CHAPTER III : FINANCIAL RISK [1]

The previous chapters have focused on the shortcomings of traditional energy valuation models: exclusive reliance on unit COE measures, exclusion of tax effects and the use of arbitrary discount rates that ignore risk. Chapter 2 addresses the first criticism. It advances arguments that in essence say that a more complete understanding of the costs and benefits of new energy technoligies, particularly, capital-intensive modular technologies, must await further development in accounting measurement. New concepts and measures will no doubt ultimately help value the full range of flexibility and reposniveness that such distributed technologes offer in a highly dynamic electricity markets, along with their complementary benefits, which will likely become more apparent as fully functioning markets evolve. Indeed the valuation of manufacturing technologies followed such a path. While this line of inquiry is important, it is well beyond the scope of this book, which, rather is focused on procedures for properly reflecting the effects of taxes and market risk on COE estimates.

The effect of taxes is briefly discussed in Chapter 1 and is treated more explicitly in Chapter 4. This Chapter lays the foundation for the poper treatment of risk of as it applies to valuing energy technlogies. Recall that total risk can be loosely defined as the standard deviation of periodic (e.g. monthly or annual) costs. Cost approaches that ignore risk will always find that a *risky* annual cost stream has the same present value as an equivalent but *safe* cost stream. Such an outcome violates not only fundamental finance theory, but simple common sense as we have seen. Rather, finance theory requires that euro-for-euro, a risky cost stream must have a *higher* present value since it is less desirable than a safe cost stream.[2]

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[1] Portions of this chapter were previously published in: S. Awerbuch, *How to Value Renewable Energy: A Handbook for State Energy Officials* (March 1996), prepared for the Interstate Renewable Energy Council. IREC website www.irecusa.org ; *Electricity Journal* 1993"The Surprising Role of Risk and Discount Rates in Utility Integrated-Resource Planning," ***The Electricity Journal***, Vol. 6, No. 3, (April) 1993, 20-33 , ** Electricity Journal 1995"Market-Based IRP: It's Easy!!!" ***The Electricity Journal***, Vol. 8, No. 3 (April) 1995, 50-67, and Advances in Solar Energy, "New Economic Cost Perspectives for Solar Technologies," in: Karl W. Boer (Editor), ***Advances in Solar Energy***, ***An Annual Review of Research and Development***, Boulder: American Solar Energy Society, October 1995

[2] This is opposite of the intuition for a risky benefit stream, which would have a *lower* present value than a "safe" stream. The difference arises because risky cost streams move systematically against economic cycles (i.e. they are high when the economy, and hence income, is low as further discussed in this Chapter. Note that such a stream—which is high when other income is low— is quite attractive to a recipient who would value it by discounting at a rate below the riskless rate of return. Given perfect information, both payer and recipient will use the same discount rate to value the

This intuition— that a risky cost stream is less desirable— seems to be widely understood. As discussed in Chapter 1, homebuyers, for example, overwhelmingly choose fixed rate mortgages even though adjustable rate mortgages carry initially lower interest rates. These borrowers obviously conclude that the projected fixed-rate stream of payments has a lower present value, and thus is more desirable.

Basic risk ideas also appear to be widely understood by financial investors. They rcognize that riskier investments— those with riskier expected income streams— will generally have higher expected returns. This is the basis of the CAPM. Thus a riskless US Treasury Bond may yield 4% while riskier, low-grade junk-bonds bonds may yield 10%. Treasury investments are therefore more costly relative to junk bonds. To illustrate: in order to obtain anexpected income stream of $100 per year, one must invest $2500 in Treasuries, but only $1000 in junk-bods. On this simple basis the junk bond investment seems the better bet— the "least cost" option.

Yet investors of all types and all risk-aversions purchase riskless US Treasury obligations even though they cost more. Don't these investors all want the least-cost option? Obviously these investors recognize there is more to it; they understand that the two income streams have different levels of risk and must each be discounted at its own risk-adjusted rate in order for the outcome to have any meaning. If the same discount rate is used to value both interest streams, the results will always favor lower-cost, riskier alternative— the junk bond in this case. This is a key reason why fossil-fired technologies appear so cost-effective relative to renewables.

The example in Table 4-1 illustrates the somewhat absurd results that occur when a single discount rate is used to evaluate alternative investments of different risk. Yet this is precisely how energy technologies are valued by engineering models– with a single arbitrary discount rate – even though the risk of each technology alternative is different. The Table shows the promised annual payment from a 10% low grade or "junk bond" and a government bond paying a 4% coupon. We can assume that both bonds are trading at $1000.[3]

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payment stream. For additional discussion see S. Awerbuch, "Market-Based IRP: It's Easy!!!," *The Electricity Journal*, Vol. 8, No. 3 (April) 1995.

[3] This assumption implies that the *expected* payment stream in each case equals the coupon rate or promised payment stream.

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Table 4-1
Valuing Two Bond Investments
With an Arbitrary (6.0%) Discount Rate

	Yearly Proceeds	
YEAR	10% Junk Bond	4% Government Bond
1	$100	$40
2	$100	$40
3	$100	$40
5	$100	$40
Present Value of Interest Payments at 6% Discount	$347	$139

Both bonds require the same initial outlay, $1000, so that we can ignore the initial outlay and focus on the annual income streams. Using an arbitrary 6% rate, the present value of the junk-bond payments is $347 versus only $139 for the government bond. This makes sense— the junk bond has a higher promised or expected annual payment and both streams are discounted at the same rate. Does this tell us that the junk bond is a better investment and that all investor should buy only it? No, it does not.

