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UTILITY INVESTMENT IN ON-SITE SOLAR: RISK AND RETURN ANALYSIS FOR CAPITALIZATION AND FINANCING

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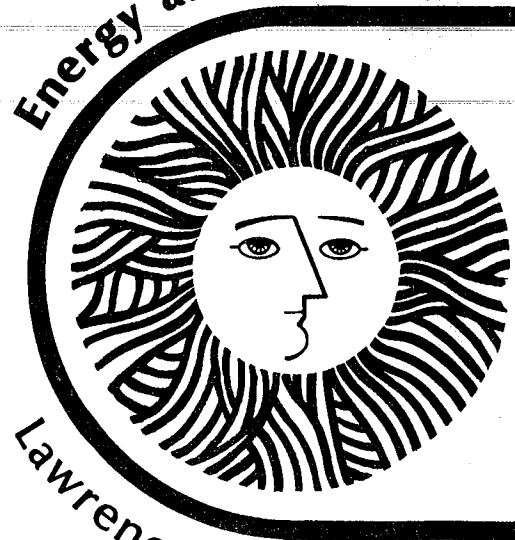
Utility Investment In On-Site Solar:
Risk And Return Analysis For
Capitalization And Financing

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UTILITY INVESTMENT IN ON-SITE SOLAR:

RISK AND RETURN ANALYSIS FOR CAPITALIZATION AND FINANCING

1. INTRODUCTION

This is a study of a set of financial strategies designed to accelerate the penetration of on-site solar heating and cooling systems. The role of financial intermediary in this analysis is played by the local regulated public utility. On site solar systems would either be owned outright by utilities and capitalized in their rate base or such projects would be financed by the utility acting as a limited purpose banker. There is widespread interest in this kind of strategy. Such interest was expressed recently for example in the report of the Office of Technology Assessment, Application of Solar Technology to Today's Energy Needs, v.1 (June, 1978). The issues surrounding these proposals are complex. Many are legal or regulatory in nature, involving questions of competition and monopoly, rate discrimination, tax regulation and so on. These are taken up in some detail in an accompanying analysis.

Surprisingly little effort has been directed at understanding the economic basis of utility solar finance or ownership. Yet at the heart of these proposals there is usually a set of assertions concerning the low cost and high volume of capital available to utilities which would make these schemes economically attractive. What is needed is a general framework in which various financing alternatives can be evaluated quantitatively. This means that the determinants of the cost of capital for such projects must be explicitly analyzed so that plausible schemes can be compared.

1.1 The Argument in Brief

In the discussion which follows these questions will be addressed using the approach of portfolio theory or the capital asset pricing

model (CAPM). In this paradign the cost of capital is estimated by looking at the market-oriented risk associated with a project and linking this to an estimated market price of risk to compute the appropriate capital charge. The underlying perspective of CAPM approach is the quantification of the value of diversification.

We will be able to use the CAPM to capture the insurance or diversification benefit of on-site solar systems which is difficult to express in the consumer decision framework. An individual's calculation of the economic return on the investment in on-site solar heating cannot easily quantify the value of this technology as a hedge against future oil embargos, macro-economic fluctuation or other energy supply uncertainties. The public utility, on the other hand, is exposed to these market-oriented risks. Utility investment in on-site solar can provide some diversification. This benefit must be folded in to the engineering economic return to estimate a final figure of merit in given circumstances. This report will outline a methodology for making these assessments in the case where utilities capitalize these investments, i.e. own the system, and where they simply finance them.

We will find that the financial risk of utility investment in on-site solar is low. The reason for this result is that such investments minimize the possibility of failure to realize the allowed rate of return. On site solar investment eliminates part of the utility's long run demand uncertainties that are presently exacerbated by investment in conventional long lead time technologies. Because on site solar comes in small increments rather than huge blocks the timing of investment can follow demand and growth patterns. The potential default risk associated with on site solar does not appear to be correlated with macro-economic movements, so there should be no risk penalty from this factor.

This low risk property of utility investment in on site solar can be captured either under capitalization (i.e. rate-basing) or under a financing option. The major financial difference between these approaches is the role of taxation. The importance of this

factor depends strongly on the applicability of capital investment incentives such as accelerated depreciation and investment credits.

Our main conclusion is that the low financial risks for these schemes means that low cost capital should be available for utility investment in on-site solar. Numerous local regulatory policies will affect the precise implementation of either capitalization or financing. These are best taken up at the case study level. Nonetheless our generic analysis suggests that the financial viability of on site solar investment is greater than that associated with investment in conventional technology whose financial risks are greater.

1.2 Outline of the Analysis

The discussion will be organized in the following sequence. Section 2 will summarize the major features of the CAPM including a survey of those applications which are most relevant to our analysis. These include utility return on equity calculations and project evaluation techniques. In section 3 we will discuss how to apply empirical results based on CAPM methods. In particular we will distinguish applications to the capitalization variant of the utility investment strategy and the financing variant. Subsidization rationales will also be discussed. Section 4 will summarize empirical results to date, including estimation problems for the various risk measures. Finally in section 5 we will review the general problem of financial risk assessment for energy technologies.

2.0 The Capital Asset Pricing Model

2.1 Definitions and Examples

The Capital Asset Pricing Model (CAPM) is based on an economic theory of capital market behavior which establishes a formal representation of the trade-off between the risk and return of investments.

There are several textbook expositions of the economic assumptions
and formal framework underlying this model (see ref. 2,3). For our
purposes, however, it is sufficient to discuss the model's two
basic parameters and their essential relations. CAPM assumes that
all investments can be thought of as random variables characterized
by an expected value of the return and some variance. The variance
of the return is identified as the risk of the investment.

