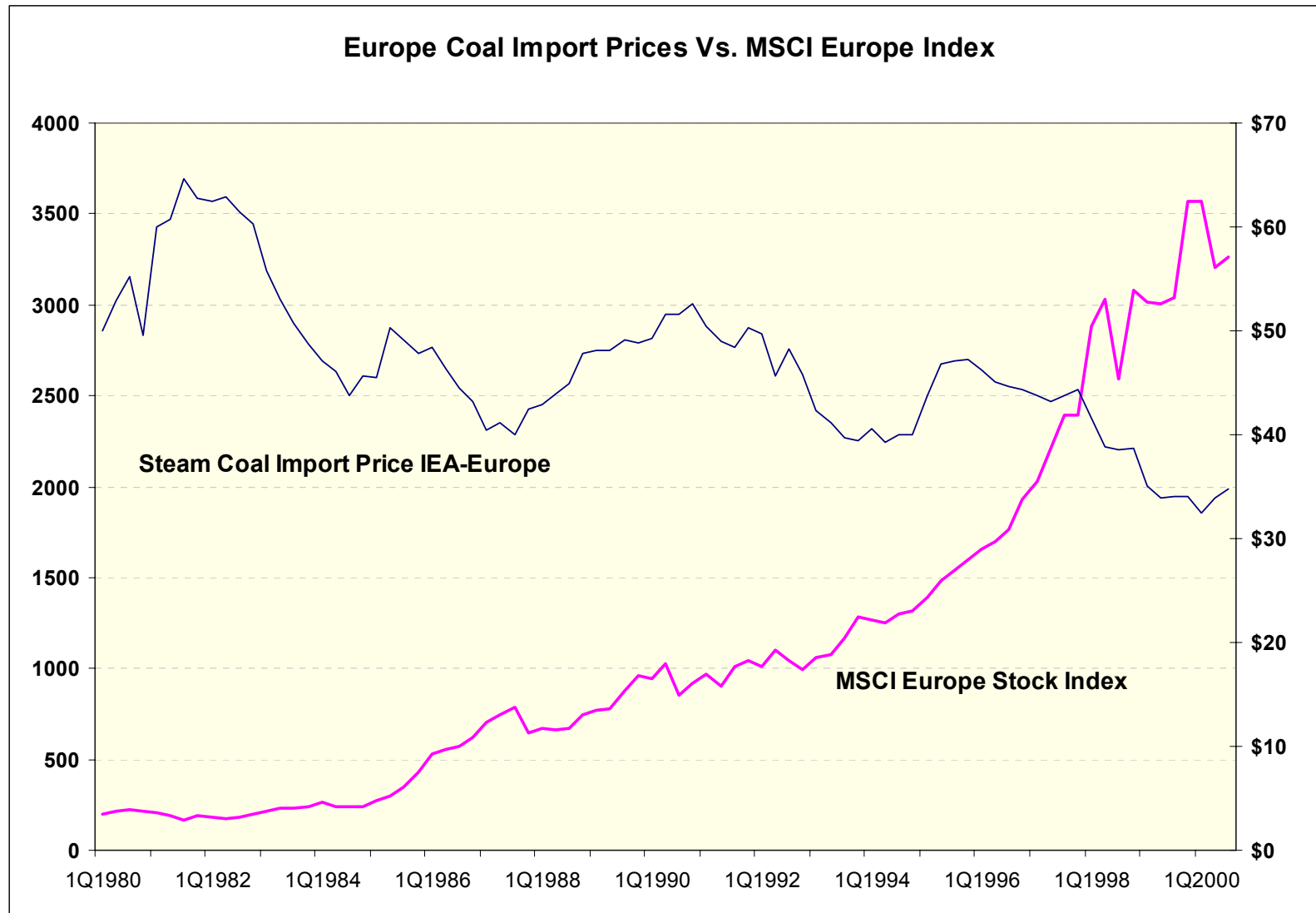


Valuing Energy Technologies Necessarily Involves an assessment of Financial Risk (Continued)

- **Fossil Fuel Prices Vary Systematically**

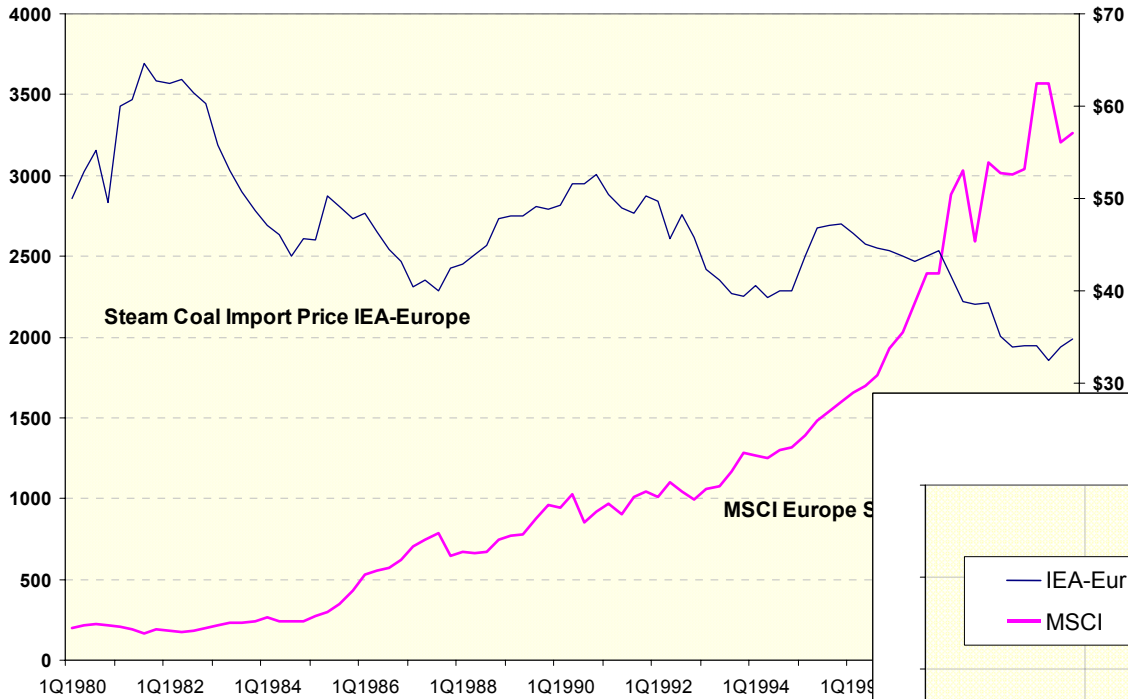
- Negative covariance with economic activity ($\beta < 0$) xx
- First observed by Lind and Arrow (Johns Hopkins Press 1986)
- Important implications for EU energy diversity/security goals xx
 - Fossil price increases seem to depress economic activity
 - More profound implications than traditional "energy security" view
- Important portfolio Implications:
 - Non-fossil generating assets produce counter-cyclical returns
 - Their value is high when the rest of portfolio is low

Systematic Fossil Price Risk Measured Against the Morgan-Stanley MCSI Europe Stock Index (Based on French & Fama)

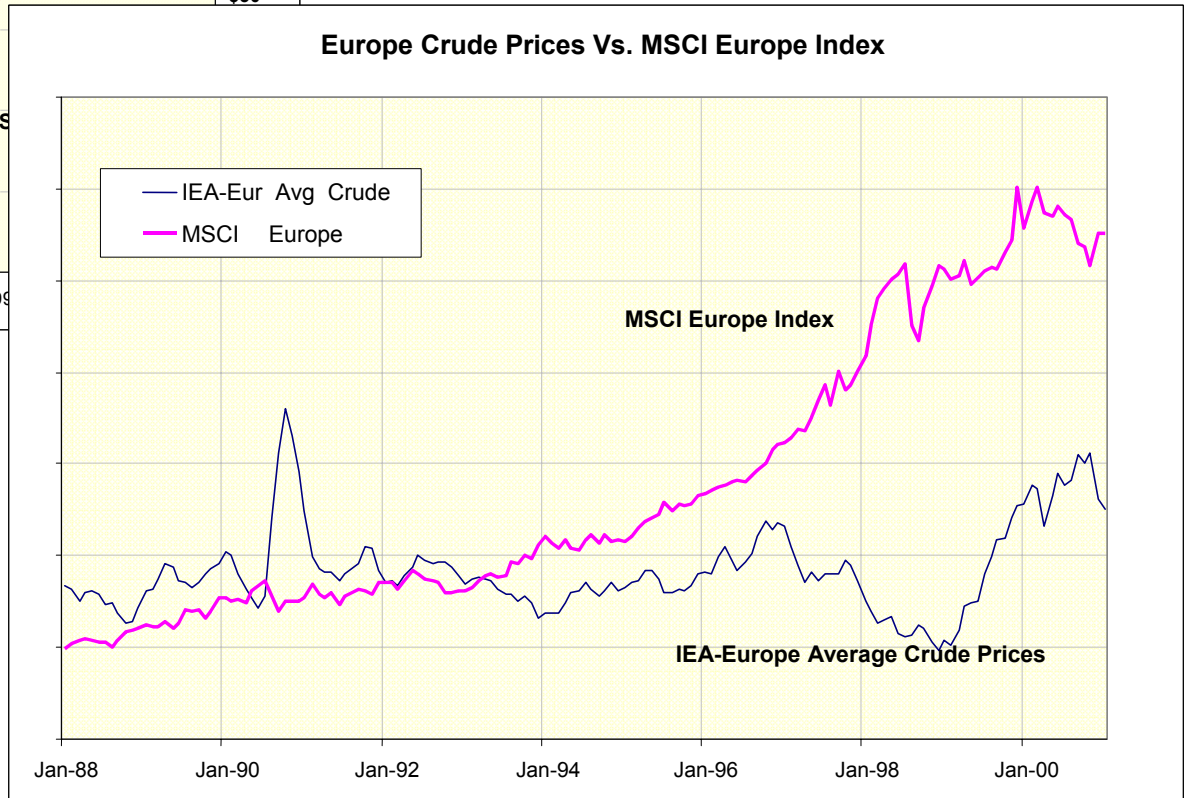


FOSSIL PRICES MOVE SYSTEMATICALLY

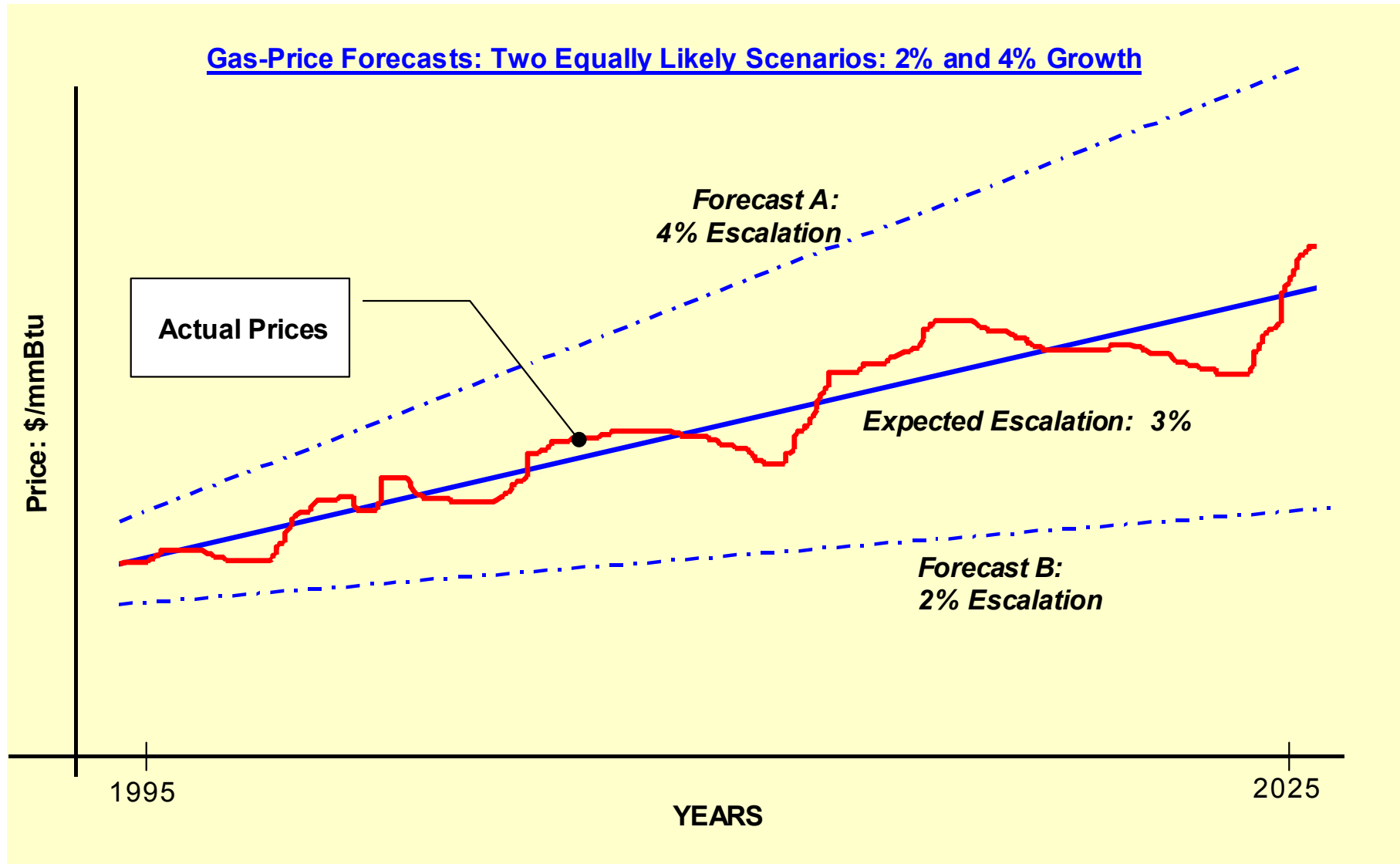
Europe Coal Import Prices Vs. MSCI Europe Index



Europe Crude Prices Vs. MSCI Europe Index



What Makes Fuel Prices Risky?