This is how engineering models compare high-risk fossil to low-risk renewable alternatives. The point is that if you use the same discount rate for fossil fuels and the capital costs of a wind turbine, you will always favor the fossil technology with its lower nominal costs, although this finding has no economic meaning. Worse, as is the case in Table 4-1, the results of such arbitrary discojnting are not unbiased, but will almost always demonstrate (erroneously) that risky, fossil-fired technologies are cheaper to operate than low risk, capital intensive RETs. This underscores the importance of the risk-adjusted procedures outlined in this book for proper policy making.

Subsequent sections of this chapter discuss the role of financial risk and distinguish its two components, *systematic* and *random* risk, and show how each is correctly reflected in the COE analysis.

The Nature of Total Risk and its Components

Engineers and planners tend to think of risk in terms of specific failures or undesirable outcomes: the risk that a technology or component will fail prematurely, for example; or the risk that fuel prices may rise in a particular year; or the risk that future environmental regulations will require fossil generators to incorporate costly retrofits. Planners sometimes use sensitivity analysis or alternative scenarios in an effort to express such risks analytically but this can be shown to lead to incorrect results,[4] primarily because individual cost movements are not random, but are correlated to other variables that affect the portfolio. For example: labor costs might be high during times when the economy is doing well— when asset returns are high. This is likely to happen when fossil prices are low. Such correlations make the proper specification of sensitivity and alternative scenarios extremely difficult. Yet sensitivity analyses routinely examine the effect of, say, a 10% increase in all the costs variables— including labor and fuel— even though such an outcome may not be likely in reality.

Finance theory enables us to approach risk differently; it allows us to estimate the market price for a unit of risk and to incorporate that cost into the analysis. It is therefore not necessary to explicitly identify all possible outcomes or cost movements. This section discusses financial risk and illustrates its two components: *systematic* and *unsystematic* risk.

As previously discussed, for the purpose of energy cost analyses, total financial risk can be thought of as the month-to-moonth or year-to-year variability in a particular operating cost stream, as measured by the standard deviation of the annual costs. Spot-market fuel prices and other risky costs will be widely scattered scattered around the mean or *expected value*. Their standard deviation will be relatively large compared to “safe” cost streams, such as the annual interest payment on a US government bond or the annual tax shelter benefits produced by the tax depreciation allowances, which will cluster closely around the expected value.[5] Euro-for-Euro, “safe” income and cost streams are more desirable. Euro-for-Euro, “safe” income streams have a *higher* present value while “safe” cost streams have *lower* present values. This idea is illustrated more fully in subsequent sections.

‘Rules for proper risk accounting’

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[4] Awerbuch, IRP its Easy, Electricity Journal, “Market-Based IRP: It’s Easy!!!” ***The Electricity Journal***, Vol. 8, No. 3 (April) 1995, 50-67

[5] In the case of US treasury obligations, which are considered risk-free, there is essentially no dispersion in the pattern of expected annual payments. The depreciation tax shelter, by comparison, is not entirely risk-free, since it is possible that the firm will have insufficient income in certain years to profitably use the shelter.

The first general rule for correctly reflecting risk in resource valuation requires that *expected cost streams be discounted at their own market-based discount rate.* This requirement incorporates two important ideas:

i) First, correct cost estimation is based on *expected,* not *modal* or *most-likely* cost;[6] expected cost has a precise mathematical definition (as subsequently discussed);

ii) Market-based or risk-adjusted discount rates are not "picked" subjectively but are estimated using capital market theory, including, where needed, the Capital Asset Pricing Model (CAPM).[7]

Systematic Versus Unsystematic Risk Components

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Total risk, measured as the standard deviation of periodic (i.e. annual) costs, consists of two components, each of which must be reflected differently in the valuation process.

Finance theory divides total risk into the following two categories:

Total Risk = {Unsystematic or Random Risk} + {Systematic Risk}
= {Diversifiable Risk} + {Undiversifiable Risk}

Unsystematic risk, sometimes called random risk, can be diversified. An example is the possibility of a turbine failure on a gas genmerating unit. Such risk does not affect

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[6] Where the probability distribution of costs is upward skewed, as it is in most construction projects, the use of "modal" or median values can lead to siginificant cost understatement; a detailed example of this problem in the case of oil investments, is given in: Kjeiotl Emhjellen, M. Emjjellen and P. Osmundsen, "Inmvestment Cost estmates and investment decisions," *Energy Policy*, Vol 30, No. 2, January 2002, p. 91-96.

[7] The CAPM enables one to estimate the discount rate for a particular cash flow on the basis of its i) systematic risk, ii) the return to a broadly diversified market portfolio (such as the Morgan Stanley MCSI Europe Index or the *S&P 500*) and, iii) the return on riskless US treasury obligations.