The first major construction of the theory is the capital
market line (CML) which is shown in Figure 1. The curve AB is the
efficient frontier of the set of feasible portfolios consisting
of risky assets. This is simply the locus of points in the space
of risk and returns which gives the maximum return for given risk
or alternatively the minimum risk for a given return. The capital
market line is constructed by adding to the universe of risky
securities a risk-free security with return R_f. The CML is a new kind
of efficient frontier describing a world in which the best you can do
in terms of risk and return is to construct a portfolio which is a
linear combination of the risk-free asset and the market portfolio
M. The proof of this result shows that the CML is that tangent to
the curve AB which goes through the risk-free rate of return R_f. The
risk free return, R_f, is usually thought of as the return on short
term Treasury bills. R_f can change over time, of course, and therefore
so will the capital market line.

The CAPM is derived from the CML by constructing a new port-
folio P which is a linear combination of a new asset i and the market
portfolio M. Then by essentially the same argument which led to the
construction of the CML it follows that the partial derivative of
the return on the portfolio p, R_p with respect to the risk of the
portfolio σ_p must be the same as the slope of the CML. Analytically
we have therefore

$$\frac{\partial R_p}{\partial \sigma_p} = \frac{R_m - R_f}{\sigma_m} \qquad \qquad 1)$$

Figure 1
Capital Market Line
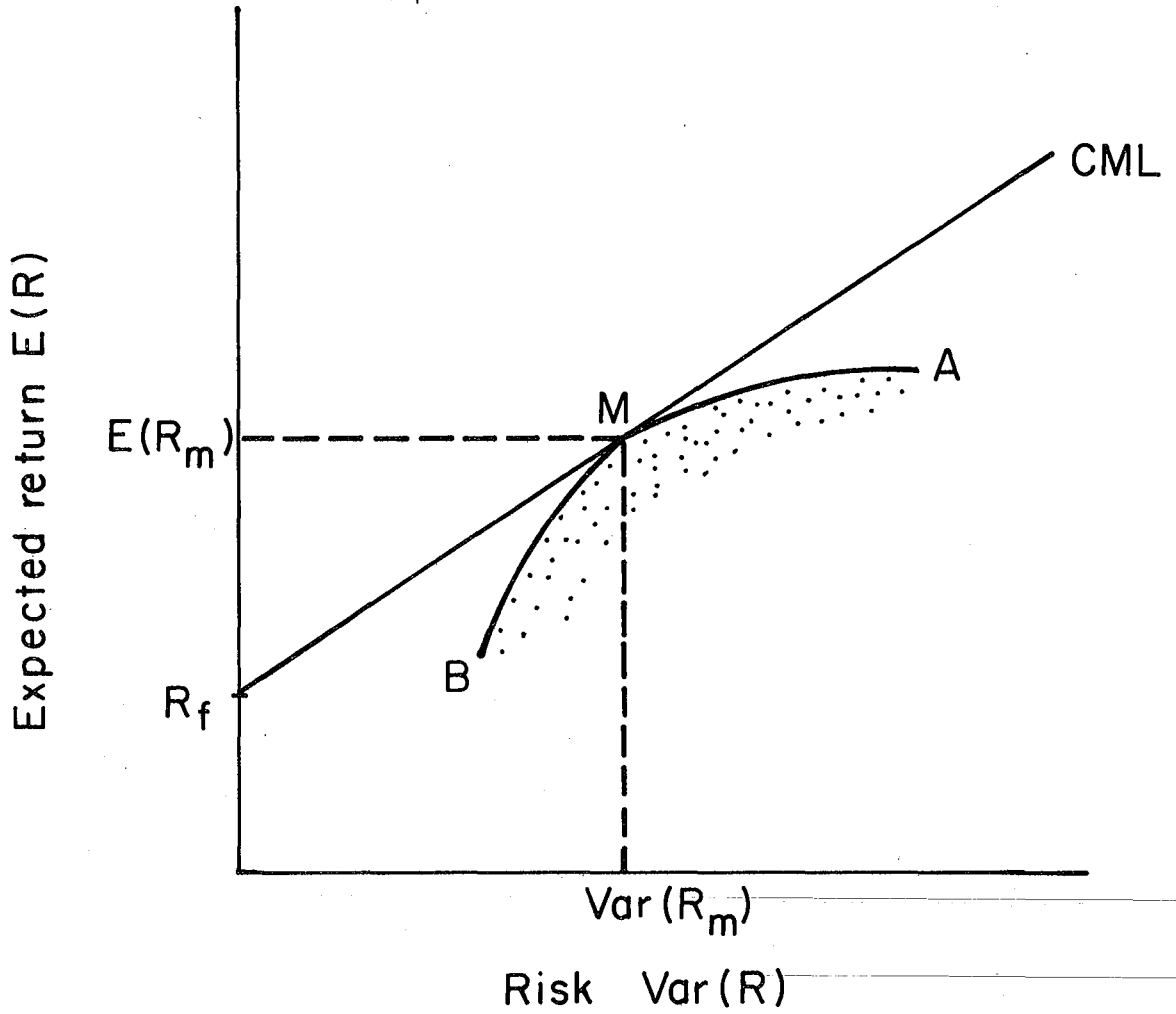
Algebraically, equation (1) can be transformed into the following valuation formula for the risky security i:

$$E(R_i) = R_f + \beta_i[E(R_m)-R_f] \qquad (2)$$

where

$$\beta_i = \frac{Cov(R_i,R_m)}{Var(R_m)} \qquad (3)$$

The derivation of equations (2) and (3) from (1) is given in Appendix 1. What these equations are saying can be expressed as follows:

Expected Return on Risky Security i = Risk-free Rate + Risk Premium which is proportional to the "volatility" of the security and the market price of risk   (4)

The second term on the right-hand side of (2) is the risk premium for security i. It consists of two components, a parameter β_i of the asset i which is called the "volatility" of the asset's return, and the "market price of risk." The latter concept is quite straightforward. It simply says that the market portfolio will give a return of $E(R_m)-R_f$ to compensate investors for the total risk being accepted. For an asset i with $\beta_i = 1$, equation (2) shows that $E(R_i) = E(R_m)$; that is, the return is the same as the market return. Equation (3) says this in the language of probability, namely that the return on asset i co-varies exactly with the market return. The parameter β_i measures the sensitivity of R_i to market fluctuations. A volatile asset, $\beta > 1$, fluctuates more extremely than the market. A "growth" stock is an example of such behavior. When the market is up, high beta stocks out-perform the indices; conversely when the market is down. An asset with $\beta < 1$ is less sensitive than the market to macroeconomic changes. Utility stocks are examples of securities with such low beta behavior. It is even possible to have assets with negative beta. These would be assets whose return fluctuated counter-cyclically with macroeconomic movements. Gold is usually cited as an example of such an asset.

2.2 The Historical Record

CAPM would not be interesting unless there were evidence that it is a reasonable model of security valuation. Finding such evidence is complicated by the model's formulation in terms of investors expectations rather than in terms of realized returns. Nonetheless various historical studies of past security performance have shown that beta and returns are correlated in the way predicted by CAPM (a review of these studies is given in ref. 4). It will be particularly useful, however, for our discussion of CAPM applications to pay some careful attention to differences between model predictions and empirical results.

In Figure 2 we summarize a common, but by no means universal, phenomenon resulting from tests of CAPM. In this graph we plot a theoretical security market line (SML) which is calculated from a version of equation (2) where expected values of return are replaced by average realized returns. We also plot an empirical or actual security market line which is simply fit to a set of points corresponding to security returns and estimated values of beta. If CAPM were exact, these two lines would be identical. Figure 2 shows the situation in which the zero risk asset has a return below the intercept of the return-beta regression (actual SML), and the slope of the empirical line is less than what was predicted. It has also been found that at times the actual slope is greater than the theoretical slope. This phenomenon has led to various adjustment rules which will allow for correction of the "raw" or "technical" beta estimation. We will highlight a few of the more interesting results of this kind.

Estimates of beta over different time periods for a given security are likely to fluctuate with considerable scatter. The scatter of β estimates is reduced if we group securities into industry related sets. Appendix 4 shows the greater degree of stability in the value of β for the Standard and Poor's Utility

Figure 2

Theoretical vs Actual Security Market Line
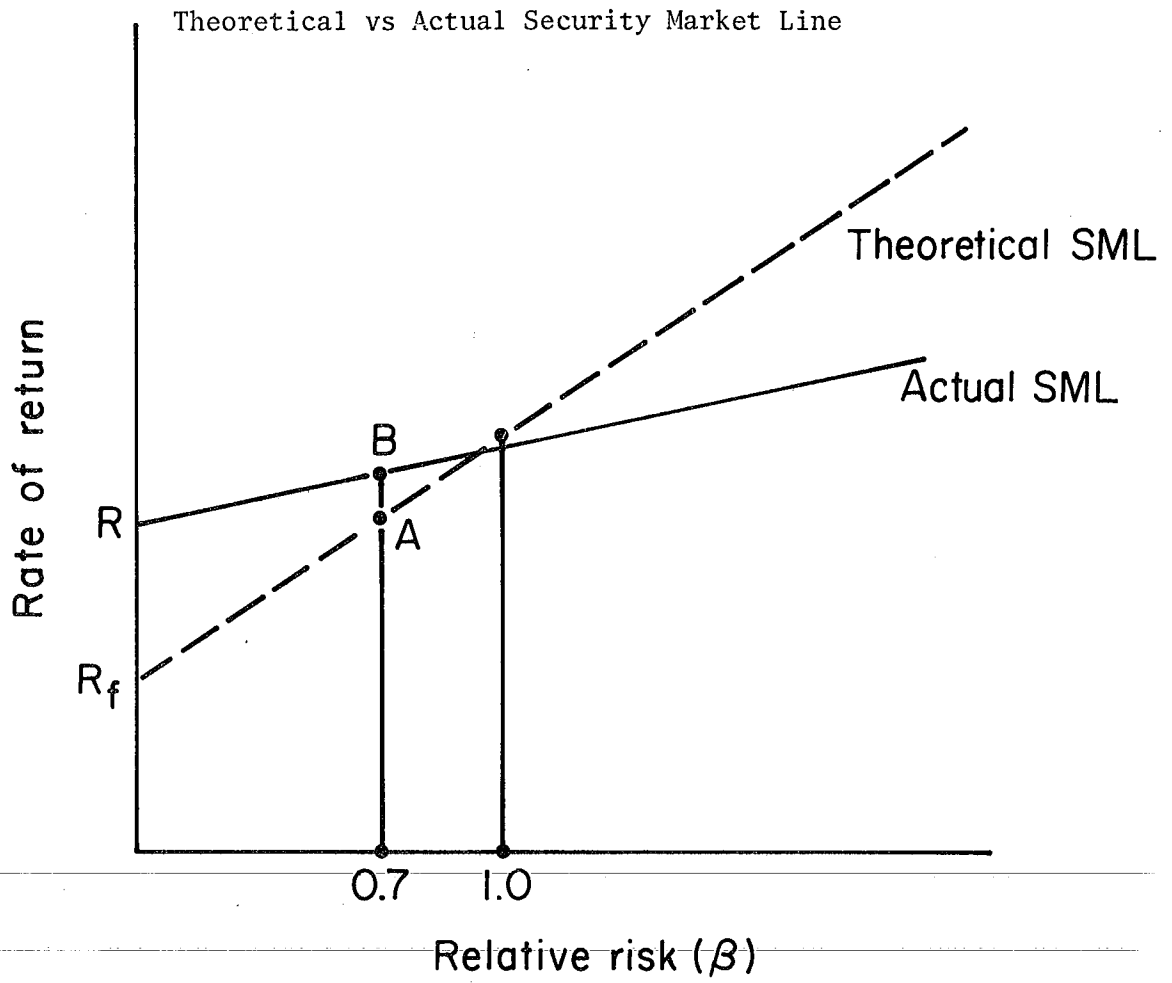
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Index compared to one California utilities. Data such as this, which is discussed more fully in Appendix 4, has been used to motivate a whole host of rules to adjust the raw beta of an individual security for various CAPM applications. One simple form of adjustment is to treat the industry average as a norm and weight this with the technical results obtained for a given security. This approach is used by Merrill, Lynch, Pierce, Fenner and Smith, Inc. and Wells Fargo Bank (see ref. 5). Another technique is the use of certain current financial indicators of a firm such as variance of cash flow, current dividend yield and market capitalization to adjust individual security beta estimates (see ref 6). Consideration of these approaches to the empirical problems of applying CAPM is essential.