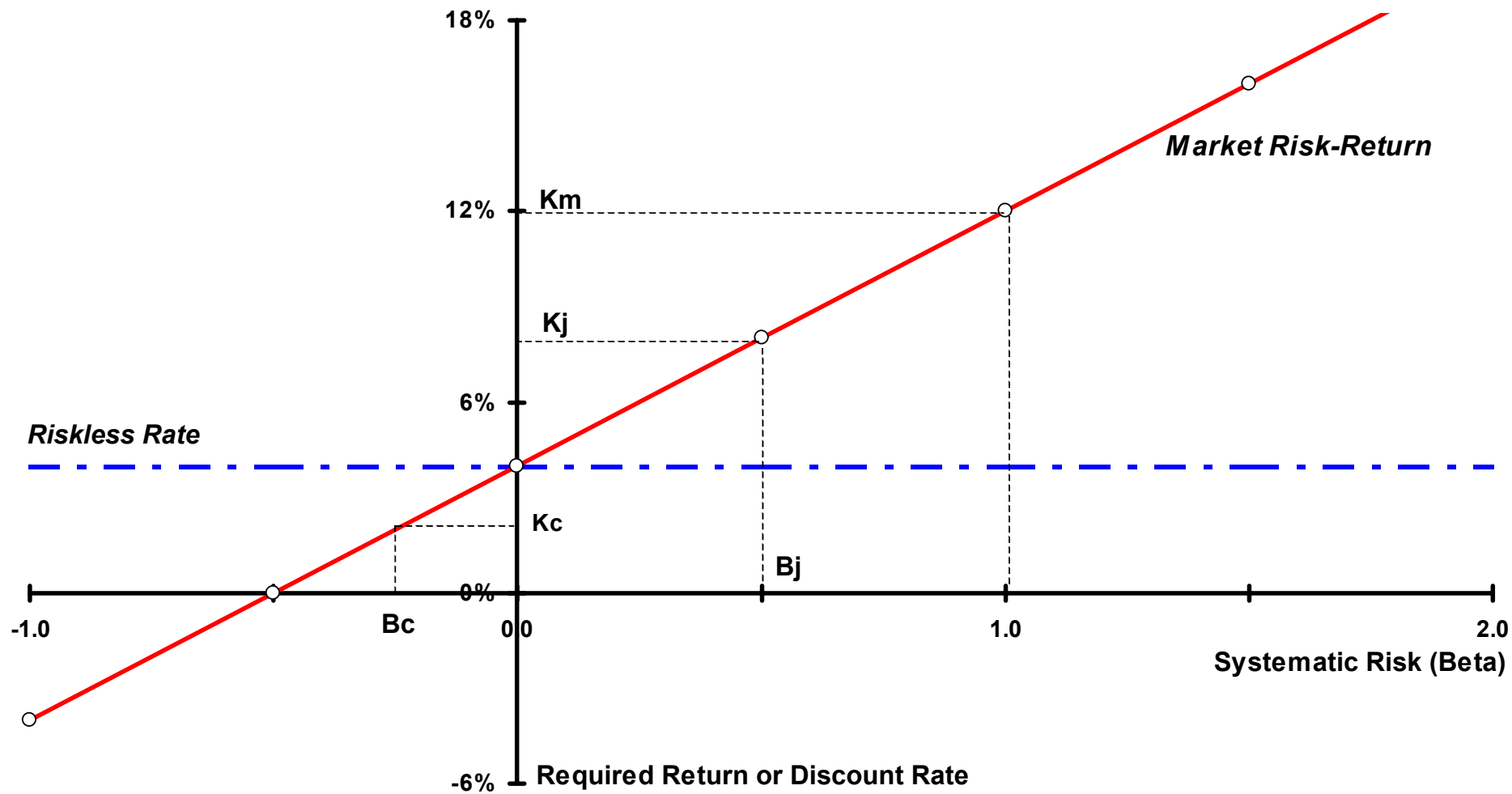
Valuing Energy Technologies Necessarily Involves an assessment of Financial Risk (Continued)

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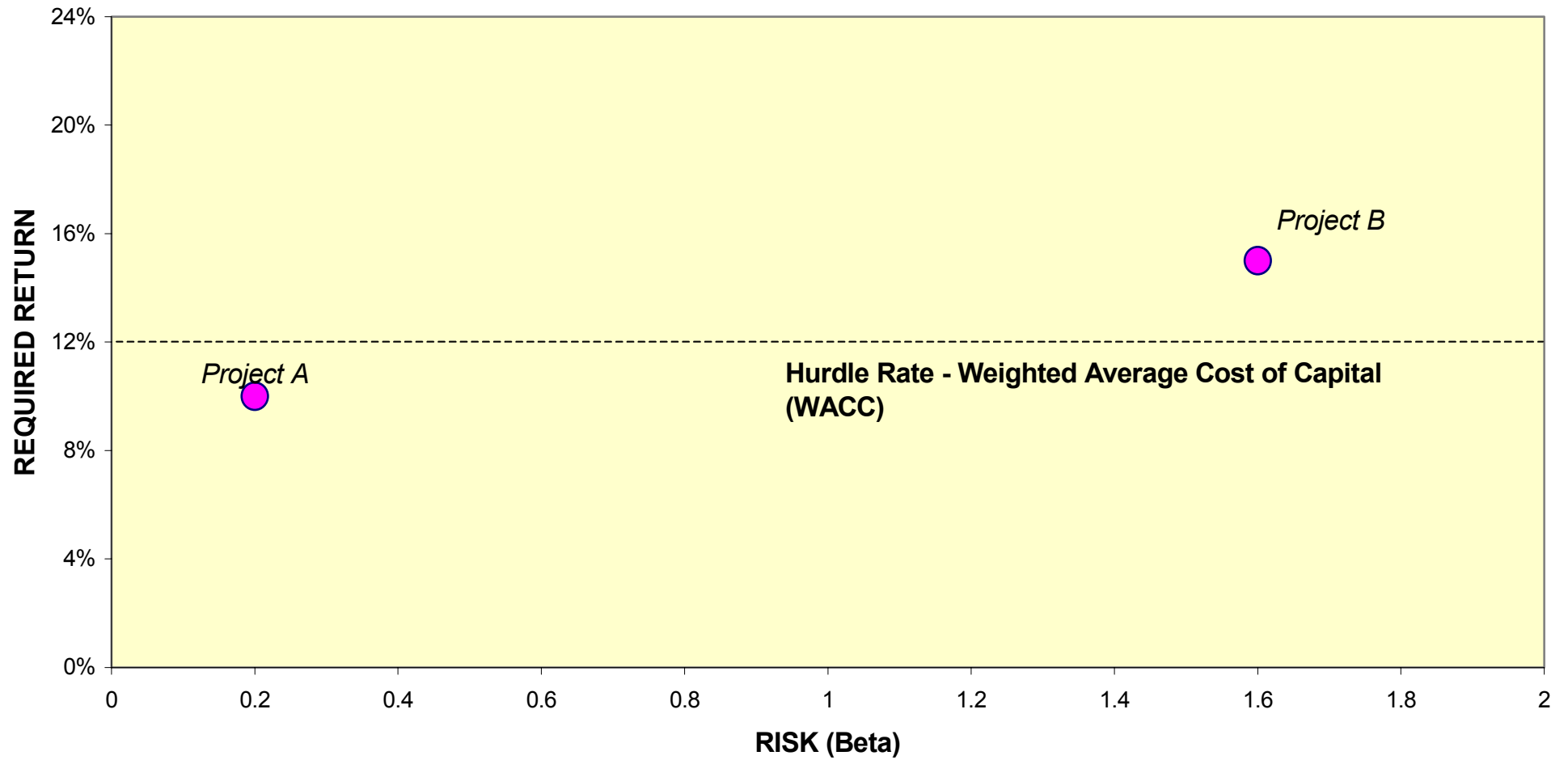
- When combined With Fixed Purchase Power Contracts: Asset $\beta = 0$
 - Financial properties mimic US Treasury obligations
- However, to the extent fossil prices and hence electric rates rise during bad economic times:
 - Renewables and other non-fossil generating sources provide *counter-cyclical* benefits
 - A form of national insurance (Lind/Arrow 1986,)

Using the CAPM to Estimate Discount Rates for Projects and Cost Streams

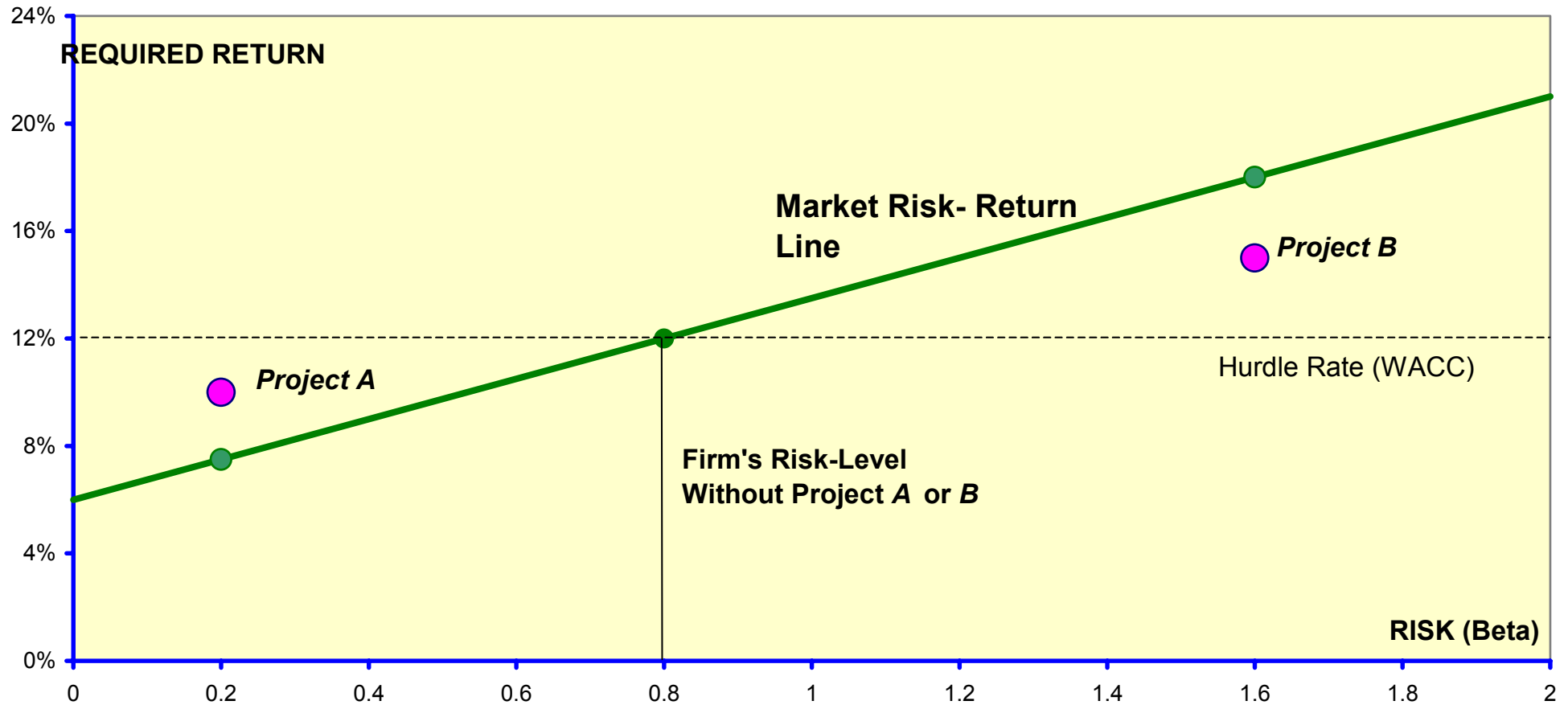
K_m = Required Return to Diversified Portfolio (Beta = 1.0)



Project Selection Using WACC For All Projects



Project Selection When Risk Varies WACC Leads to Poor Results



***Project A Raises Share Price, Project B Lowers It!
Low-Risk / Low-Return Assets Need Not Hurt Shareholder Value***

When Using the WACC to Value Projects:

"Stars Will Be Starved....."

But the Dogs Fed"

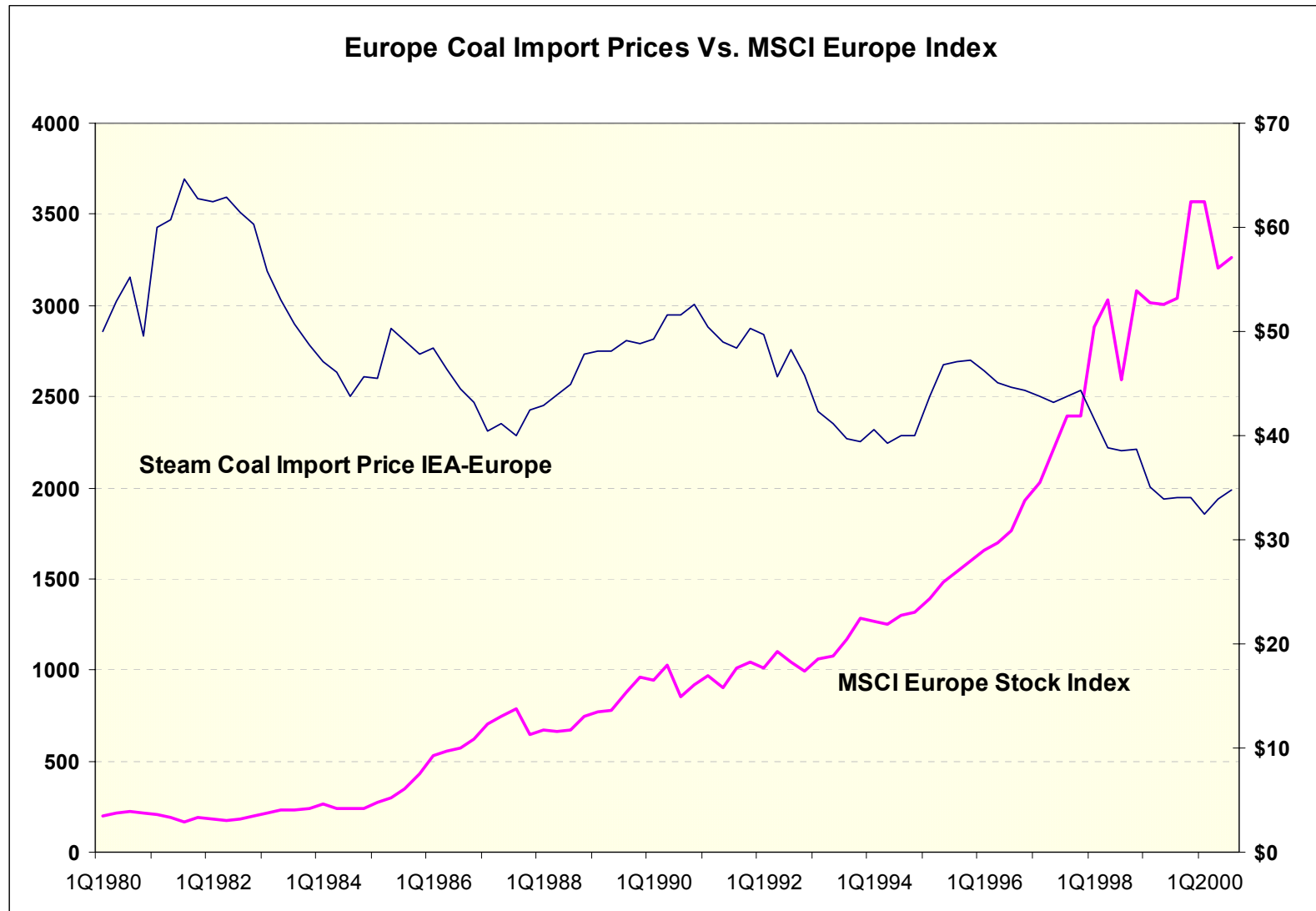
G. B. Stewart, *The Quest for Value*, Harper, 1990