The CAPM-based discount rate for a particular cost stream can be estimated as: $r_j = r_f + \beta_j(r_m - r_f)$, where r_j is the required discount rate, r_f is the riskless rate of return, r_m is the return to a widely diversified portfolio such as the *S&P 500*, and β_j, which generally must be empirically estimated, measures the systematic risk of the particular cost stream. This is discussed in detail in Chapter 5.

discount rates but is reflected by correctly estimating *expected* cash flows. Systematic risk, which cannot be diversified, is incorporated through the risk-adjusted discount rates. Engineering techniques such as sensitivity or scenario analysis cannot properly reflect systematic risk although they can help study unsystematic risks.

A classic illustration that helps clarify the distinction between the two types of risk deals with oil exploration, where an individual firm faces a high risk that it may hit many "dry holes" in a particular year. This risk, while significant to the firm's managers, is not as important to the firm's shareholders who can easily diversify this risk away by owning the shares of several oil exploration firms. From the shareholder's perspective, some firms will find more "dry holes" than others in any given year, but on average, a certain number of productive wells will be found.

Capital markets do not compensate shareholders for undertaking random or unsystematic risk since it is easily eliminated or diversified. This, in turn, means that the shareholder required rate of return or the discount rate does not reflect random risk. In the case of oil exploration firms, this is evidenced by the fact that this group has relatively low financial betas (beta is a measure of systematic risk), well below 1.0 in most cases.[8] So while oil drilling may be "risky," in the common sense of the word, most of the risk is *unsystematic* or random and is not reflected in the shareholder required discount rate. Despite the high random risk, the industry exhibits low levels of systematic risk.

Beta – A measure of Systematic Risk.

Beta is a measure of *systematic* or *covariance* risk. It measures the degree to which the changes in a particular stock (or cash flow) co-vary or co-move with the returns to a broadly diversified market portfolio (e.g. the *MCSI Europe Index*).

A Beta of 1.0 means the stock rises and falls just like the broad market. A beta of 0.2 means that when the market rise 10%, on average, the stock or cash flow will rise 2%.

The second rule for proper resource valuation, therefore, is as follows: *Discount rates are not adjusted for unsystematic risks,* whether it be the possibility of a major component failure in a gas turbine or the premature failure of a PV array or the possibility that an oil exploration firm will not have many productive wells.

Unsystematic or Random Risk — No Discount Rate Adjustment

Unsystematic risk is any risk that is diversifiable or occurs *randomly,* i.e., that is not correlated to economic events or returns to a broadly diversified market portfolio. In the case of resource alternatives, there are a number of unsystematic or random risks,

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[8] Betas below 1.0 mean that these firms are less risky than a broadly diversified market portfolio such as the *S&P 500* or the *MCSI Europe Index*.

including the so-called *technology risk*. No discount rate adjustment is made for such risks.

How Is Unsystematic Risk Handled?

While unsystematic risk does not affect the shareholder's discount rate or required rate of return, it is by no means irrelevant. When valuing a share of stock for an oil exploration firm, shareholders undoubtedly estimate the firm's *expected revenues,* which will be a function of the *expected* number of successful wells for the firm or the *expected* production volume. Expected revenues are estimated as a weighted average of the possible outcomes.[9]

In the case of resource alternatives, unsystematic risk— such as the risk that a particular component will fail or that a technology may degrade or fail before its promised useful life— is similarly reflected in the valuation process by correctly estimating *expected values* for expected asset life and the associated operating cost components. Expected values are probability-weighted estimates, as described subsequently. The expected-value cost streams must then be discounted at the correct market-based discount rate. Both steps are required.

Systematic Risk

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Fossil fuel prices and maintenance cost streams associated with various resource alternatives have an element of systematic risk, i.e., their monthly or annual fluctuations will be correlated to some extent to the performance of other assets in the economy as rerepsented by a broadly diversified asset porfotlio. A classic illustration by Professor Stewart Myers of MIT helps illustrate systematic risk and distinguish it from total risk:

> The owner of a roulette wheel is exposed to considerable business risk; fortunes can be made or lost by the "house" in any one night. But this business risk is random or unsystematic and the owner can easily diversify it by owning many roulette wheels so that on any given night some make money while others lose.
>
> Having diversified the random risk, the owner is exposed only to the remaining, non-diversifiable, systematic risk: when the economy is good more tourists show up to play than when the economy is poor. This remaining systematic risk cannot be diversified.[10]

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[9] This would involve estimating the probability of certain outcomes and their associated revenue level; estimating expected values is discussed subsequently in this Section ___.

[10] Stewart Myers ?? [** this may be from 1980 Postscript on simulation]

Diversification cannot eliminate the systematic risk of a portfolio of oil exploration firms. Even though their annual "success" rate will remain fairly constant, oil prices, and hence the value of new oil finds, changes over time. Since oil prices are systematically related to economic activity (as discussed subsequently), oil revenues will also vary systematically relative to economic activity. Even if a portfolio included all oil exploration firms, its value would change in response to changes in the economy since these economic changes are correlated to the value of oil. This is the systematic risk of the oil portfolio.