2.3   Application to Utility Equity Returns.

Because public utilities are regulated, the price of their securities is influenced by the non-market administrative decisions of the regulatory commission. However, the judicial principles on which regulation is based suggest that CAPM might be a useful tool for setting the allowed rate of return on equity capital. This follows from the standard language on the criteria for determining the rate of return incorporated in the Hope decision:

> The return to the equity owner should be commensurate
> with returns on investments and other enterprises having
> corresponding risks. That return, moreover, should be sufficient
> to assume confidence in the financial integrity of the enterprise
> so as to maintain its credit and attract capital (ref 7).

CAPM is nothing but a methodology for determining the price of risk for equivalent securities.

In practice, however, the theory runs into the problem indicated by Figure 2. When CAPM is applied to utility stocks we have found that β is consistently less than one. For β sufficiently less than one CAPM might predict lower equity returns than the actual market line. In Figure 2 the distance   between points A and B indicates the kind of underestimate in equity return that may result from straightforward

use of CAPM. This empirical problem, coupled with the real-world
implausibility of some of the CAPM postulates, has led some authors
to reject this regulatory application of the model (see ref. 8).

This argument is particularly important for our subsequent
discussion, because we will argue that on-site solar investment would be
quite a low-risk, i.e., low beta, project for a utility. A
logical conclusion from this line of thinking might be the following
regulatory incentive paradox. Suppose a reluctant utility is
persuaded by its regulators to capitalize on site solar investment.
As a reward for this compliance, the regulators promptly lower the
utility's allowed return on equity to correct for the reduced beta of
the company as a result of the solar investment. This amounts to
providing negative financial incentives for behavior ostensibly
desired by the regulators.

Such a paradox results only when there is a confusion of time
scales. Allowed returns on equity are decided on a time scale of
one to two years. Energy project evaluation applications of CAPM
methods are addressed to time scales of 10 to 30 years. The financial
diversification benefit of utility investment in solar cannot be
expected to show up instantly in market valuation or reduced security
beta. These may be long-term trends, but their magnitude may not
be noticeable within the error ranges of CAPM techniques. What
can be estimated with greater reliability is the relative financial
risks of competing technologies. It is on this subject that CAPM
can provide useful discrimination because the range is large. We
will take up this more general topic in section 5. For now we must
shift attention to the specific techniques for applying CAPM to
project evaluation.

2.4   Project Evaluation

We would like to estimate the risk premium of a project as a
function of the agent who undertakes it and the project's return
characteristics. The investment decision from a purely financial

point of view amounts to a test of whether the excess return of the
project exceeds the risk premium. Following Mossin (ref.3), we can
write this as

$$\mu_z - r_f\, I_z \geq Rb_z, \qquad (5)$$

where

μ_z = expected return on project z

r_f = risk-free rate

I_z = investment cost of z

R = market price of risk

b_z = risk measure

The excess return is the difference between the expected return and
the return on a risk-free asset $(\mu_z - r_f I_z)$.
To derive a general expression for the risk premium Rb_z, we again follow
Mossin and break up the risk measure into the three terms which
follow

$$b_z = \text{cov}(z,m) + \text{cov}(z,J) + \text{cov}(z,z) \qquad (6)$$

where

m is the market return (random variable)
z is the return of project z (random variable with mean μ_z)
J is the return on other projects of the firm J.

In Appendix 2 we show that for small investments (compared to the
size of the firm) equation (5) and (6) reduce to the following

$$E(r_z) - r_f \geq [E(r_m) - r_f]\beta_z. \qquad (7)$$

This expression is just CAPM scaled down to the project level. The
key parameter is β_z. This is the co-variance of the project's rate of
return with the market rate of return divided by the variance of the
market rate of return. It is a convenient feature of eq (7) that
it is expressed in terms of rate of return, rather than in units of
dollars. Equations (5) and (6) are expressed in gross dollar
returns not percentage rates.