**ILLUSTRATIVE RISK ADJUSTED
COST-OF-ELECTRICITY ESTIMATES
FOR IEA EUROPE**

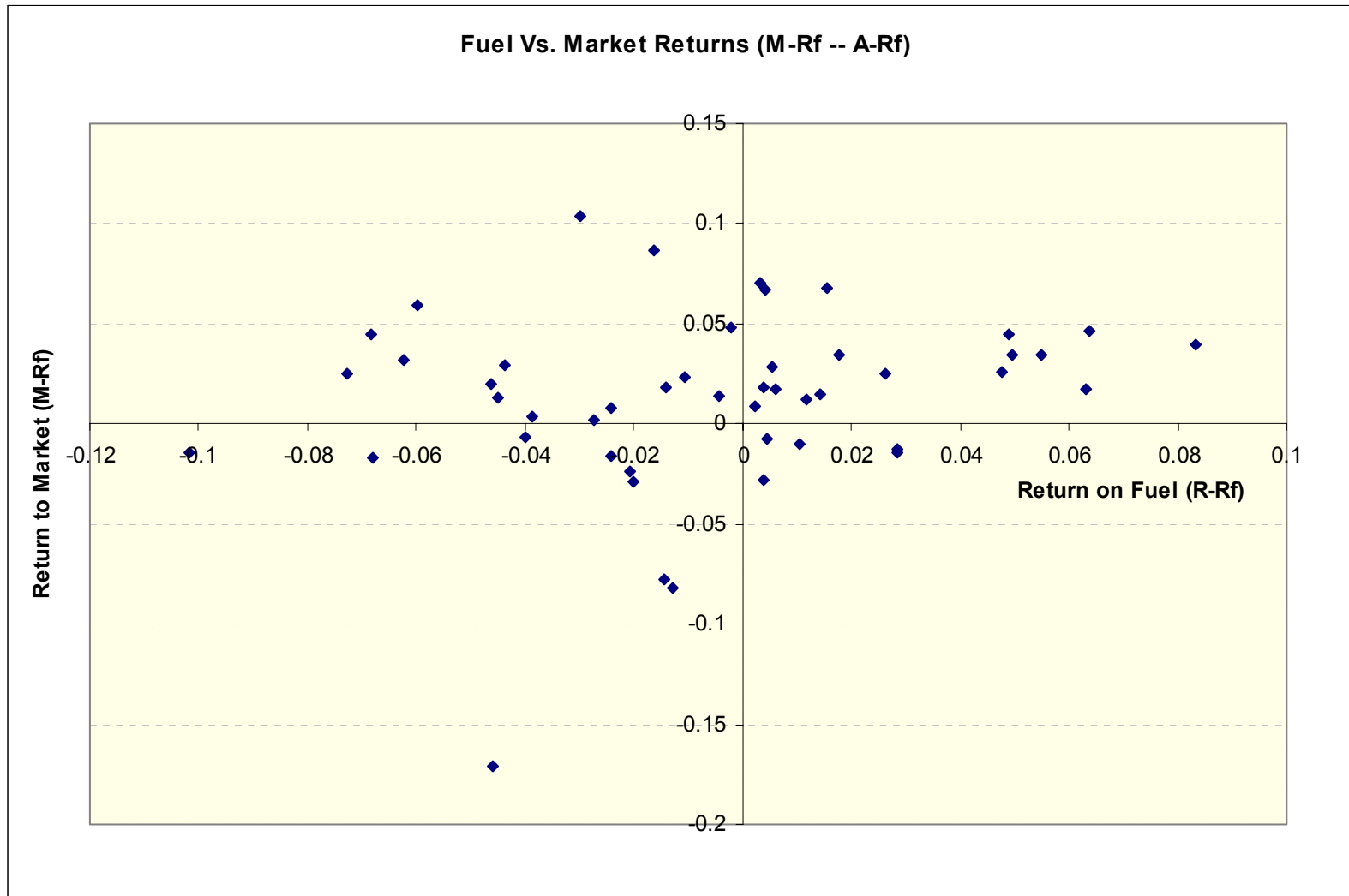
POST-TAX RISK-ADJUSTED COST-OF-ELECTRICITY ESTIMATES

- **Extends Previous US-DOE Funded Research**
- **Riskier Costs \Rightarrow Lower Discount Rates \Rightarrow Higher Present Values**
- **Reflects the Effect of Taxes and Depreciation Tax Shelters**
 - Effects not uniform across technologies
- **Enables “Apples-to-Apples” Comparison**
 - Important in today’s environment of heterogeneous technological alternatives **
- **C-O-E Estimates Can be Interpreted as the cost at which a 30-year contract for electricity delivery would trade in efficient markets**
 - Differs from Engineering-based COE Estimates

Estimating Discount Rates: Systematic Fossil Price Risk Measured Against the Morgan-Stanley MSCI Europe Stock Index (Based on French & Fama)

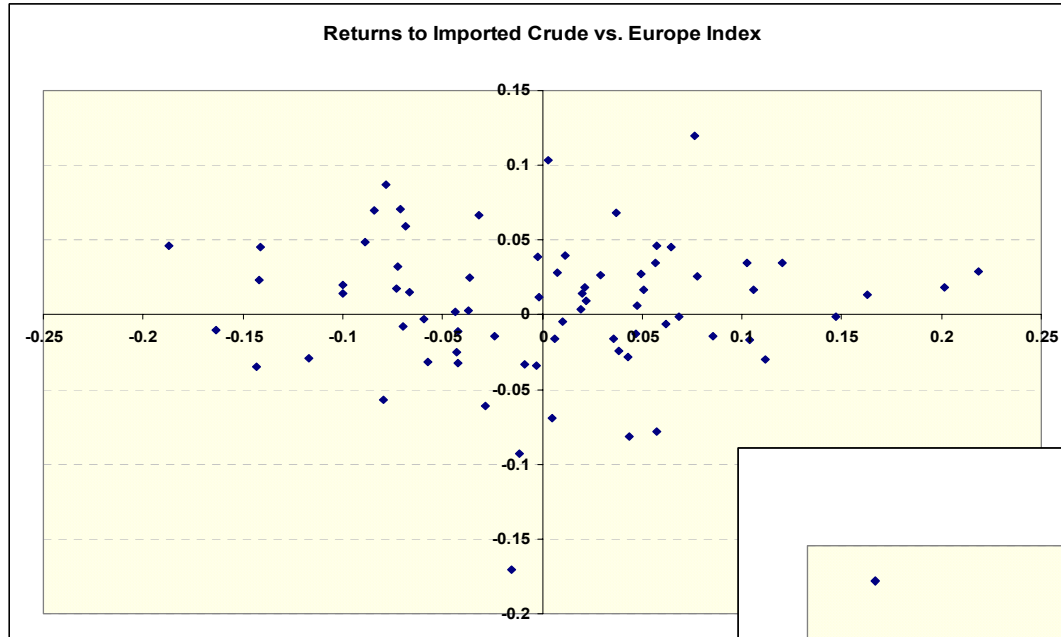


Returns to Europe Import Gas Vs. Returns to *MSCI* Europe Stock Index (60-Month Beta = -0.15)

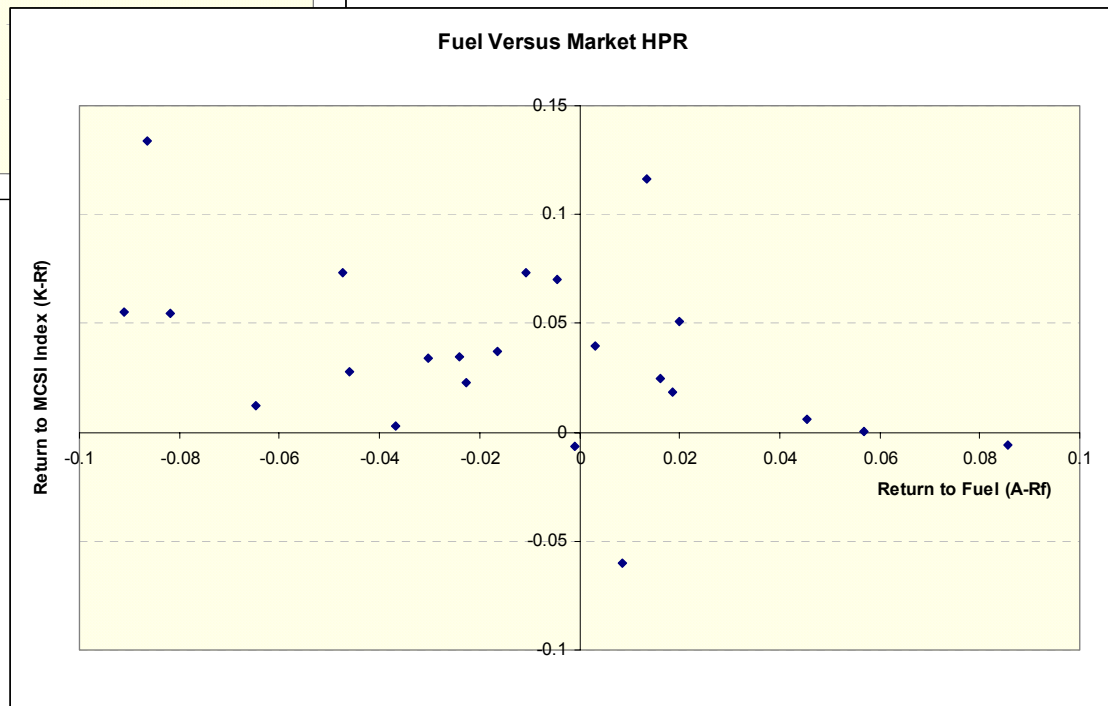


60-MONTH RETURNS TO EUROPE OIL & COAL Vs. *MSCI* INDEX

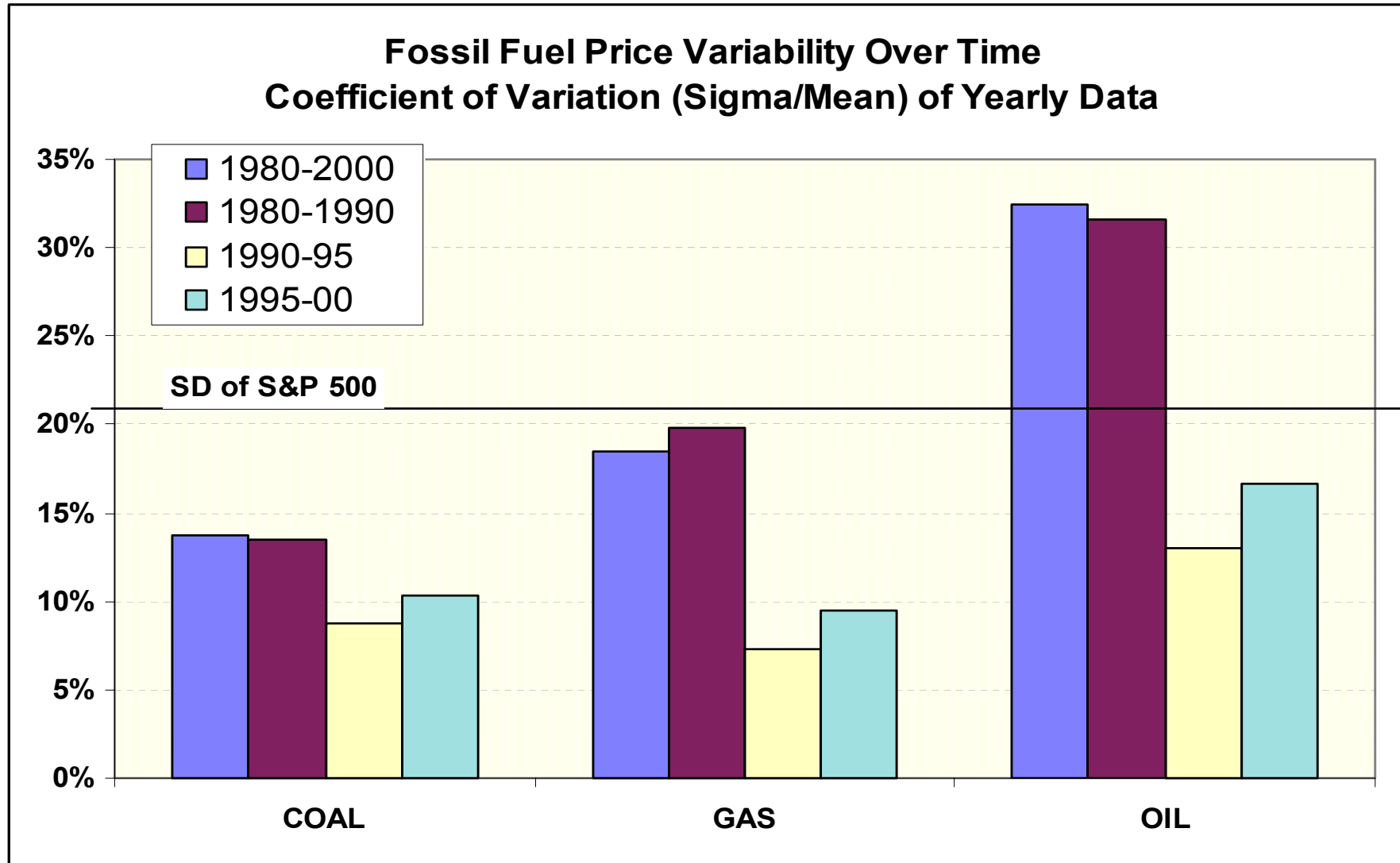
Crude Oil Imports (Beta = -0.05)



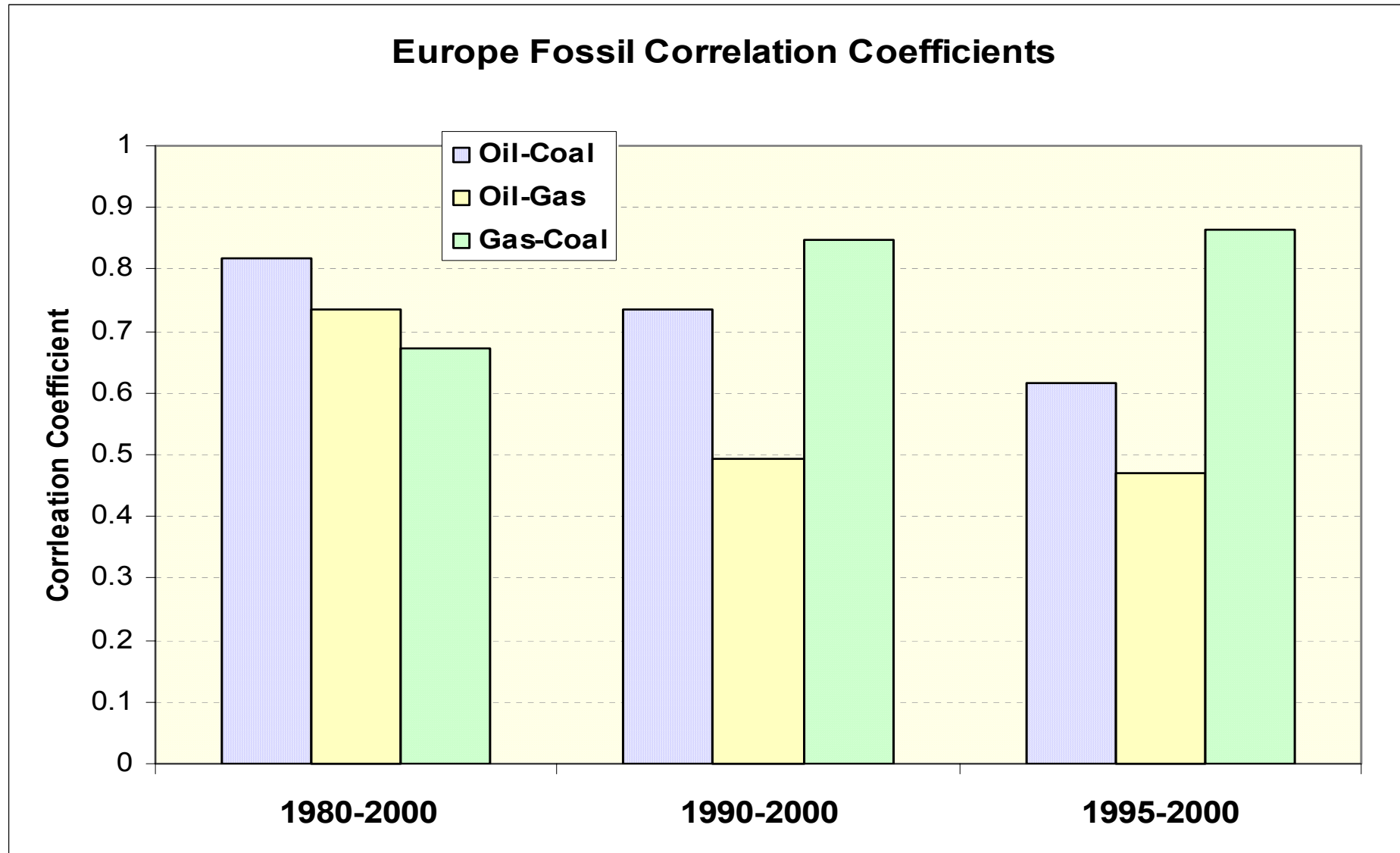
European Steam Coal Imports (Beta = -0.45)