For the cost streams of energy projects, systematic risk can be measured by constructing a *cash-flow beta* that is conceptually similar to the equity betas reported for common stocks and some bonds. Discount rates are estimated from this cash-flow beta using the capital asset pricing model (CAPM) which relates beta to the required discount rate. The cash-flow beta measures the co-movement of systematic month-to-month (or year-to-year) changes in a particular cost stream such as fuel, as compared to the changes in the overall performance of the capital markets (as measured by the *S&P 500* or the Morgan Stanley *MCSI Europe Index*). The market's performance is the relevant indicator since it provides an estimate of the market price of risk— the discount or rate of return rate at which an investor undertakes a particular risk.

To illustrate: suppose that a firm is uncertain about future annual maintenance costs, but is able to find an investor willing to provide such maintenance over a 20-year period, in return for an up-front (present value) payment. This investor will estimate the systematic risk of owning the obligation and determine the present value compensation necessary to make the investment attractive, relative to its market or systematic risk. The investor could diversify any unsystematic risk— such as a major component failure or unusually high maintenance at a particular plant— by owning many such maintenance contracts

Unsystematic Risk: How to Incorporate So-called "Technology Risk"

As discussed above, discount rates are not adjusted for random risks, which generally includes so-called "technology risk." Uncertainty about a new technology or the life of a component, for example, is reflected by adjusting expected cash flows, not discount rates. This can be illustrated using PV as an example, although gas turbines are also subject to premature random failures. PV projects are frequently valued over an assumed 30-year life, for example, partly as a consequence of manufacturers' claims. Suppose, however that actual field experience suggests the following simple distribution of PV module failures: 80% of modules last 30 years while 20% fail at the end of 20 years. The expected life for this technology can be estimated as:

$$\text{Expected Technology Life} = .80 \times 30 \text{ years} + .20 \times 20 \text{ years} = 28.0 \text{ years.}$$

So while an individual module may fail at any time, which might create significanmt risk for a small PV owner, the expected life, given a large enough number of modules, is 28.0 years. This takes care of the "technology risk" issue: the 28.0 year life would be used in the cost valuations. Therisk has been diversified.

We can look at this somewhat differerntly. The expected module life, a diversifiable, risk, is 28.0 years, so that with enough modules we would expect that in a large installation 1/28 or 3.57% of the modules to fail each year. The owner can compensate for this risk by setting aside a replacement reserve, which becomes part of the expected operating costs for an installation. The risk has been managed by converting it into a known cost; no discount rate adjustment is made.

Viewed in this manner it becomes clear that module failure, like turbine or any other random failure, is diversifiable, just like the random profits and losses from a roulette wheel. This result holds even if the expected failure rate is higher, say, 25%. In this case, the owner of one or two modules may worry about the risk of module failure, but, given the central-limit-theorem (commonly known as the "law of averages") this risk is fully diversified with a large number of modules.

Gas Turbine Failures

Alstom and other manufacturers guarantee their turbines and make provisions in their accounts to cover potetial losses. Thorugh this procedure they efficiently diverisify the risk of failure for their customers, who may not be able to do so. The manufacturers normally make provisions in their accounts only if there are signs that a particular contract is going wrong. One example is Alstom's heavy-duty gas-turbine business, which currently has euro 1.6 billion of provisions against it.

From: "Nasty numbers," *The Economist* print edition, Dec 6, 2001, Paris.

Unsystematic Risk: The Case of Maintenance Cost

Similar procedures can be used to estimate *expected* maintenance costs, given a distribution of anticipated fixed maintenance costs for a new technology, as shown in Table 4-2.

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Table4-2

Expected Annual Operation and Maintenance Costs Given Several Possible Outcomes

	Probability	Annual O&M per kW	Factor [a/]
Outcome 1: System Performs Below Expectations	50%	$250	$ 125
Outcome 2: System			

Performs As Expected	20%	$150	$ 30
Outcome 3: System Performs Above Expectations	30%	$100	$ 30
Expected Outcome:	Expected Annual O&M per kW:		$185
a. The expected cost factor for each outcome is the Probability × the annual cost.			

The resulting total expected annual cost, $185/kW, must be discounted at an appropriate risk-adjusted rate to reflect the systematic risk of labor costs.[11]

Expected maintenance costs for mature technologies are estimated the same way. The O&M costs for a gas turbine, for example, must include the expected costs for failure and replacement of major components. Such an expected annual cost stream can be estimated as:

$$\text{Expected cost of turbine failure in year}_t = C_t \bullet P_t \,,$$

Where C_t and P_t are, respectively, the year_t cost of replacing the turbine, should it fail, and the year_t probability that a failure will occur. This cost stream would be discounted at a rate appropriate for maintenance costs, i.e., a rate that reflects the systematic risk of labor and material costs, since both of these will likely fluctuate with changes in economic condition. There are other risks, e.g.: the risk of additional environmental regulation, that are also unsystematic and whose costs can be estimated in similar fashion.

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Unsystematic and Systematic Risk: Understanding the Risk Components of Projected Fuel Prices

The unsystematic risk of a cost stream is incorporated by estimating the *expected* annual values; these are are discounted at the appropriate risk-adjusted based discount rate to reflect the remaining systematic risk (discount rat estimation is discussed in etail in Chaptger 5). Consider a future stream of annual outlays for natural gas. Gas-price forecasts vary considerably, but even if one particular forecast were known to be correct, it can only be correct *on average*. Actual gas prices will still vary systematically, year-to-year, with changes in economic conditions.