Equation (7) has the important subtlety that it is not an invariant for all financial actors. The regulated utility will face a lower default risk in solar finance than other potential intermediaries. If someone refuses to pay his utility bill, he risks losing the essential energy services provided by the utility. Other financial actors do not have this leverage. This means that with regard to this factor β be estimated from a more stable proxy for utility investment than would be reasonable in a different situation. The default risk is lower for utility bills than for finance company payments for example. Thus although we have eliminated the second term in eq. (6), the covariance of the project and the firm, from our estimate of the risk premium in eq. (7), we still must consider risk estimates to be a function of the actors involved.

For our purpose equation (7) can be used to determine the finance charge seen by the customer in the various utility finance or ownership schemes. Since equation (7) represents the risk premium for the investment, the finance charge can be set as follows:

$$\text{Finance charge} = \text{Risk-free Rate} + \text{Risk Premium} \quad (8)$$

Equation (8) represents a simple flow-through approach to the cost-of-capital question for utility investment in on-site solar. It says that the consumer will pay a rate of interest equal to the utility's threshold rate of return for accepting the investment. In the simplest case the finance charge calculated from equation (3) will equal the expected rate of return from the engineering economics. Then there will be no additional complexities. In most cases these two will not be equal. Therefore we must study the regulatory and financial consequences of the case where the expected rate of return differs from the finance charge. This is taken up in Section 3.

3.0   Regulatory Applications

Regulated utilities are limited in the return they can earn on investment by that which the state or local jurisdiction allows. It has been argued that such rate of return regulation provides an incentive towards over-capitalization; inputs will not be used in optimal proportions. This is the famous Averch-Johnson Thesis that has been the subject of extensive discussion. (ref. 10, 11). This argument

is discussed in the case of on-site solar in an accompanying analysis
(ref   ). For our purposes it will be sufficient to discuss the
various regulatory options available to State Commissions that can
adjust realized returns with expected returns. Before turning to this
subject we must spend some time analyzing the rate of return
calculation in our current context.

3.1 Rate of Return Calculations

In principle it is straight forward to calculate the rate of
return. We assume that the appropriate measure is the internal
rate of return that is found by using the discounted cash flow (DCF)
method. We will write down a simple version of this basic problem.
To find internal role of return, solve for x in equation (9):

$$C = R_o \sum_{i=1}^{n} \left(\frac{1+r_e}{1+x}\right)^i , \qquad (9)$$

where

$\quad$ C = capital cost ($)
$\quad$ n = life-time
$\quad$ r_e = escalation rate of energy prices (%)
$\quad$ R_o = return (benefit) in first year ($)

One difficulty in using the method stems from uncertainty
concerning the escalation rate in energy prices. More fundamental
is the problem of assigning a value to the conventional energy
displaced by the on-site solar system. This is really just the
marginal cost problem. The first year's return, R_o , is the
product of some units of energy displaced times a price per unit. The
difficult practical problem is to decide which price truly represents
the margin. There is considerable controversy on this problem
(see ref. 12). The main ambiguity involved is the question of
identifying "displaced" supply costs. On-site solar will reduce
utility energy (kwh) requirements immediately and thereby produce
fuel cost savings (short-run marginal costs). In the long run some
capacity (kw) costs may be saved. These can be difficult to identify.

Techniques are available to estimate this in particular situations
(see ref 13), but the question calls for detailed case study.

For our purposes it is sufficient to get a first-order approximation.
We will make estimates by using the customer's cost of electricity as
the value of energy saved and escalate this with an expected rate of
increase in oil prices. The latter is an appropriate escalator for
oil-based utility systems such as those in California. The benefit
stream must also be modified by expenses for maintenance. In Table 1
below we perform some sample calculations for California's conditions.
These results show that the rate of return on solar hot water heating
can vary widely. If we were to examine active space heating systems
in the same way the return could be expected to be lower in general
(ref. 14).

There are other corrections to the rate of return calculation
that may also need to be made. Several studies have found that electric back-
up for on-site solar may cost more on the margin than electricity
supplied for other technologies providing thermal end uses (ref. 1, 32)
Such results are very dependent on solar system configuration and
climate. Since this phenomenon is essentially a cost and not a
financial risk, it can best be treated as a deduction from the benefit
stream. The back-up cost may also be transferred to other or all
ratepayers by regulatory decision. There are examples of such transfers
of cost in the area of utility insulation finance (see discussion of
Consolidated Edison Program in ref. 15).

Finally we must consider the question of on-site solar system
reliability. The important distinction to be made here is again the
difference between a cost and a risk. If a certain fraction, say 10%,
of the solar systems which a utility has invested in are not function-
ing for one reason or another, then the average rate of return
will be reduced by 10%. Although reliability problems will cause
variation in the cash flow associated with these investments, it is
a random not a systematic variation. Therefore it is excluded from
our estimates of beta and shows up on the return calculation as
decreased revenue.

Now we have identified all the components of the return calculation except for taxes. We will defer the discussion of taxation to our treatment of the utility ownership or capitalization alternative. First we will discuss the conceptually simpler alternative of utility finance.