Total Fossil Fuel Risk Over Time

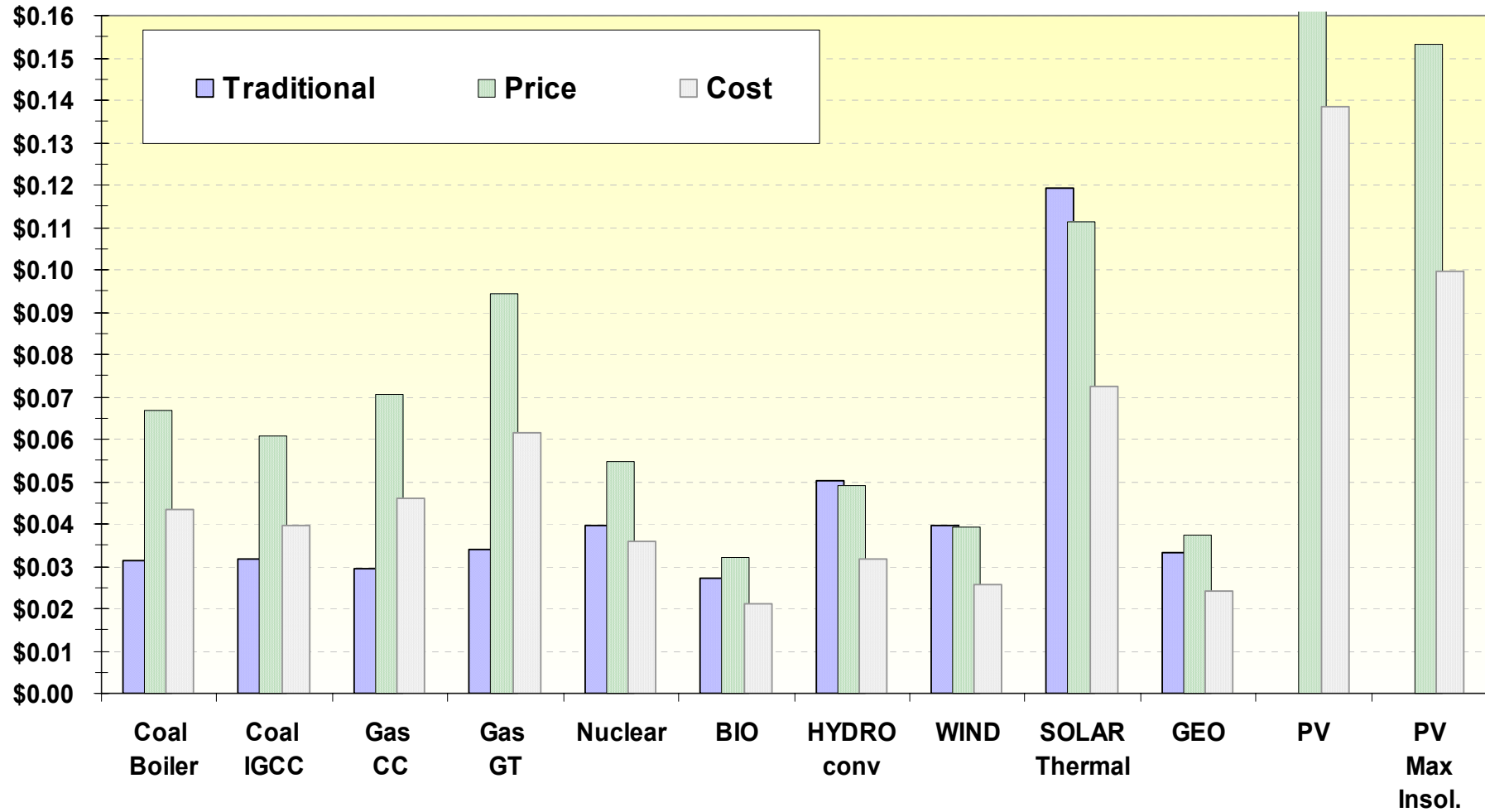


Fossil Correlations Over time: The Gas-Coal Portfolio Offers Little Opportunity for Diversification

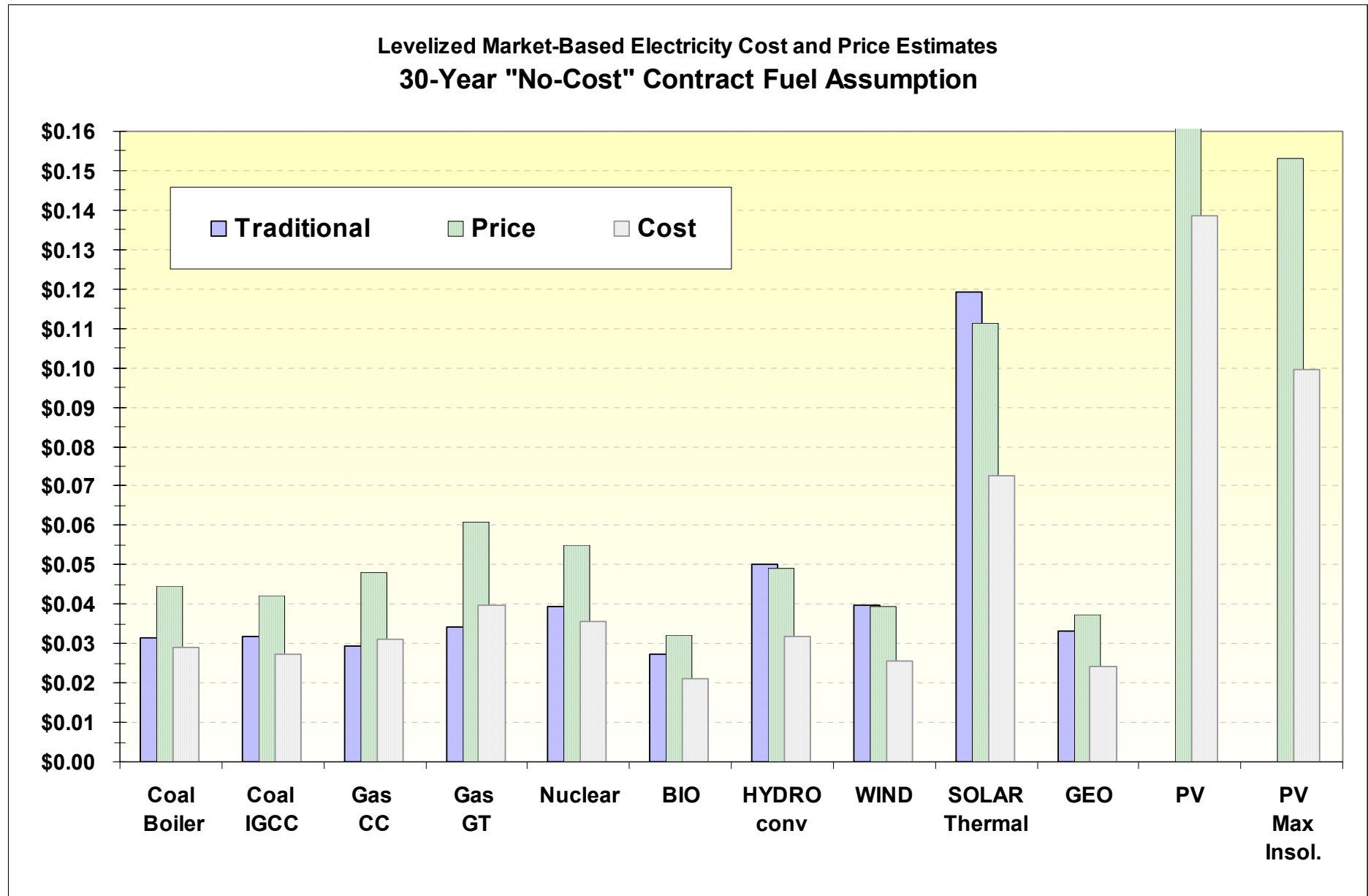


Risk-Adjusted Cost-of-Electricity Estimates: "Historic Fuel Price Risk"

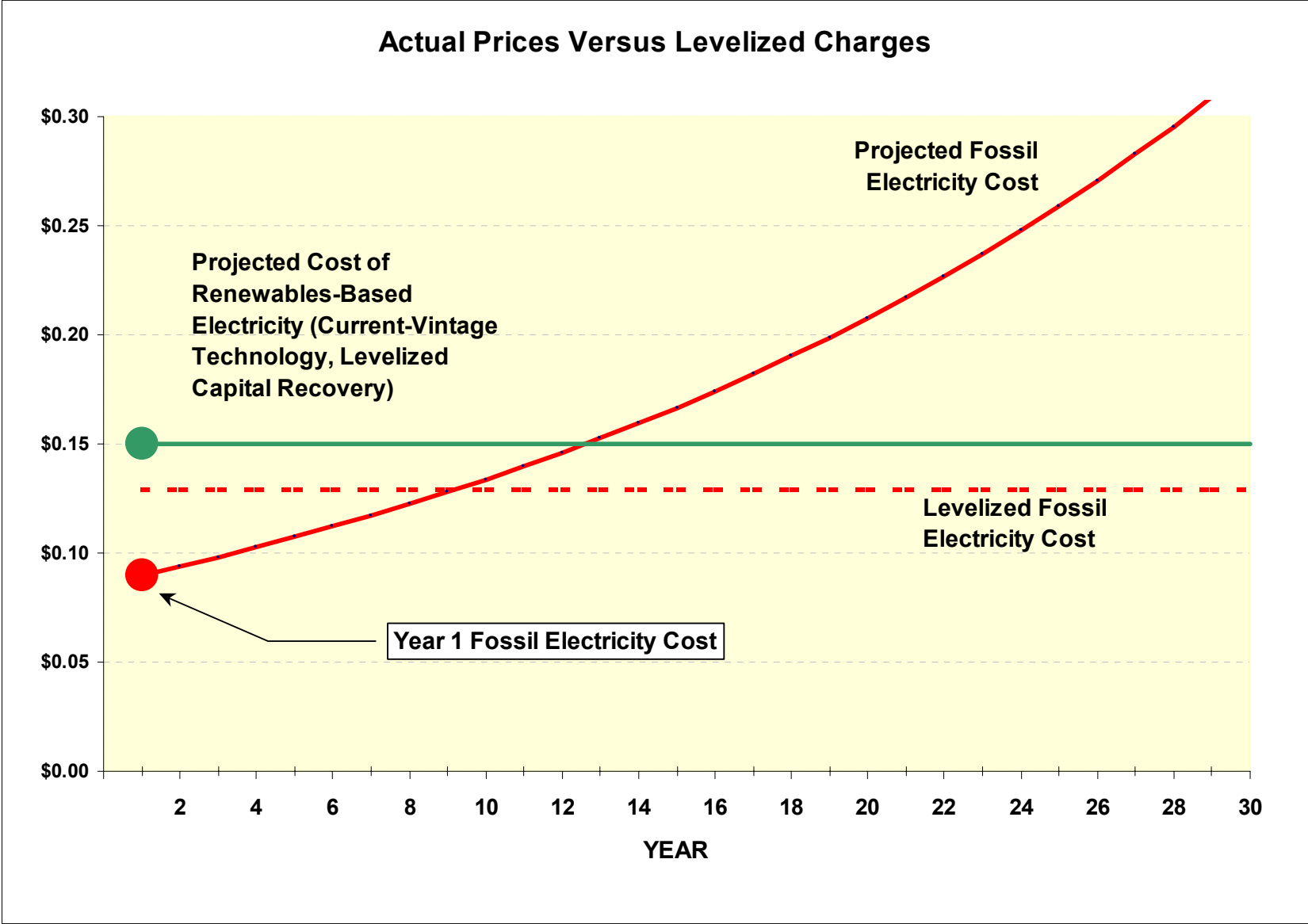
Levelized Market-Based Electricity Cost and Price Estimates
- Historic Fuel Price Risk -



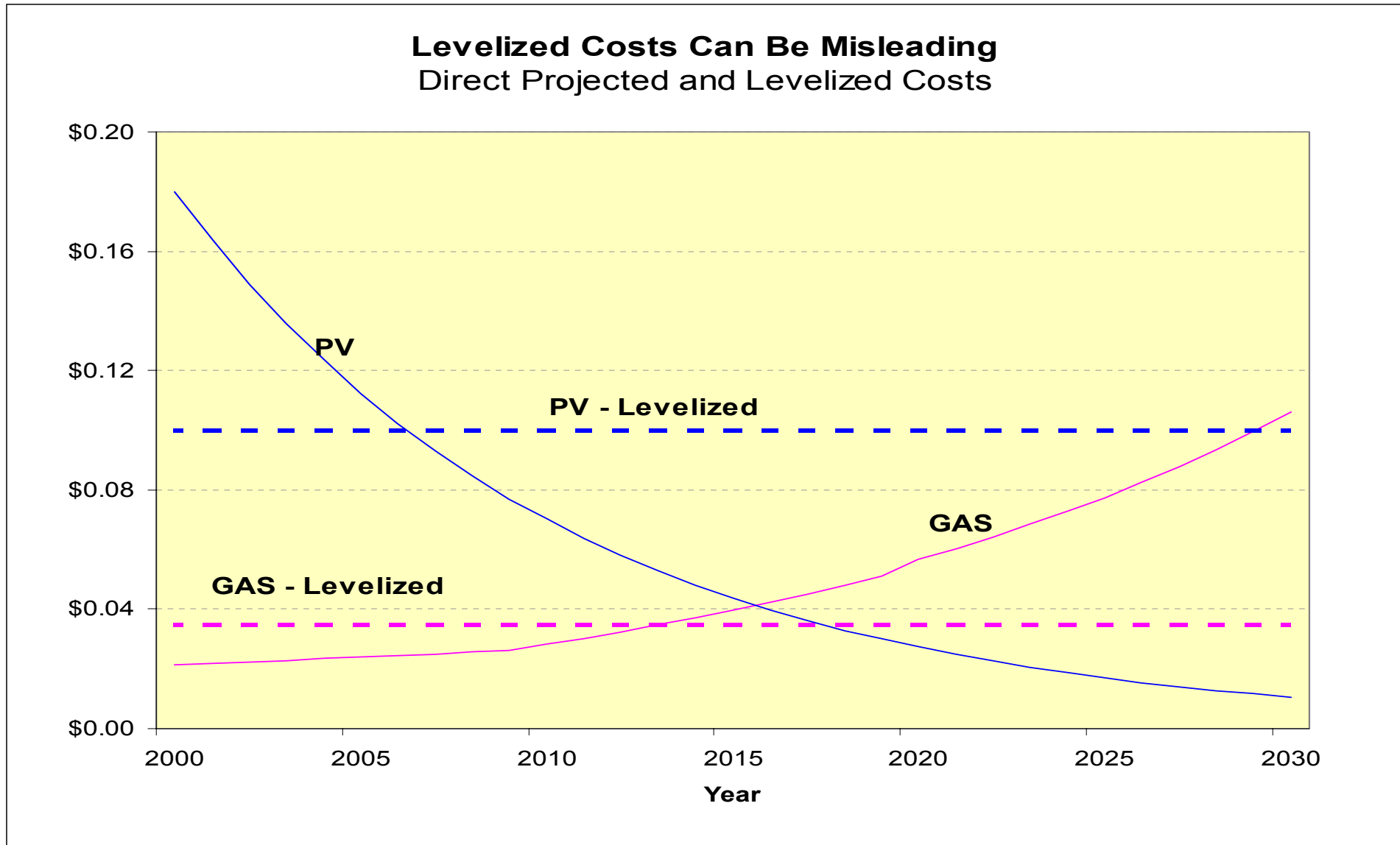
Risk-Adjusted Cost-of-Electricity Estimates: "No-Cost" Contract Fuel