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Figure 4-1 illustrates. It assumes that two gas escalation forecasts exist, 2% and 4% per annum, and that each of these outcomes is equally likely. If the gas-price escalation rate

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[11] Costs for labor and other O&M inputs will vary systematically with the economy: they likely will rise when the economy is doing well and fall during periods of recession.

is driven only by random factors,[12] then an *expected*, escalation rate can be estimated as the average of the two possible outcomes:

$$\text{Expected escalation rate} = .5 \times 2\% + .5 \times 4\% = 3\%$$

Figure 4-2
WHAT MAKES FOSSIL PRICES RISKY?

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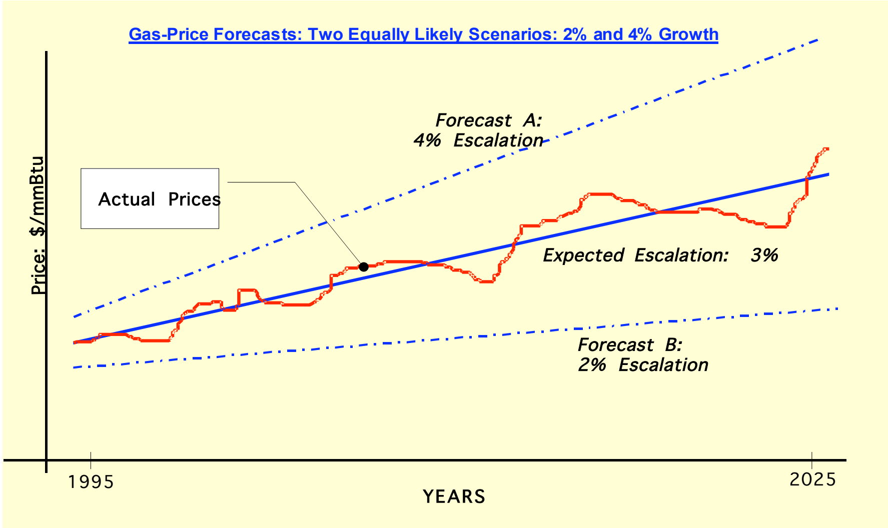

Source: S. Awerbuch, *How to Value Renewable Energy: A Handbook for State Energy Officials* (March 1996), p. 35, prepared for the Interstate Renewable Energy Council.

This expected escalation rate (Figure 4-2), even if reliable to a *high degree of certainty*, will only be correct on average. Actual gas prices will vary around this expected value, in a systematic manner with changes in economic conditions— changes in natural gas prices, while largely unpredictable, are correlated to economic events and hence the returns to other assets in the economy. And this is the important risk factror of fossil prices: every time they rise, economic activity declines.[13] The risk-adjusted discount rate

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[12] The outbreak of war, for example, or new exploration technology that makes finding and drilling for gas less expensive; strictly speaking, even such factors are probably not entirely random but are driven by economic events, including the gas prices themselves.

[13] See subsequent section on fuel price volatility and economic activity.

only compensates for this *systematic* risk. It does not compensate for the fact that the expected value is itself difficult to predict.

The random risk of estimating the correct expected escalation rate can be considered a *planning risk*. Simulation or sensitivity analysis can help us understand how sensitive our present value cost estimates are to this planning risk. But this sensitivity analysis will be misleading, unless all discounting is performed at the appropriate risk-adjusted rate that reflects the systematic variability of gas prices. For planning purposes therefore, a present value cost estimate can be made at 2% escalation and 4% escalation, using risk-adjusted discount rates. If the two outcomes are equally likely, the results can be averaged to yield an *expected* present value cost. However, simply performing sensitivity analysis using an arbitrary discount rate, yields results that significantly understate the present value cost of gas fuel. Appropriate nominal after-tax discount rates for gas outlays are in the range of 2% to 3% (See Chapter 5). If the present values computation is performed at arbitrary rates of 7% or 10%, as is commonly done, the present value of future gas outlays will be greatly understated. No amount of sensitivity analysis can rehabilitate such an incorrect estimate.

Correct resource valuation must reflect both random and systematic risk components. This means that properly estimated expected cash flows must be discounted at risk-adjusted discount rates. Sensitivity and other engineering procedures for handling risk tend to focus only on random risk, ignoring the important systematic component.

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Reviewers: Should this section come sooner? Is it OK here? Chap 1, already seems long.

NOTE -- this section was updated and improved in the Abstract for Italy proposal

The Relationship Between Systematic Fossil Fuel Price Risk and Economic Activity: Implication for Valuation and Energy Security

It is widely believed that that oil price increases cause economic disruptions that reduce income and the profitability of assets.[14] To the extent that this relationship holds, it has powerful implications for energy security and diversity issues as already addressed in Chapter 1. The cost of even minute percentage declines in the total returns to all assets in IEA countries is enormous. If rising fossil prices cause economies to spiral down, then renewables can contribute signicantly by mitigating this effect, thereby creating benefits that go well beyond their relative valuation on a kWh basis.