3.2 The Financing Option

Let us consider the case in which the regulatory commission limits the utility to the role of financing agent for on-site solar. From the consumer's point of view the utility is providing a financial economy of scale by reducing the risk premium on the investment. In sectin 4 we will present arguments supporting the proposition that the beta for these projects is low; our first approximation is 0.15 for the cases considered. Using equations (7) and (8) we can translate this into a finance charge. We need two estimates to make this calculation. The first is the appropriate risk-free rate. The second is the market price of risk, $E(r_m) - r_f$. For the sake of illustration we will rely on the values estimated by Prof. Whitcomb in a recent regulatory proceeding (ref. 9). Using a long term average for the market price of risk, he estimates its value at 8.86%. For the risk free rate, Whitcomb estimates 7.0%. Now we make our finance charge calculation;

$$\text{Finance Charge} = 7.0 + 0.15 \ (8.82) = 8.41\%$$

This rate is low. It is below the first mortgage interest rate faced by most consumers and well below expected rates from other financing alternatives available to consumers. These include second mortgages or home improvement loans.

It remains to be determined, of course, whether the regulatory commission will adopt the finance charge estimated in this way or some other figure. In the most analogous situation, the utility finance of insulation, actual finance charges vary from 6.5% to 14% (see ref. 15). The extreme values represent either a public

Table 1:   Internal Rate of Return as a Function of
Region, System Lifetime and Taxation

Assumptions   Solar Hot Water Heater Capital Cost = $1500 (ref. 29)
Annual Maintenance Expenses   = $60/yr. (ref. 29)
Energy Price Escalation Rate   = 5.1% (real dollars)/yr. (ref. 30)
Inflation Rate   = 5%/yr.

Regional Performance and Value (Energy Displaced and 1978 cost per unit)

San Diego: 4800 kwh, 4.8¢/kwh (ref. 29)
Northern California: 2800 kwh, 4.0¢/kwh (ref. 31)

Internal Rate of Return

	Lifetime		
	10 yrs.	15 yrs.	20 yrs.
Case 1.			
No Federal Tax			
San Diego	14.5%	20.0%	22.3%
Northern California	0	6.0%	10.0%
Case 2.			
48% Federal Tax			
San Diego	8.8%	13.3%	15.3%
Northern California	0	3.8%	6.8%
Case 3.			
55% State Tax Credit			
33% Personal Income Tax			
San Diego	25.5%	29.5%	30.8%
Northern California	3.5%	11.5%	15.0%

Note: California grants a 55% state income tax credit for solar. This
benefit, however, also shows up as a reduced deduction for federal tax
purposes. The cost of the reduced deduction is the dollar magnitude of the
state solar tax credit times the marginal federal tax rate. These joint
impacts can be expressed as a reduction to an "effective" state tax credit
by the formula

Effective Tax Credit = Nominal Credit - Marginal IRS Rate x Nominal Credit

policy commitment to the program (the low or subsidized rate) or a profit making approach (the high rate). The value of the CAPM method for estimating the financial risk of on-site solar investments is that it creates a yardstick for policy decision. If a regulatory commission wants to subsidize solar investment it will set a rate below the CAPM estimate. Conversely if the decision is to treat this activity as another profit center. The important point is that degrees of consumer subsidization or utility incentivization can be measured.

From the consumer side, a rational decision to invest in on site solar would be indicated if the expected return exceeded the finance charge. This would mean that in terms of cash payments the sum of the utility bill plus solar payment would be less than or equal to the previous utility bill, i.e. without solar. The analysis of the consumer's position would also have to take tax incentives into account. California already has a tax credit for solar investment and federal action in this area is being considered. These effects will improve the consumers rate of return on the solar projects, but would not change the finance charge. See Table 1 for examples.

Finally there are a number of problems surrounding the actual design of a financing programs. We will only indicate a few of these. Separate accounts must be created for financing programs. Regulators must decide how much freedom the utility will have with the cash flows generated. Will the funds received be treated as income for the purpose of calculating the interest coverage ratios? How much of each payment will be credited to interest and how much to principal? If a subsidy program is chosen, how will the extra costs be allocated? These problems get us into the policies specific to one commission or another. Therefore they are best treated on the case study level where detailed variants can be examined.

3.3 The Capitalization Option

When we turn our consideration to the ownership or capitalization alternative, we can no longer ignore the role of taxation. Qualitatively

it is clear that the after-tax rate of return from on site solar
will be less than the before tax return that is associated with
the financing option. To quantify the effect we must adjust the cash
flow in year i to reflect the reduced net benefit. Considering only
federal taxes for the moment, we re-write the ith term in the DCF
equation (9) as follows:

$$\text{Cash Flow} = \text{Revenue} - \text{Expenses} - \text{Taxes}, \quad (10)$$

$$\text{We express Taxes} = \tau \left[\text{Rev}_i - \text{Ex}_i - \text{Dep}_i \right], \quad (11)$$

where τ = federal tax rate; Dep_i = depreciation
allowed in year i.

Substituting (11) into (10) we get Cash Flow

$$= (1-\tau) \left[\text{Rev}_i - \text{Ex}_i \right] + \tau \, \text{Dep}_i \quad (12)$$

In Table 1 we show the effect of taxation on the rate of return assuming
straight-line depreciation and 48% tax rate. These results would
improve if we used capital incentives such as investment tax credit and
accelerated depreciation. However, there is some question about the
applicability of these incentives to on-site solar investment (16) If
applicable, however, the rate of return could increase by 50%.