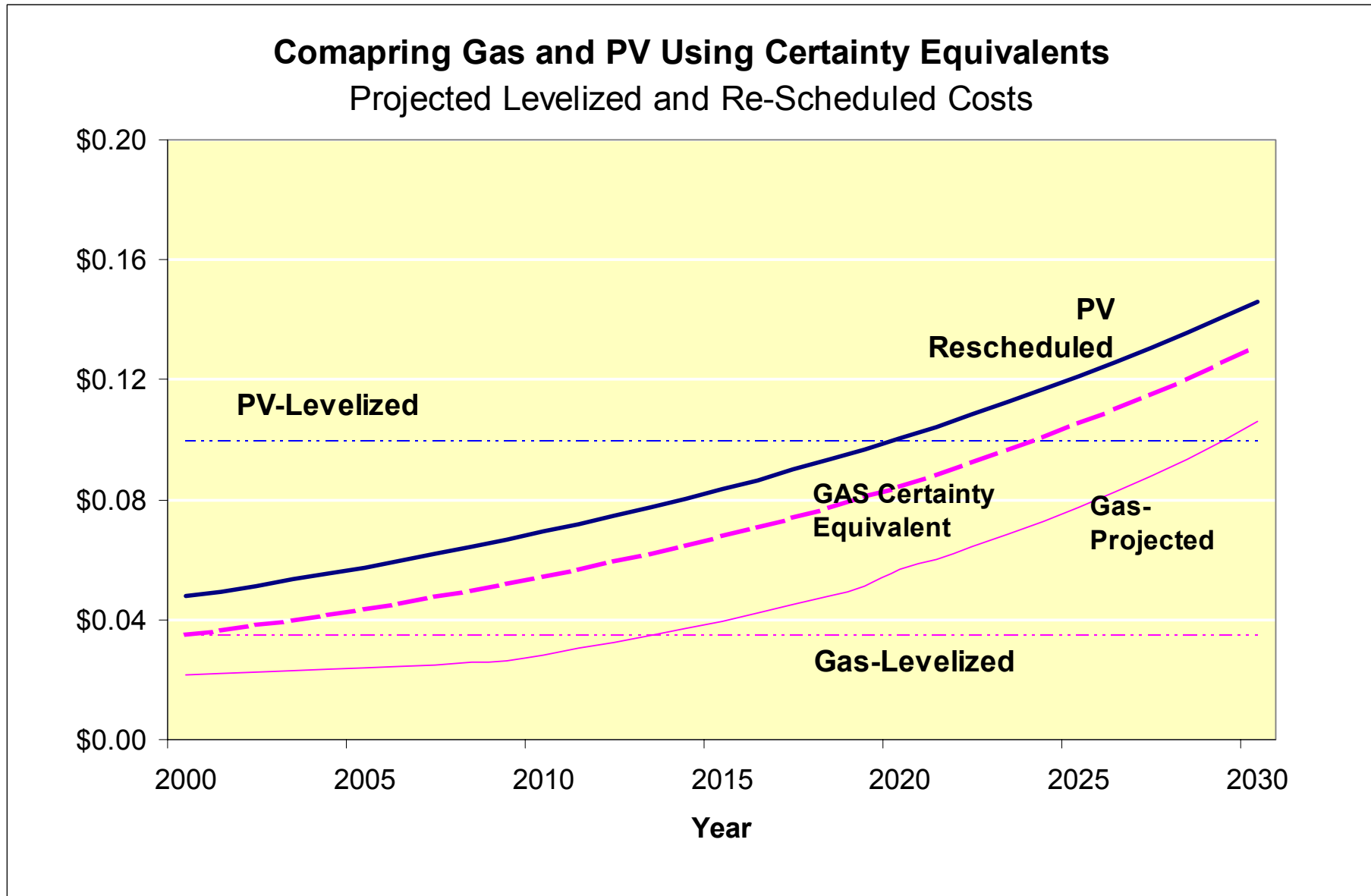
Levelized COE Estimates Cannot be Compared to Actual Market Prices



LEVELIZED COSTS MASK IMPORTANT INTER-TEMPORAL INFORMATION

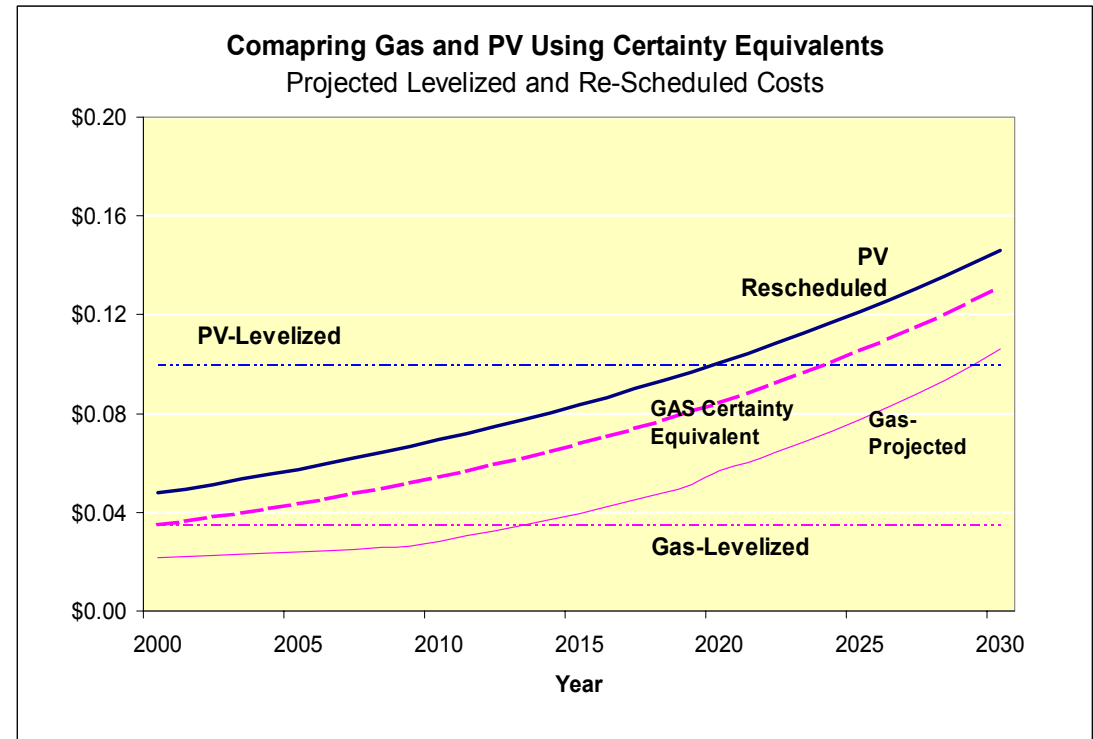


LEVELIZED COSTS MASK IMPORTANT INTER-TEMPORAL INFORMATION



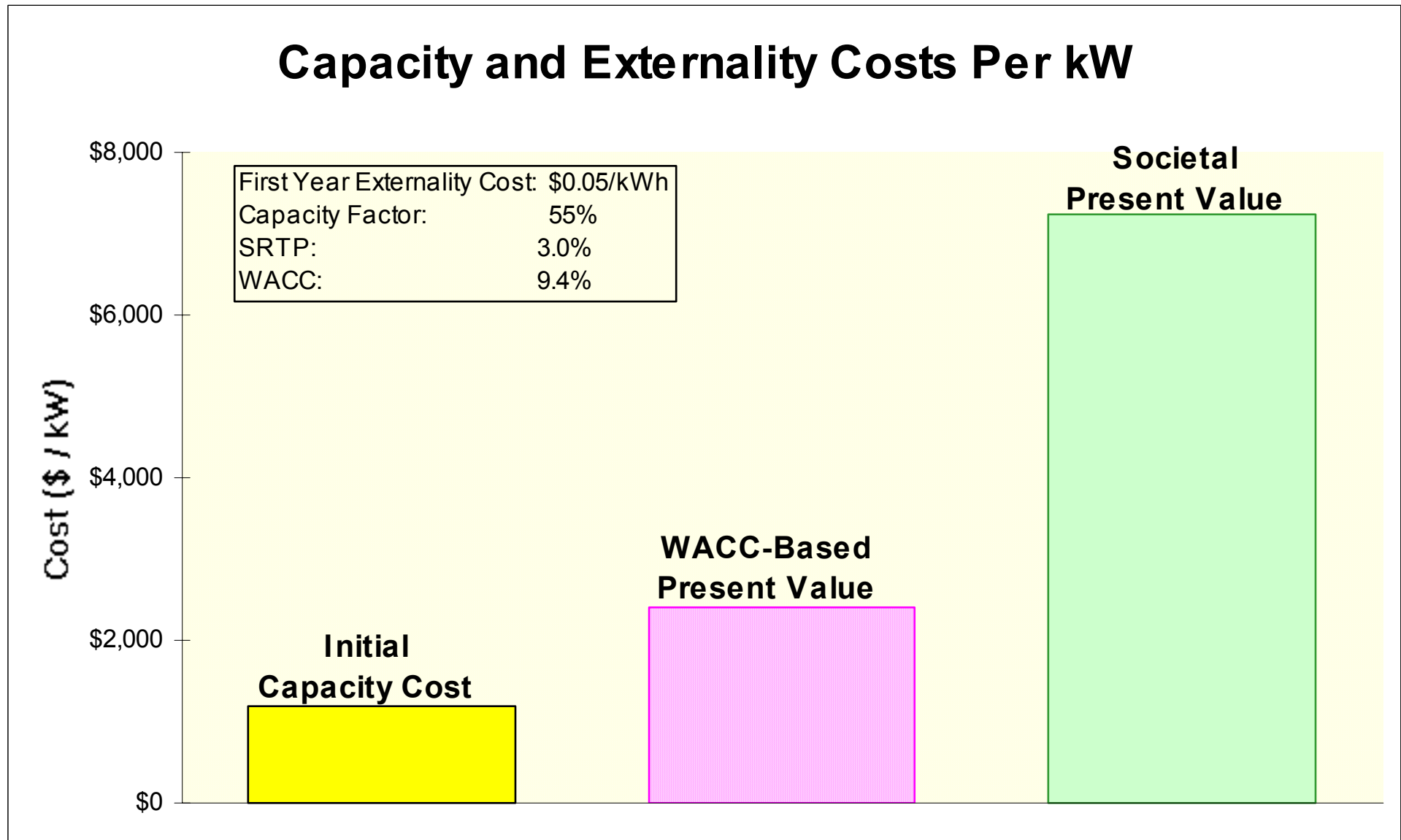
CAN WE ALTER OUR COMPACT WITH FUTURE GENERATIONS? RENEWABLES CAN RESHAPE THE LEGACY WE LEAVE FOR THEM

- **Fossil Fuel Usage Saddles Future Cohorts With Rising Fuel and Environmental Costs**
- **Should We Alter Our Compact With Future Generations?**

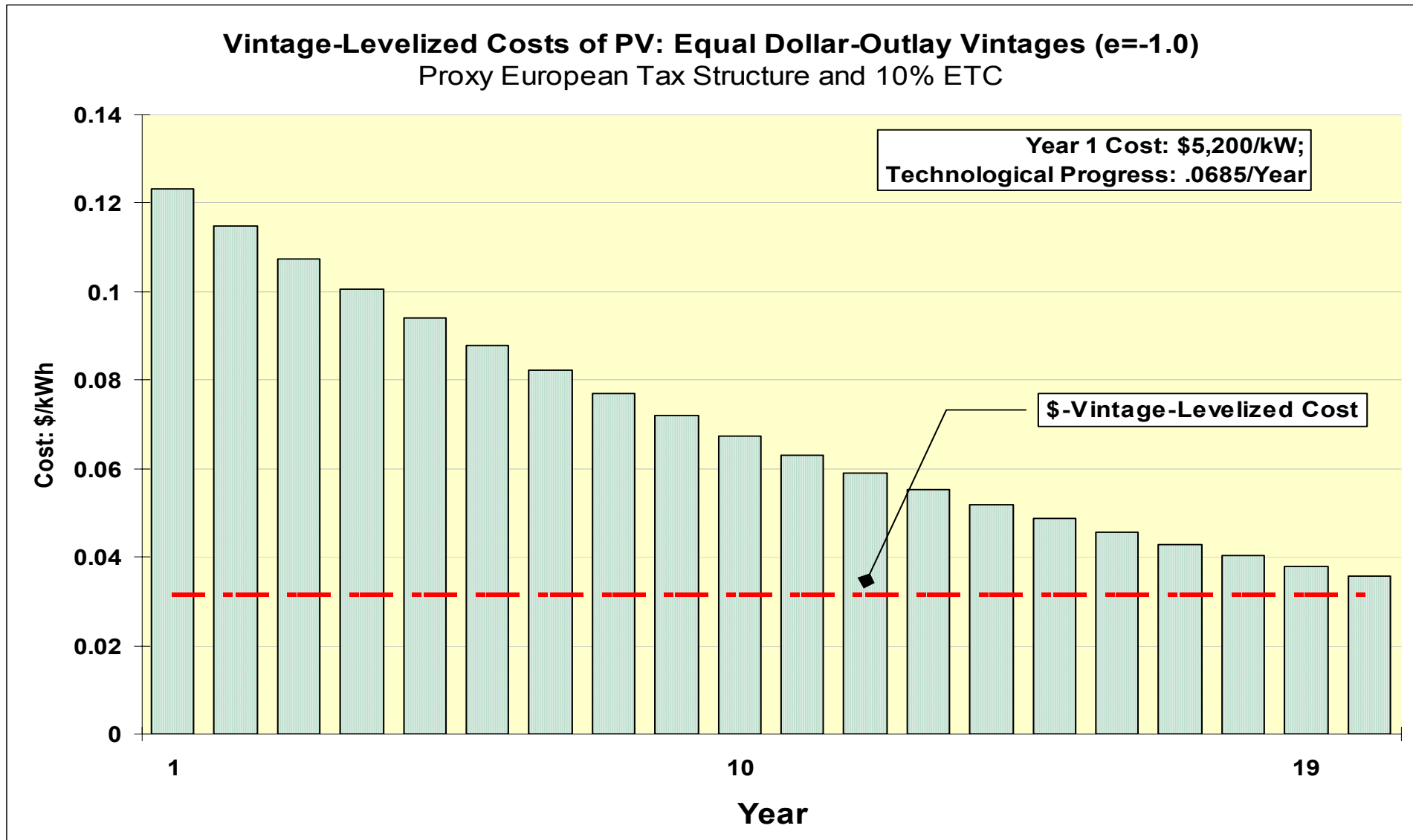


It may be no greater injustice to install renewables now and shift capital recovery to future generations!