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[14] e.g. see *US News & World Report,* "The Hidden Picture," April 29, 1991, p. 50;

The negative correaltion between fossil prices and economic activity also affects energy cost valuation. Traditional cost models discount future gas or oil outlays using arbitrary rates, often in the range of 7% to 10% or even higher. However, if the covariance between fossil prices and the returns to other assets is indeed negative, as the macro-economic evidence discussed below suggests, then appropriate discount rates for future gas or oil outlays must be considerably lower. Lower discount rates produce higher present values. Traditional models therefore may significantly understate the true present value cost of fossil fuel outlays.

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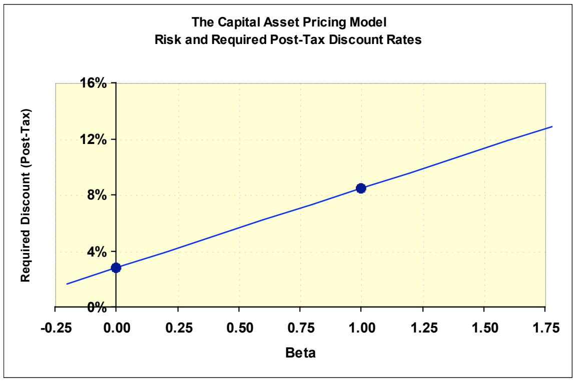
The Capital Asset Pricing Model (CAPM) relates Beta (β), or systematic covariance risk, to discount rates. A cost stream with $\beta = 0$ is discounted at the risk-free rate of return, around 3% (post-tax) in today's market (Figure 3-1). Negative betas imply lower discount rates. Chapter 5 develops a set of empirically derived CAPM-based beta estimates for fossil fuels in IEA-Europe. The estimated betas are small and generally negative, suggesting discount rates in the range of 2% to 3% (post-tax). The maco-economic evidence of the negative impact of oil prices on the economy discussed below is consistent with the empirical beta estimates of Chapter 5, and provides further support for the idea that cash flow betas of fossil fuel streams must be negative. This means that traditional models discount gas and oil outlays too heavily, thereby significantly understating their true cost.



Macro-economic Evidence:

The interrelation between oil price movements and economic activity has been studied in most industrialized countries.[15] The research generally indicates that oil price changes

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[15] Yang, Hwang Huang, *Energy Economics* July 2002 *see also* -- FEDERER For an excellent recent survey of this literature see: Evangelia Papapetrou, "Oil price shocks, stock market, economic activity and employment in Greece," in *Energy Economics* Vol. 23 (5) September 2001, 511-532; see also Perry Sadorsky [1999] "Oil price shocks and stock market activity," *Energy Economics* 21 (1999), 449-469; Rotemberg, J.J.; Woodford, M., Imperfect Competition and the Effects of Energy Price Increases on Economic Activity, *Journal of Money, Credit, and Banking*, Volume 28, Issue 4, Part 1 Nov. 1996, Pages 550-577

have a powerful effect on economic activity, and that oil price increases are responsible for almost every post World War II US recession.[16] Howrath and Sanstad, find that "energy price shocks induce systematic economic dislocations."[17] More recent evidence shows that oil prices are also "important" in explaining stock price movements in the US and Canada.[18] Sadorsky obtains even more powerful results: for the post war period (and especially, after 1986), his findings suggest that oil price movements explain more of the error in forecasting real stock returns than do interest rates. These results imply that oil prices have profound negative affects on employment, output and stock market performance.

While this statistical evidence is complex and based on advanced econometric techniques that are less than transparent to most, public policy makers, using their own experience of the devastating economic affects that past oil shocks have produced, seem to act as if the relationship holds. Their speeches and policies indicate their belief that rising oil prices will dampen economic activity. Indeed the relationship seems intuitive.

For example, US Energy Secretary Spencer Abraham, speaking in March 2001, tied the recent US economic slowdown to rising energy prices: "This nation's last three recessions have been tied to rising energy prices and there is strong evidence that the latest crisis is already having a negative effect. Rising energy costs are hitting every family's checkbook, primarily affecting those who can afford it the least."[19]

Abraham clearly understands the fossil fuel price risk; fuel costs will be relatively high during bad economic times. Because it is systematic and not divesifiable, this risk affects everyone more or less and produces the worst possible set of circumstances for businesses and households: high fuel prices hit people when they are already feeling recessionary pressures— low incomes, layoffs, and depressed home values, thereby exacerbating their economic situation.

Rotemberg, Julio, "The Effects of Energy Price Increases on Economic Activity," *Energy Policy Workshop*, MIT Center for Energy and Environmental Policy Research, November, 1993.

[16] J. D. Hamilton (1983), Oil and the macroeconomy since World War II. J. *Political Economy*, 92 2 (1983), pp. 228-248. The evidence for other industrialized countries, however, seems less clear.

[17] Richard B. Howarth and Alan Sansatad, "Discount Rates and Energy Efficiency," *Contemporary Economic Policy,* Vol. XIII, (July 1995), 101-109, p. 104.

[18] Papaetrou, op. cit.

[19] Reuters, March 21, 2001, reported by Tom Dodgett.
www. PLANETARK.org/dailynewsstory.cfm?newsid=10170.