From a practical point of view it would be more difficult to make
the rate of return calculation in this case because of the marginal cost
problem. This difficulty is academic in a sense, because regulation will
set the rate of return for this investment at the rate earned by any
capital in the utility's rate base. The analogue of the subsidy and
incentive problem discussed for financing is now seen in comparing the
risk adjusted finance charge estimated from CAPM with the return on rate base.

If the return on rate base exceeds the risk adjusted finance charge,
the utility is making a profit. The regulator can then choose to allow
this as an incentive, or reduce the excess return by making an annualized
adjustment to total revenue requirements. This is a policy choice, but is
not without economic consequences. Allowing the financial incentive should
be reflected in higher prices for utility equity and therefore a reduced
capital burden on rate payers. This can be compared to the benefit rate
payers receive from the reduced revenue requirements associated with denying
the financial incentive. Quantification of these trade-offs will depend on
particular circumstances and are best estimated by individual case studies.

It might also happen that the return on rate base is less than
the risk adjusted finance charge. In this case the solar investment would
require a subsidy from other ratepayers to avoid further deterioration of
the utility's financial position. It is unlikely that the magnitude of
differences in this case would be persist   because the solar beta is
going to be less than the beta of the utility's stock. Therefore the
cost of capital for the solar investment will be less than the cost of
capital for the "average" utility investment. In the short-run the
realized rate of return on rate base may be low because of regulatory lags,
interest rate changes and so on. In the long run the return on rate base
will exceed the risk adjusted finance charge for on site solar. This is
true because currently planned projects are typically higher beta proposi-
tions than solar. This latter point will be pursued in greater detail in
Section 5.   The reasons for this will begin to emerge in our discussion of
the factors which do and do not contribute to the solar beta. This dis-
cussion appears in Section 4.

Despite the emphasis in this discussion on the regulatory rather
than the engineering-economic aspect of the return, regulators cannot ignore
the latter. A policy which mandates investment in uneconomic projects can
only be justified by extraordinarily important social or political goals.
In the variety of on site solar technologies, some have high returns, some
have low or negative returns. A useful contrast is the passive approach to
space conditioning compared to active systems. The former has relatively
low incremental costs because it involves design concepts and marginal
additions of material. Active systems involve considerable hardware: collectors,
pumps, storage tanks, etc. It is easy to understand how a utility might own
active systems. The engineering economics of such systems can be poor (ref. 14).
Passive systems promise better economics, but it is not clear how a utility
can own anything in this case. This example suggest that there is no simple
set of rules which will promise the optimal policy in all cases. Whether
capitalization or utility finance will make sense in a given situation will
depend on both regulatory policy and the nature of the project involved.

4.0   Empirical Results

In this section we will discuss empirical issues associated with
applying CAPM methods to the utility solar investment problem. The discussion

will be divided in two parts. First we discuss the validity of CAPM in explaining the returns on utility stocks. We will examine both aggregate industry behavior and individual firms. Second we will discuss the process used to estimate the beta for utility solar investment.

4.1 CAPM Applied to Utility Securities

There are two equations which can be used to estimate security betas. The first method is a straightforward application of equation (2) expressed in rates of return rather than monetary returns and replacing expected values with realized values. We write this version as follows:

$$(r_i - r_f) = \beta_i (r_m - r_f) + \alpha_i, \qquad (13)$$

where

r_i = rate of return on security i
r_f = risk-free rate of return
r_m = return of the market
β_i = volatility of security i
α_i = constant to be estimated.

Equation (13) can be estimated by forcing α_i to be zero and calculating beta.

Another formulation of CAPM is the Sharpe single index model (ref. 2). This resembles eq. (13) except for the role of the risk-free rate. To estimate beta in this formulation we consider the following equation:

$$r_i = \beta_i' r_m + \alpha_i'. \qquad (14)$$

The parameter α_i' in this equation should be the risk-free rate, r_f. In Appendix 3 we show that while we occasionally get the result $\alpha_i' > r_f$, which is the situation pictured in Figure 2, α_i' is in fact not significantly different than r_f. We could also compare the estimates of beta from eqs. (13) and (14). If we found that $\beta_i = \beta_i'$, this would show that beta is independent of which method is used to estimate it, or alternatively that the risk-free rate is not correlated with the market.

In Section 2.2 we mentioned the effect of periodization of the scatter of points underlying an estimate of security betas. In Appendix 4 we show how lengthening the period over which β is estimated improves the fit of model to data for the utility index and the individual securities. There is a trade-off in the choice of interval between improved statis-

tical reliability and loss of information concerning the true range of
scatter. This phenomenon is the most difficult to overcome in a practical
sense if CAPM were to be applied, for example, as the sole determinant of
utility equity returns.

4.2 Estimating Beta for Utility Investment in On-Site Solar

There are actually two approaches to estimating beta. The most conventional
method is the use of historical data in a regression equation. This is the
approach used in Sec. 4.1 and documented in Appendix 3. An alternative approach
has been outlined by Rosenberg and Guy (ref. 17) which proceeds from an
analysis of the degree of uncertainty of economic events and the response
of security returns to these events. This latter approach has conceptual
appeal but is difficult to use in practice. For our purposes it will turn
out that ordinary regression methods will be suitable to estimate beta for
utility investment in on-site solar. To make this argument plausible we
will include in our analysis a discussion of the fundamental causes of risk in
the utility industry. We then proceed to apply this inventory of risk to the
case at hand, after accounting for special characteristics of the on-site
solar investment.