TRADITIONAL VALUATION ALSO DISTORTS ENVIRONMENTAL ISSUES



WE MUST VALUE ENERGY STRATEGIES -- NOT TECHNOLOGIES



The Role of *Quality* in Electricity Generation/Delivery

Manufactured Products	Electricity
<ul style="list-style-type: none"> - Lower energy & labor content - Higher info-content - More value to customer <p style="text-align: right;">(Drucker)</p>	<p>Fewer kWh's with higher info-content and greater value:</p> <p style="text-align: center;"><i>"Fewer, Smarter kWh's"</i></p>
<p style="text-align: center;">Mass-production <i>versus</i> Flexible, just-in-time manufacturing</p>	<ul style="list-style-type: none"> - Distributed generation - Virtual utilities - Lower reserve requirements - Reduced excess capacity - Decentralized Grid Operation - Mass-Customization

Understanding and Valuing Distributed RETs: The Role of Organizational and Infra-structure Changes

- **RETs/DG: First Reorganization Around New Technology in 100 years**
 - Cannot be understood in context of current (19th Century) utility Organizations
 - Existing T&D Networks, PEx, ISO structures, AGC, etc. -- all developed in support of large-scale central generation
 - do not support RETs
- **Fully Exploiting RETs will require Infra-structure changes**
 - “Informed” T&D Networks
 - Smart Meters
 - Discreet Load Matching – intermittent resources and loads
 - Decentralized network operation – no centralized AGC

Understanding and Valuing Distributed RETs: The Role of Organizational and Infra-structure Changes

- **Example: Reorganization –Bessemer Steel and Word Processing Both Required Organizational and infra-structure changes**
 - Bessemer: US- Reorganization, floor-plan, upstream & downstream flow-control quadruples productivity (Clark)
 - Word Processor: just a new typewriter - give it to the typing pool
 - exploitation required major organizational, (disintermediation) and value changes
- **Learning How to Fully Exploit Renewables is Non-Trivial**

Renewables are as much a substitute for fossil plants as computers were a “substitute” for typewriters & calculators

Mechanical Vs. Cognitive Paradigms: The New Information Economics

- **Mechanical Production Paradigm:**



Efficiency (Mechanical) = Input/Output

— e.g.: Btu / kWh, \$ / kWh, € / km driven

Mechanical Vs. Cognitive Paradigms: The New Information Economics

- **Cognitive Production Paradigm— The Information Age:**



- Mechanical-age measures & decision tools do not work
- Information-age firm is a decision-factory
 - Design for quality decisions
 - Decision quality =
 f (data availability, processing speed,
asset reconfiguration/deployment)
e.g. steel mini mills, Williams mobile turbines

VALUING RENEWABLES AS A RADICAL ARCHITECTURAL INNOVATION – WHAT IT REQUIRES

- **Integration of Modern Valuation Theory & Development of New Accounting Concepts, Insights and Valuation Measures**
- **Beyond Direct Costs- A Search for Complementary Benefits**
 - Overhead Reductions, Information-Based Capabilities
- **Avoiding Myopic “Shoehorn” Analyses**
 - Full Exploitation Involves Organizational Learning and infra-structure changes

“ The amazing historic stability of key relationships depletes our capacity to imagine anything different... “ Bernstein, *HBR*

“The New Religion of Risk Management”

VALUING RENEWABLES AS A RADICAL ARCHITECTURAL INNOVATION – WHAT IT REQUIRES

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- **Beyond Direct Costs- A Search for Complementary Benefits**
 - Overhead Reductions, Information-Based Capabilities
- **Avoiding Myopic “Shoehorn” Analyses**
 - Full Exploitation Involves Learning and Organizational Restructuring Around New Technology
- **Understanding the Attributes of New Technology**
 - Financial Risk Reduction, Flexibility
 - Enhanced Capabilities and Strategic Options
- **Understanding Full Costs of Current Operating Process**
 - Hard to determine from line-item costing -- need ABC

Synopsis: A Richer Accounting Vocabulary

- **Today's Cost & Value Measures Conceived in Context of 19th Century Organizations and Technology**
- **Learning How to Fully Exploit Renewables is Non-Trivial**
 - Example: 1950's office environment couldn't exploit word processing

Renewables are as much a substitute for fossil plants as computers were a "substitute" for typewriters & calculators

- **Renewables are Often *Passive, Capital-Intensive and Infinitely-Durable* - This Affects Cost Accounting Measurement**
 - Asset replacement not driven by 'wear & tear'
 - Costs not readily 'metered' -- 'Matching' cost & output difficult

How do you value a fax machine with the standard accounting-based DCF model?

SO WHY DOESN'T EVERYONE SWITCH?

- **Many are Switching – European Growth rates for Wind/PV = 30% - 40%**
- **Modular Renewables Represent *radical architectural* innovation (Henderson and Clark) in electricity delivery – like CIM and steel mini-mills**
 - Both Seemed intuitively appealing but failed B-C tests
- **Competitive Firms Have Often Failed to Adopt Promising New Technologies**
- **The Effect of Market Power**
 - Electricity produced in oligopolistic, markets
 - Fuel price increases can be passed through to consumers,
 - Investors may not give long-term fuel price risk the attention it deserves
 - May continue with the familiar and relatively inexpensive no, gas
- **Alfred Chandler-- firms keep doing what they have done in the past, especially in the presence of market power.**
 - E.g. IBM was slow to adopt the PC
 - Sunk costs— in the mainframe technology.

PORTFOLIO-BASED VALUATION

SHIMON AWERBUCH, PH.D.

IEA, PARIS

PORTFOLIO-BASED VALUATION

- **A Generating Alternative's "Stand Alone" Costs Not Very Meaningful**
 - Must evaluate a technology's contribution to portfolio *cost* relative to its contribution to portfolio *risk*
- **Renewables *Enhance* the Energy Portfolio's Performance**
 - *Reduce* expected generation cost and risk

Selecting the "Least Cost Alternative" is like asking your broker for
30-year stock-price forecasts

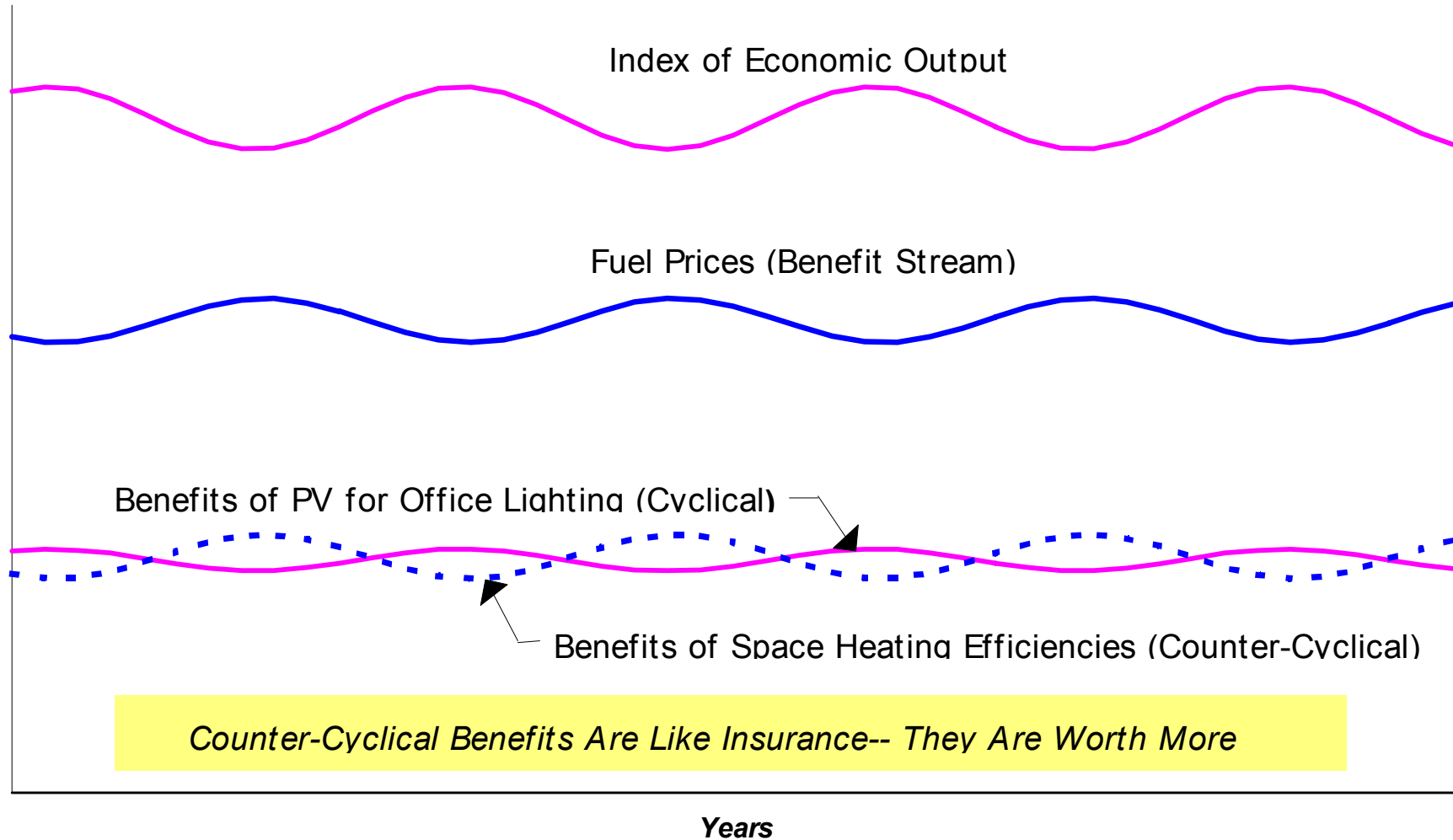
*If financial investors applied valuation techniques used for
energy technologies they would invest only in
junk bonds and high-risk stock!*

PORTFOLIO-BASED VALUATION: IMPORTANT IMPLICATIONS FOR PRIVATE PORTFOLIOS.... AND FOR NATIONAL ENERGY DIVERSIFICATION/SECURITY

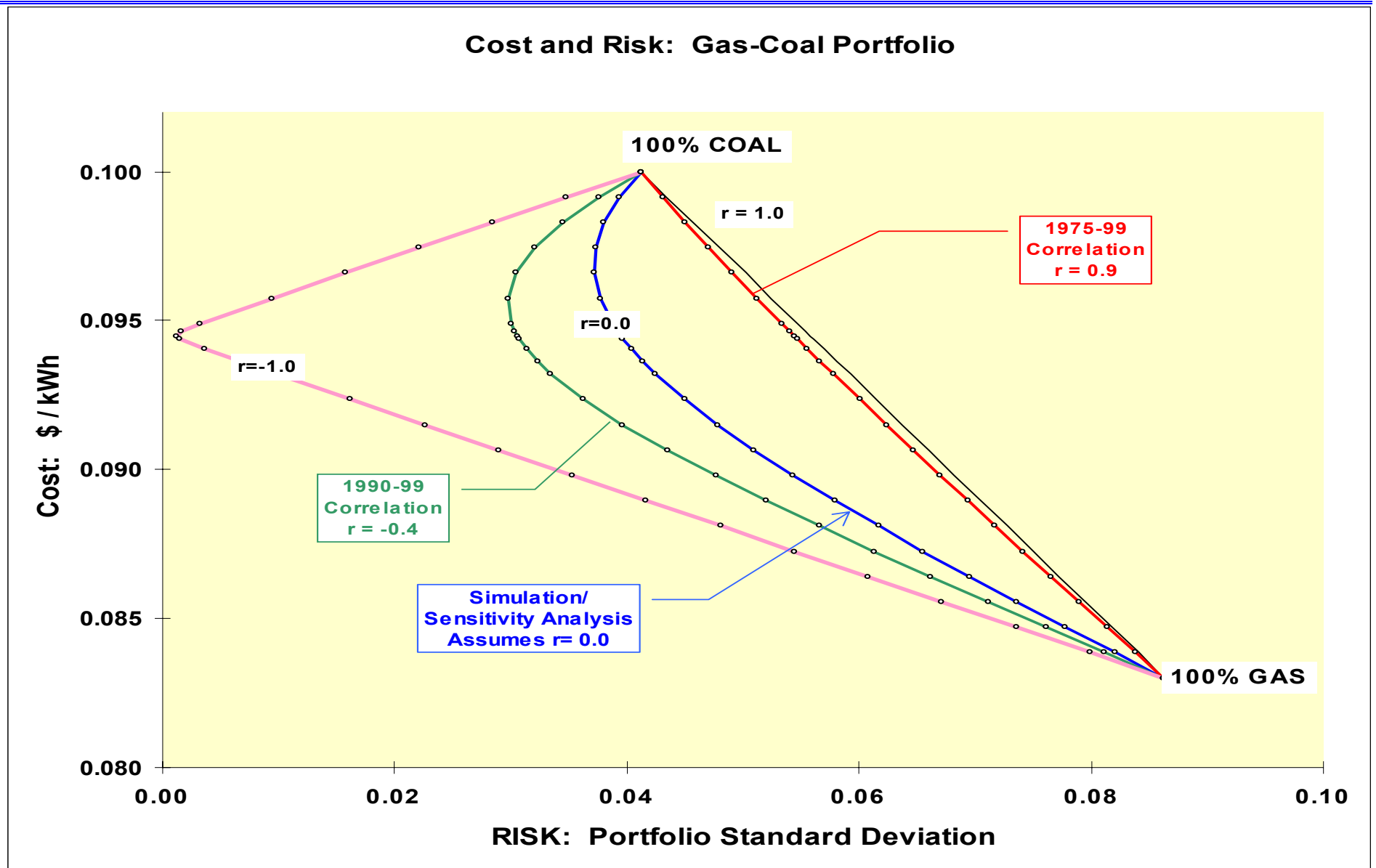
- **Non-Fossil Energy Assets Provide Counter-cyclical Benefits**
 - Mitigate fossil price volatility
 - An important aspect of *energy security*
 - An inefficient portfolio that is unnecessarily exposed to fossil price fluctuations reduces *energy security*
- **Payoff occurs when economy is doing poorly**
 - A form of “national insurance” (R. C. Lind, K. Arrow, *et. al.*)
 - Potential basis for portfolio hedging
- **Customers Can Optimize Their Own Portfolios**
 - Choose mix of fixed- and risky (spot priced) electricity

Diversified Portfolios With Renewables/Efficiency

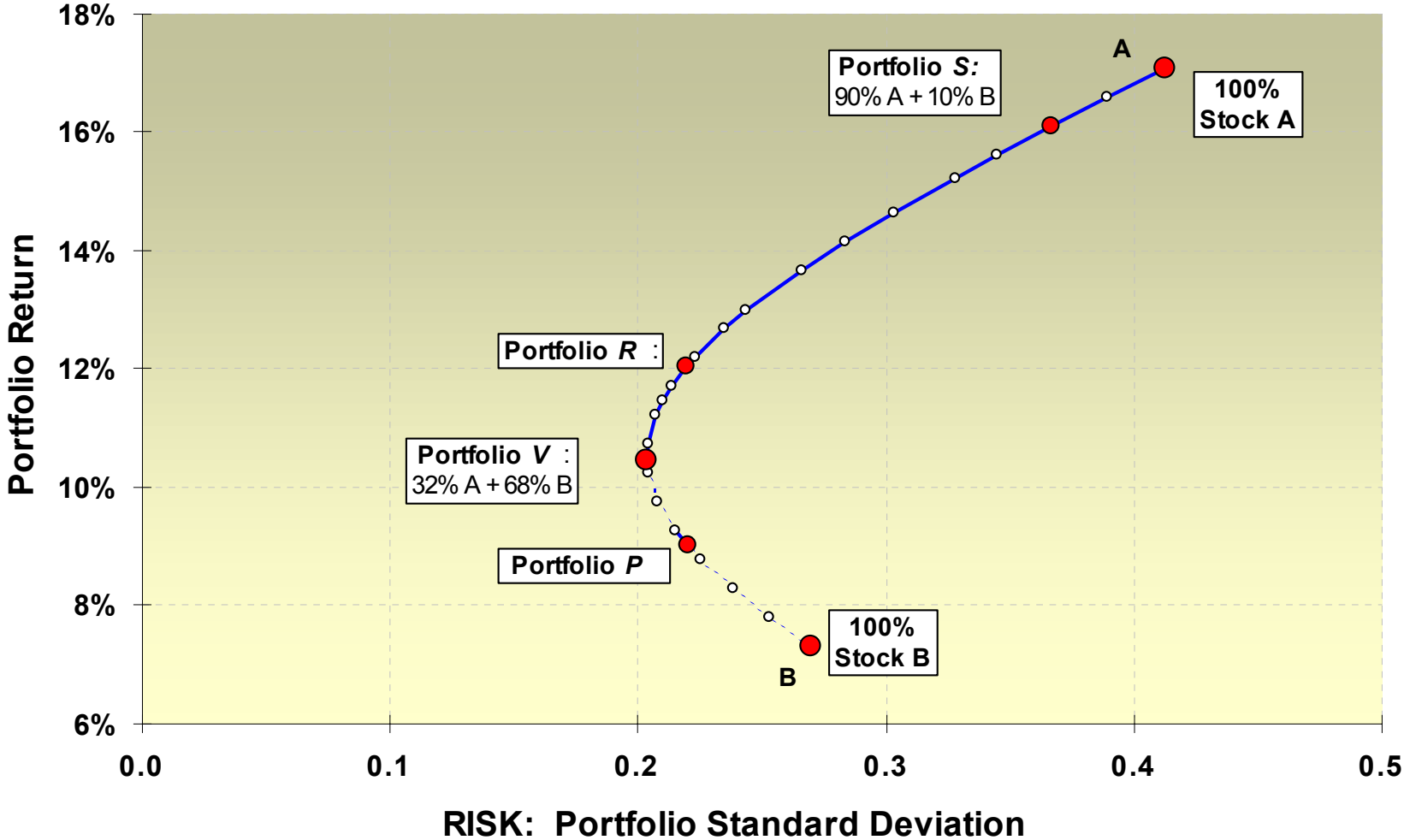
Economic Output and Energy Prices (\$)