Although the fossil fuel price risk cannot be diversified, renewables offer a means of dealing with it. The noted economist, Robert C. Lind, has argued that they represent a form of societal insurance against high fossil prices, since they will pay off during times of high energy costs, which are also bad economic times:

> "Our models predict that higher energy costs will result in a lower GNP," which creates "a reasonable presumption" that the benefits of renewables (and energy efficiency) "will correlate negatively with GNP."[20]

To conclude, rising oil and gas prices seem to hurt economic activity and wealth— they reduce people's income from employment and from their financial and other assets. This is an important "energy security" consideration. The negative relationship between oil prices and economic activity also has another powerful implication— it clearly implies that traditional COE estimates significantly understate fossil fuel costs. Although the evidence seems substantial, these important implications are largely unrecognized.

Cites – {not all of these directly quoted in text. What do w/?}

Save these cites – We may need them in other sections – where I do not always have exact reference.

Awerbuch, Shimon, 1995 "New Economic Cost Perspectives for Valuing Renewables," Chapter 1, *Advances in Solar Energy,* Karl Boer, Editor, Boulder: *American Solar Energy Society*.

Awerbuch, S., T. Mouck J. Dillard, and A. Preston *Energy Policy*, 1995 – "Capital Budgeting, Technological Innovation and the Emerging Competitive Environment of the Electric Power Industry," (with Jesse Dillard, Tom Mouck, and Alistair Preston), ***Energy Policy***, Special Issue, *"Valuing the Benefits of Renewables,"* Vol. 24, No. 2, February 1996

Awerbuch, S. *Electricity Journal*, April, 1993; April 1995;

Brealey Richard and Stewart Myers 1991, *Principals of Corporate Finance,* McGraw Hill

Neil Seitz, 1990, *Capital Budgeting and Long-Term Financial Decisions,* (Especially Appendix 11-A on the valuation of risky cost streams), Dryden Press.

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[20] "A Primer on the Major Issues Relating to the Discount Rate for Evaluating National Energy Options," in: Robert C. Lind, Kenneth Arrow, et. al. (Eds.) *Discounting for Time and Risk in Energy Policy,* Washington, DC: Resources for the Future, [Johns Hopkins University Press] 1982, p. 63. .

The Effect of Different Societal Cost Profiles on Risk and Aggregate Net Income

Because the economies of IEA member countries are so heavily dependent on fossil fuels,[21] few, if any other commodities seem to have the power to disrupt economies the way fossil price spikes can. IEA countries carry little substitute capacity, and due to the long-lived nature of energy assets, bringing substitute capacity on-line is a slow process. Because of the pervasiveness of fossil-based electricity generation, the interests of consumers and society are not always congruent with the interest of energy investors.

Figure 1-1~~(repeated in chap 4~~) shows how timing and the co-movement of different national income and cost streams affect risk. These three illustrations show how the timing of large national import outlays, such as outlays for fossil fuel or grain, affect the variability of aggregate national net income. The **average** values for aggregate national income, cost, and net income are the same in each of the three panels, but the correlation between income and cost varies.

In Panel 1, the national export cost stream rises and falls with aggregate societal income: costs are high when income is high. Such costs do not contribute to increasing the variability or security of aggregate societal income; in fact, they reduce such variability. In Panel 2, costs are constant, which increases net income volatility slightly. (The percentage variability of net income in Panel 2 is greater than the percentage variability of gross income.) Panel 3 illustrates the effects of fossil price volatility on national income: prices and hence outlays rise when aggregate income falls. This serves to exacerbate the variability of society's net aggregate income. During economic downturns, net income is lowest in Panel 3. This is the energy security aspect of fossil price volatility.

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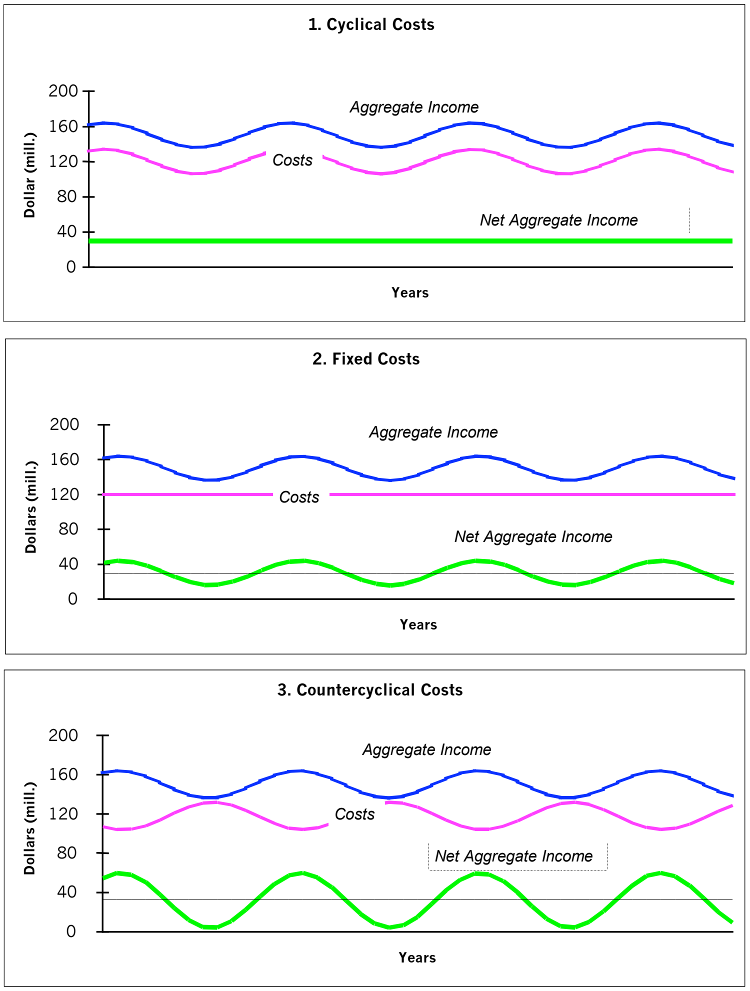
[21] Indeed the economic slowdown caused by recent fuel price surges seems to be even more pronounced in Europe, (Martin Wolf, "A Catalyst for Further Change," *Financial Times,* Wednesday, Jan. 2, 2002, page 13.)