The "Portfolio Effect"

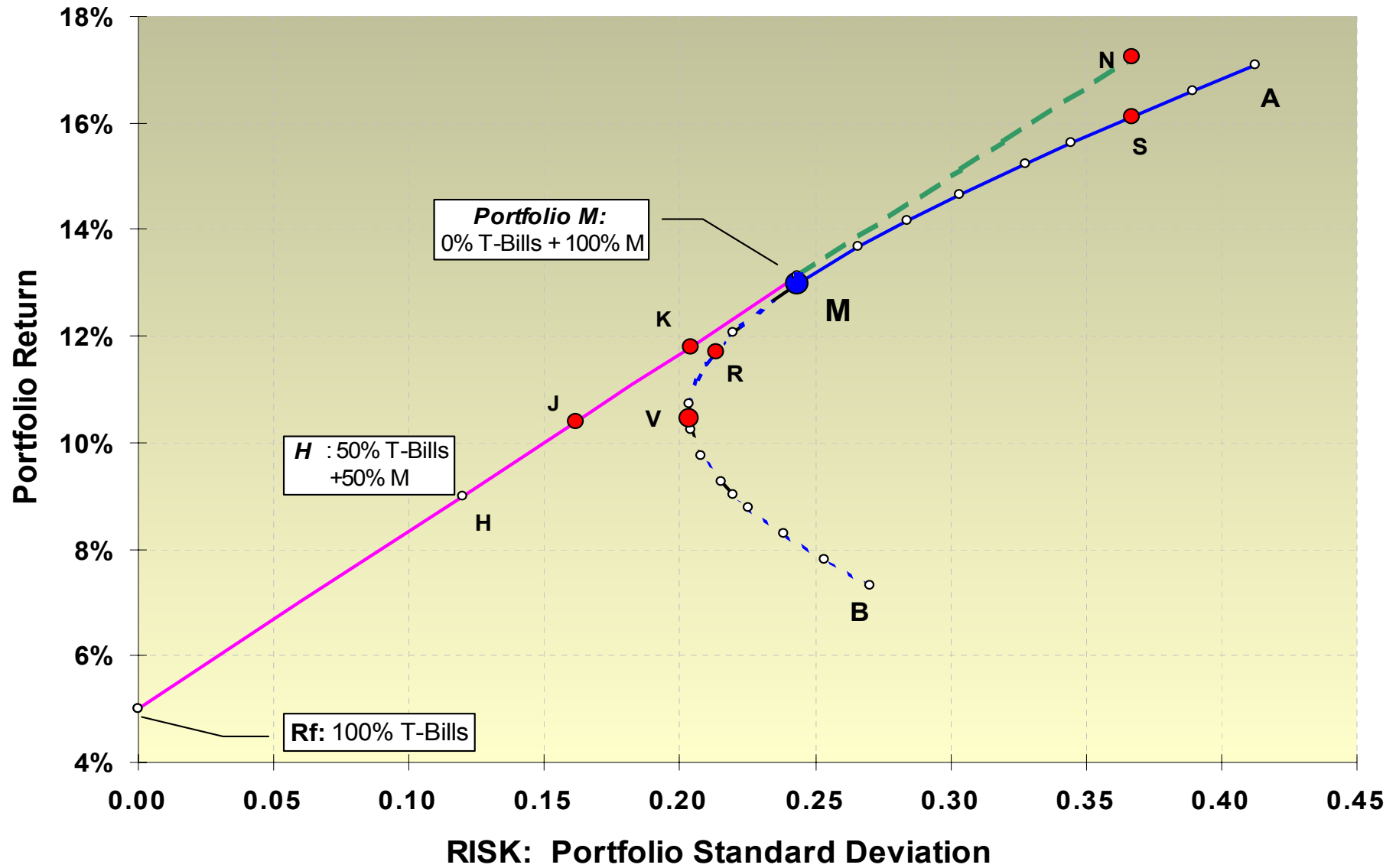


Risk and Return for Portfolios of Risky Assets Only ($\rho = 0.6$)



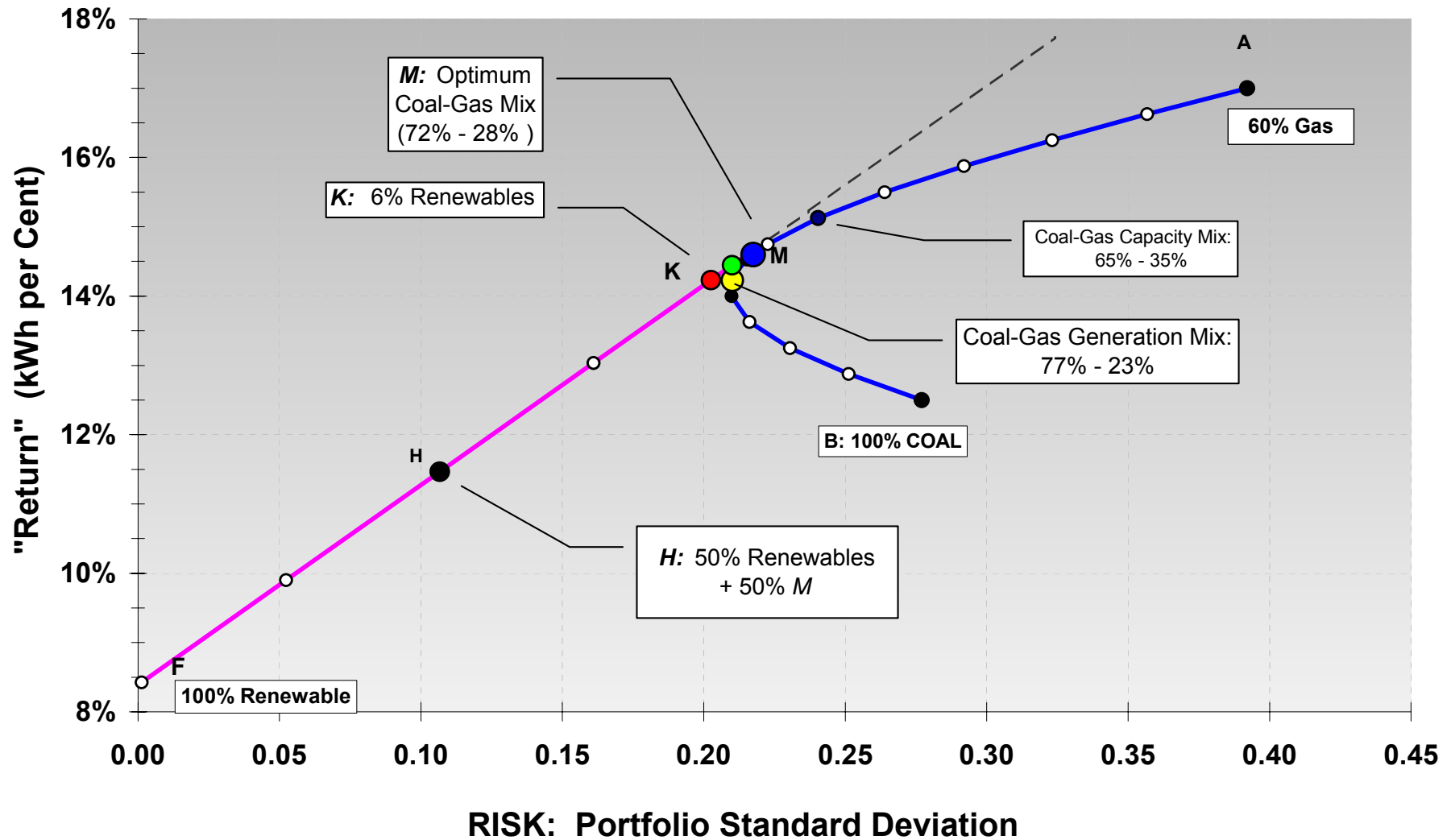
Source: S. Awerbuch, "Getting It Right: The Real Cost Impacts of a Renewables Portfolio Standard," Public Utilities Fortnightly, February 15, 2000.

Portfolio Risk and Return in the Presence of Riskless Assets



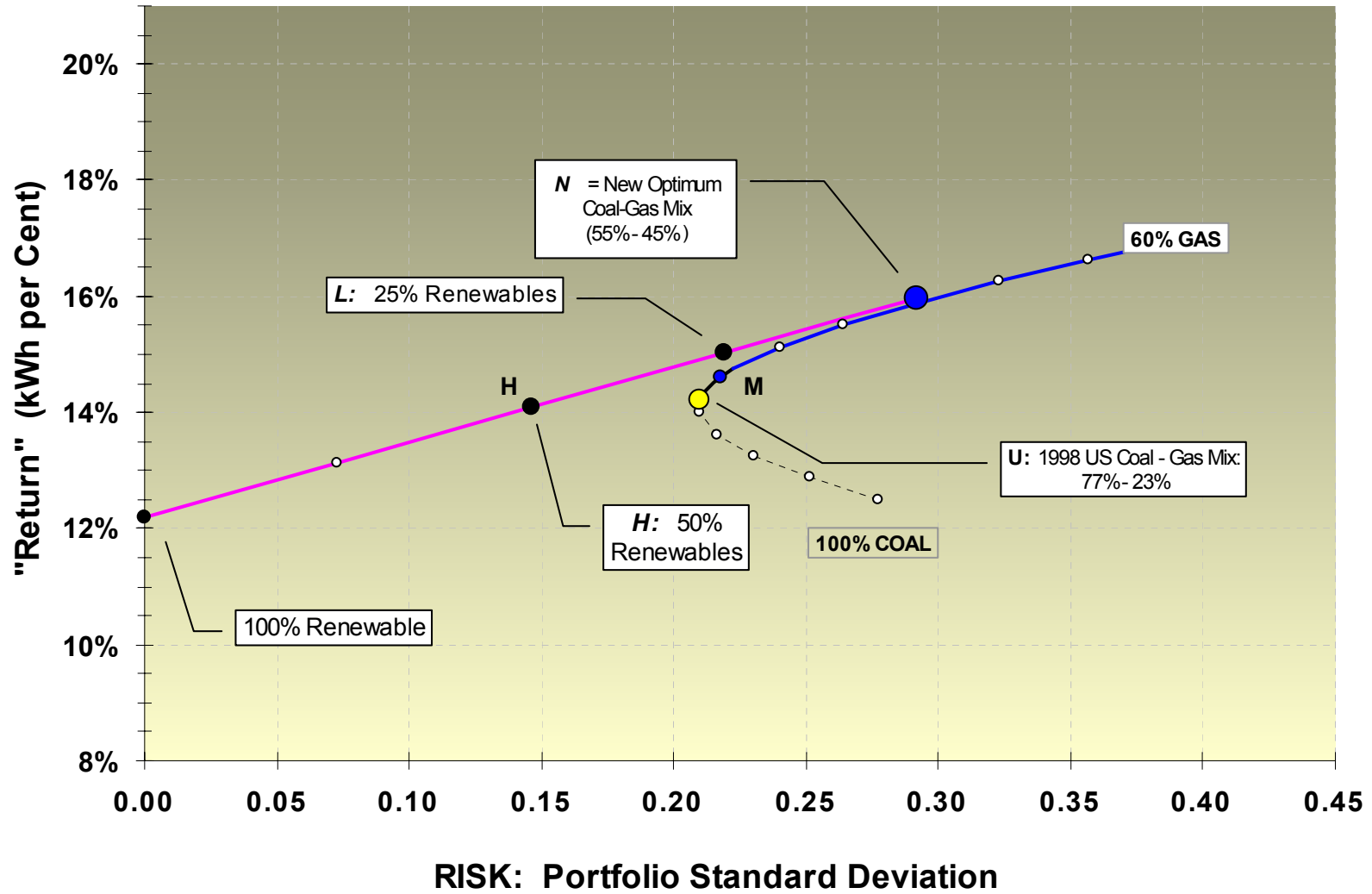
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Risk and "Return" for Three-Technology US Generating Portfolio Assumed Cost for Riskless Renewable: \$.12/kWh



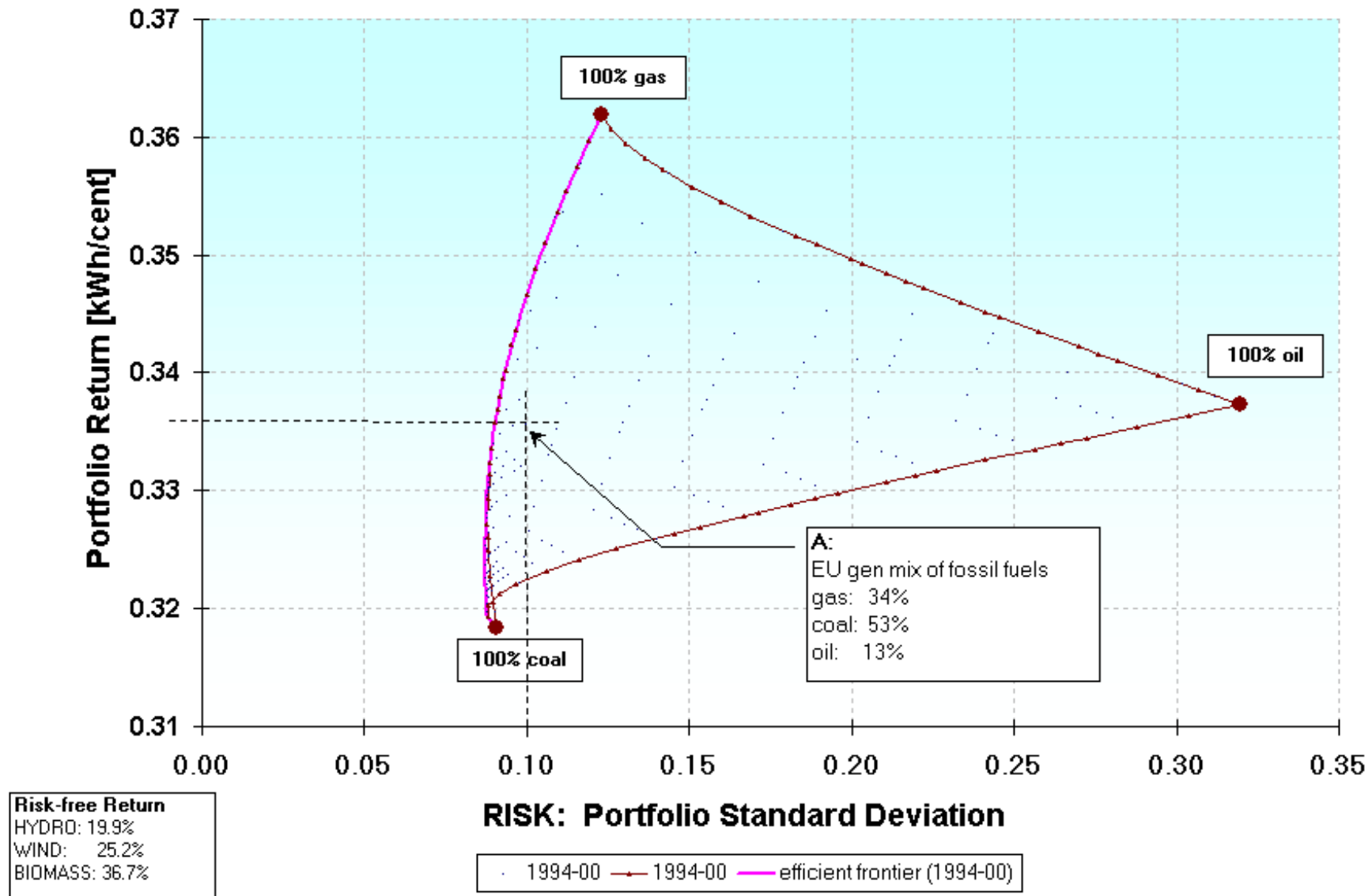
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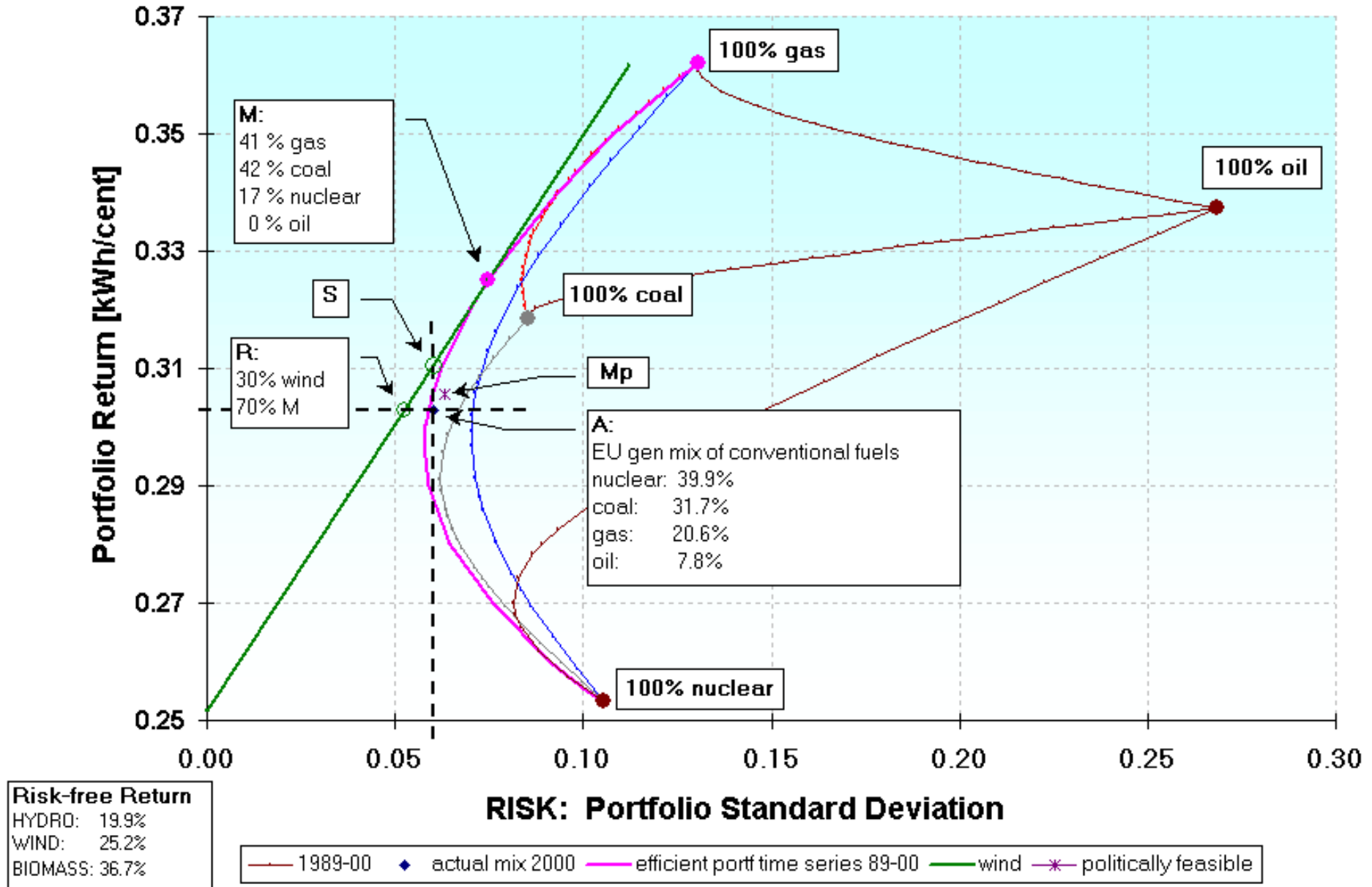


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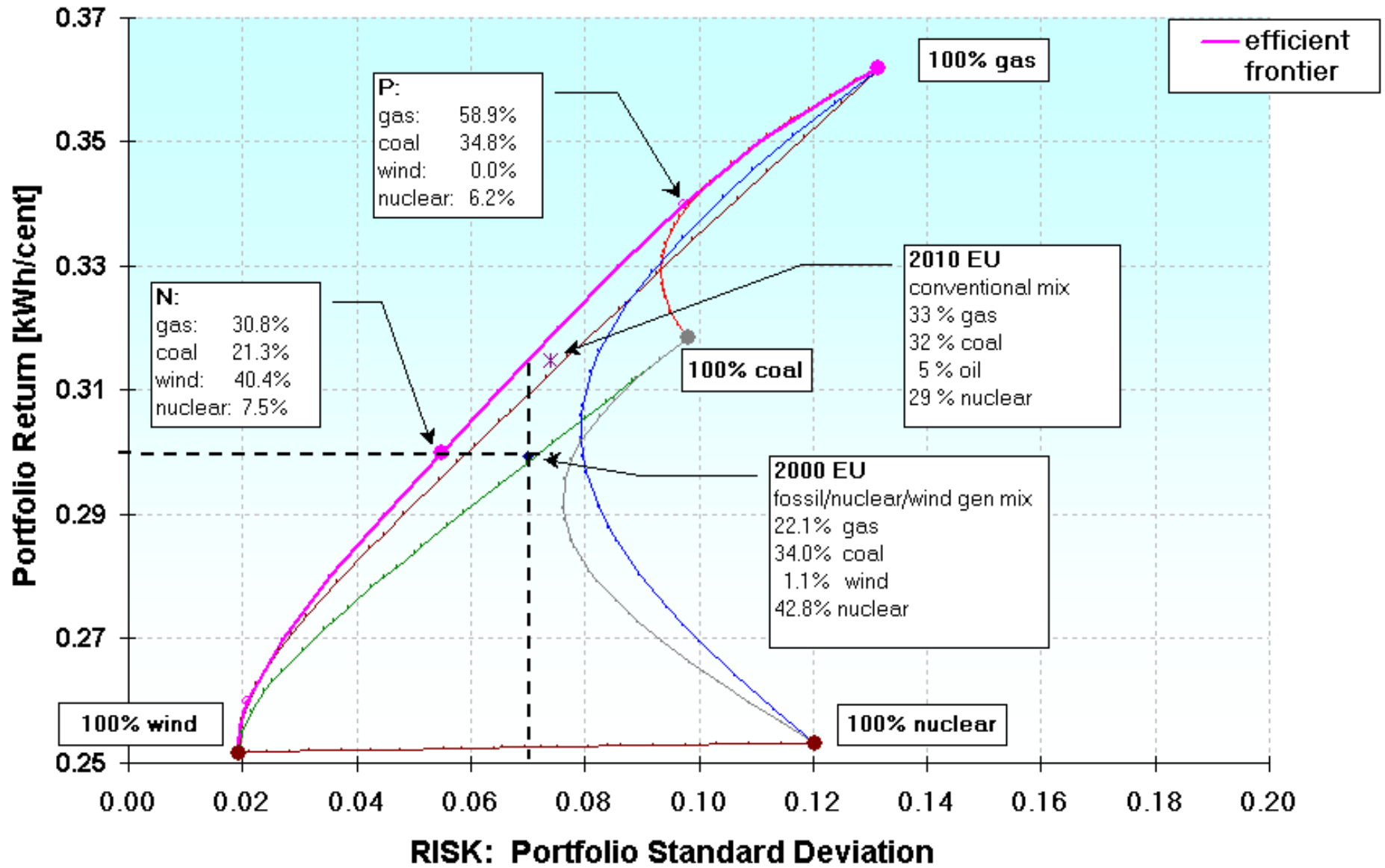
Portfolio Risk and Return in the Presence of Riskless Assets - fuel IEA Europe



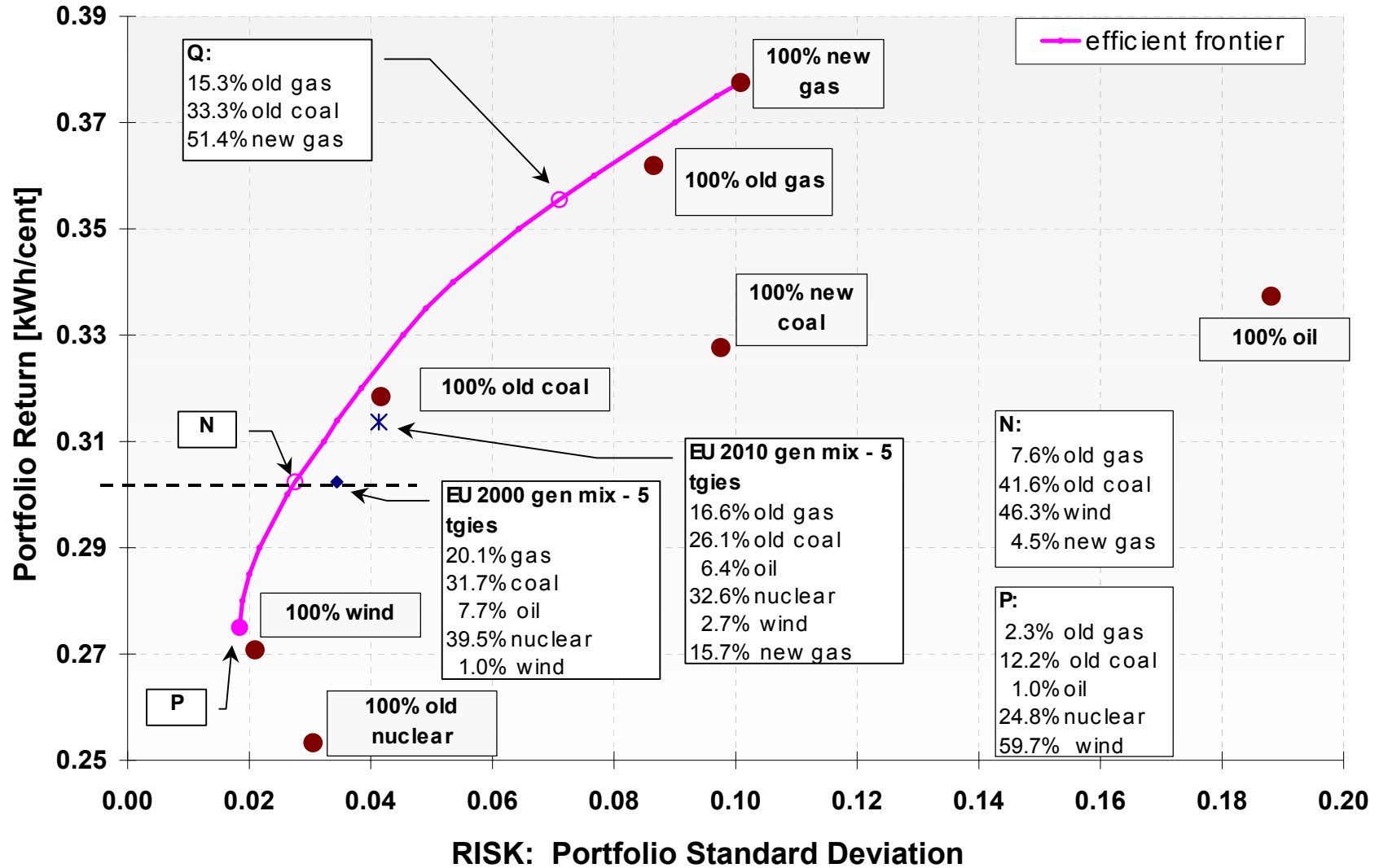
Portfolio Risk and Return: Traditional Assets and Wind - fuel IEA EUROPE



IEA EUROPE: Portfolio Risk and Return fuel and O&M risk



Portfolio Risk and Return fuel and O&M risk vs new investment



Conclusion: Managing Risk With Physical Assets

- **Generators manage fossil risk using financial instruments**
- **Is hedging with fixed-cost technologies equally effective?**
- **Financial contracts/hedges are neither costless nor riskless**
 - LBNL: 10-Year hedge using forwards: \$0.005 USD/kWh
1-Year hedge using call options: \$0.003 USD /kWh
- **Everyone hedging for the same thing**
 - Not an adequate national policy
 - Given sufficiently severe price spikes system could implode
 - US examples of defaults
 - Requires more regulatory oversight
 - Now widely called for in US (CERA "Energy Restructuring")

SUMMARY

- **Valuing Energy Technologies: Risk Adjusted Cost of Electricity Estimates for Conventional and Renewable Resources**
 - Fossil Price risk is counter-cyclical ($\beta < 0$)
 - The cost streams of PV/Wind and other renewables are systematically riskless
 - When these and other considerations are included many renewables appear cost effective relative to gas-based generation
- **Hedging With Fixed Cost Renewables -- Portfolio Based Analysis**
 - The addition of PV/wind and similar renewables to a fossil portfolio reduces generation cost and risk
 - Just as all efficient financial portfolios include some riskless securities (usually government obligations), optimal generating portfolio need to include some proportion of fixed cost renewables

The Moral

1. Fully Understanding Renewable Technologies Requires

- a) The integration of modern portfolio based financial valuation models
- b) The development of new accounting concepts and valuation insights and measures;

2. Trying to understand renewables using today's accounting valuation vocabulary is roughly equivalent to trying to appreciate Shakespeare by 'listening' to a Morse-code rendition of *Hamlet*.

TRANSMISSION/DISTRIBUTION NETWORK ORGANIZATION, REGULATION AND PRICING

INCREASED NETWORK ACCESS FOR RENEWABLES/DG: MITIGATING THE CONCENTRATIONS OF MARKET-POWER

- **Market-Power Concentrations are Suspected in California and Other Cases**
(Illustrates Problems of Establishing Electricity Markets Dominated by Formerly Regulated Giants)
- **Competitive electricity markets require open network access to mitigate concentration of market-power**
 - Increasing the *number* and *diversity* of suppliers connected to the network enhances competition- potentially important role for DG/renewables
- **Network Governance & Regulation is Critical to Promoting Such “third-party” Open Access**
 - Network system owners/operators must have a stake in promoting access and kWh throughput
 - Can be accomplished with for-profit network operators under price cap regulation
 - Network restructuring will help meet recent EC renewables targets

TRANSMISSION/DISTRIBUTION NETWORK ORGANIZATION, REGULATION AND PRICING: AN IMPORTANT POLICY MECHANISM FOR ACCELERATING RENEWABLES

- **Existing network protocols evolved to support central-station technology under ratebase regulation**
 - Centralized AGC Protocol
- **DG/Renewables require “Informed” networks and new protocols**
 - Bi-lateral contracting
 - Decentralized operation & decision-making
 - *e.g.: Loads* provide own load-following and other ancillary services
 - Analogous to “Mass-customization” in manufacturing - Dell computer
 - Intermittence & pool pumps
 - Analogous to “Mass-Customization” in manufacturing - Dell computer
 - intermittence & pool pumps
- **Increased network access mitigates concentration of market-power**
 - Increasing the *number* and *diversity* of suppliers connected to the network enhances competition- potentially important role for DG/renewables

STOP