Figure: 1- 1__ **Risk and Costs of Societal Projects**



The Effect of Different Societal Cost Profiles on Risk and Aggregate Net Income

For example, virtually all new capacity additions in Europe and the US over the last several years have been natural gas fired.[22] Developers of this new capacity undoubtedly evaluate its financial viability, but, they may be less affected by gas price volatility than electricity users. If (or perhaps when) gas prices rise again at some future point, generation costs will rise as well, to the extent that marginal capacity is gas-based. This is an inevitable outcome, given the inelastic nature of short-run electricity demand and the relative market power of electricity producers.[23] This combination of inelastic short-run demand and relative market concentration implies that the profits produced by gas-fired generation will be relatively unaffected by future fuel price surges because higher fuel prices can be passed through to end-users.

Rising fuel costs therefore affect electricity customers more than producers. This is especially true for residential customers who have few options for supply. While it is possible that market mechanisms may develop instruments that effectively hedge fuel price risks for customers over long periods of time, such mechanisms are neither costless nor foolproof. Given the right set of circumstances, the widespread use of financial hedges could lead to potentially dangerous imbalances that could cause markets to collapse.[24] This situation suggests that fuel driven price volatility imposes more of a cost on society than on electricity producers. Such a situation suggests that policy makers increase their efforts to help promote fixed-cost technologies which can provide a portfolio hedge that mitigates fossil price volatility and its negative energy security implications.

Risk-adjusted COE estimates can help guide energy security policy. For example, the risk-adjusted COE estimates presented later in this chapter clearly suggest that when market risks are considered, the cost of gas generation is quite high relative to a number of renewable resources. This should signal policy makers in IEA and other countries that the strategy of continued expansion of gas-based capacity, to the exclusion of renewables and other fixed-cost resources, has dangerous energy security implications.

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[22] For example, 41,339 MW of the 44,410 MW planned capacity additions in the US between 2001 and 2004 are natural gas-fired (Source: EIA www.eia.gov/cneaf/electricity/ipp/html1/t1p01.html). For OECD Europe the gas capacity share increases from 14% to 40% through 2020; ignoring retirements, almost 100 percent of capacity increase is gas-based; see: WEO-2000, p. 368.

[23] [e.g. see: B. Halvorsen and B.M. Larsen, "The Flexibility of Household Electricity Demand over Time," *Resource and Energy Economics* 23(1), (2001), 1-18

[24] S. Awerbuch, “Getting it Right: The Real Cost Impacts of a Renewables Portfolio Standard”*, Public Utilities Forthnightly*, February 15 2000. **do we want to say more?

Portfolio Valuation and Energy Security

Financial portfolios are widely used by investors to manage risk. Similarly, it is important to conceive of electricity generation alternatives not in terms of their "stand-alone" cost, but in terms of how a particular alternative contributes to the *costs* of the generating portfolio relative to how it contributes to the *risk* of that portfolio. At any given time, some alternatives in the portfolio may have high costs while others have lower costs, yet over time, the astute combination of technologies serves to minimize overall generation cost relative to risk.

Financial investors understand that the future is unpredictable; rather than emphasizing fortune telling, they focus on building robust portfolios that maximize expected return for the given level of risk. By contrast, traditional energy planning procedures focus on finding the so-called *least-cost* alternative— a dubious procedure that is roughly analogous to trying to identify *the* single best performing stock over the next 30 years and your money in it. Identifying "least-cost" technologies is probably no longer relevant, or even possible in today's dynamic environment and it would make more sense for policy makers to focus on developing efficient generating portfolios that include a variety of technologies and financial and contractual options.

Portfolio theory provides a guide to establishing robust generating portfolios that can lower overall cost and year-to-year cost fluctuations. This helps create sound support for national energy security policies. Preliminary portfolio results[a/] fully complement the risk-adjusted costs presented here: both suggest that extending our reliance on volatile fossil fuel for electricity generation serves to increase the expected risk of the generating portfolio disproportionately to any possible expected cost reductions. Both approaches therefore provide the same policy guidance with respect to energy security: to reduce overall electricity costs we must increase the share of fixed-cost technologies.

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a. S. Awerbuch, *Public Utilities Fortnightly*, February 15, 2000 and S. Awerbuch, "New Economic Cost Perspectives for Solar Technologies " in, *Advances in Solar energy*, 1995 op. cit **