4.2.1 Default Risk

On-site solar investments will impose a default risk on the utility
which invests in them or finances them. The default risk, i.e., the risk
that someone will not make the monthly payment for the system, can be divided
into two components, the vacancy rate and the uncollectible rate. If a
house with such a system is empty, no one is amortizing the capital investment.
If the house is occupied, there is a chance that the bill will not be paid,
i.e., it is uncollectible. Of these two effects, it is the vacancy rate
which is larger. For example, data collected by Electrical World shows
that in the Western states the uncollectible rate went from just over 0.2%
in 1970 to just under 0.3% in 1975 (ref. 18). By contrast, the vacancy
rate for multi-unit residential buildings in the West has ranges from 4
to 8% (see Appendix 5). Since the magnitude of the uncollectible rate and

its variation is less than the vacancy rate we can neglect the former until we have estimated beta for the latter effect.

We look for the co-variance of default risk with the market by estimating the following equation:

$$Occ = A + B \times R_m,$$

where
Occ = the occupancy rate (1-vacancy rate)

R_m = market rate of return, and   (15)

A, B are constants

In Appendix 5 we show that B is not significantly different than zero. This means we can also ignore the uncollectibles because its range of variation is less than the vacancy rate. Although these results do not demonstrate that there is no default risk, they do show that the market related component of the default risk can be neglected. This is the only part of the risk which matters in the CAPM. The default risk is the only additional risk burden that distinguishes on-site solar systems from other utility investments. It remains to determine the magnitude of other typical risks of utility investment as they apply to on-site solar.

4.2.2   Conventional Utility Risks

Regulated utilities face three basic kinds of financial risk. The first is essentially political; it is the risk that the regulators will not pass costs through to the customers because raising energy prices is unpopular. The second risk is administrative; it is the lag between the occurrence of costs and their incorporation in rates. In a period of increasing average costs the utility must wait to recover its expenses until its application for increases is processed. The phenomenon of regulatory lag is a short run incentive for efficiency, provided the gap does not grow too large (see ref. 11). The third category of risk is that the market will not realize the rate of return allowed by the regulator. This last category is the one which will concern us since it is directly relevant to CAPM analysis. Indeed utilities today are

having just this kind of difficulty. Rates of return are not reaching authorized levels, and as a result utility equity is selling below book value. We shall examine these market risks in some detail.

A recent summary of the market related uncertainties and risks in the electric utility industry today is given by the Policy Overview of the California Energy Commission's Biennial Report (ref. 20). The following list of factors highlights the major problems:

(A) Demand Uncertainty - the impact of higher prices, voluntary and mandatory conservation means that future demand is difficult to determine.

(B) Changes in Energy Costs - the prices of fuels and conversion technologies are uncertain and unpredictable,

(C) Long Lead Time Projects - large supply projects take years to complete, have uncertain costs and completion dates and tie up large amounts of capital for years before earning a return.

While this list is by no means exhaustive it does include the major generic risks of the energy supply industry. Moreover, the problems tend to interact with one another. Long lead time projects are riskier when the uncertainty of demand is increasing. A long lead time technology is more vulnerable to changes in factor costs than a short lead time system.

On-site solar systems eliminate much of the risk associated with (A) - (C). Because it is matched to end-use demand, there is no uncertainty associated with a long term forecast of future requirements. The demand for hot water and space heat is inelastic compared to other energy requirements. The lead time for on-site solar is short, on the order of months rather than years. Thus, the utility can adjust its solar investment program to match the variation in population growth and new housing construction. It does not have to accept the risk of building large projects over many years with the expectation (or hope) that demand will justify the investment. In the present climate of rapidly rising energy costs, utilities must face the prospect that large commercial or industrial customers may choose to satisfy their energy requirements

independently. Utility involvement in on site solar investment will reduce some of this risk. Finally there is no cost escalation risk associated with solar conversion. Cartels cannot manipulate the price of fuel.

These arguments do not mean that there is no risk at all. On-site solar is a long term investment and bears the interest rate risk that all such investments face. Electrical utilities face an interest rate risk that is typically greater than other industries (see ref.21). This is really just the corollary of the finding that utilities are low beta industry compared to the market as a whole. If security prices are less sensitive to market fluctuations, they will be more sensitive to interest rate fluctuations. The market risk of on-site solar then is comparable to the market risk of any other long term investment such as high-grade corporate bends. We estimate the following equation

$$BROR = \alpha_1 + \beta_1 r_m,$$

where $\quad$ BROR = rate of return on Standard and Poor's $\hspace{2cm}$ (15)
$\hspace{3.5cm}$ high-grade corporate bond index

$\hspace{2.7cm}$ r_m = market rate of return

$\hspace{2.7cm}$ α_1 = constant

$\hspace{2.7cm}$ β_1 = $\dfrac{\text{Cov } (BROR, r_m)}{\text{var } (r_m)}$.

The results of this regression are shown in Figure A8 The parameter β_1 is the slope of the fitted line and has the value 0.15. Detailed results are collected in Appendix 5.

The conclusion of this discussion is that beta for utility investment in on-site solar appears to be low. The market related financial risk is small for the data we have examined. Our results, however, are contingent on the validity and generalizability of the methods. Moreover, the possibility remains that market related default risk may be non-zero in particular cases. We have relied upon aggregated data for one region that may be misleading.

If this factor turns out to be significant in a given market, there are important methodological consequences. Use of our single proxy for the solar beta then becomes untenable. What is worse, we will have to construct a model for aggregating various effects into a single aggregate measure, the project beta. This problem brings us back to consideration of the underlying determinants of beta, the uncertainty of economic events and their impact on particular assets. We will outline the features of this problem in Section 5. But before turning to that discussion we will complete our analysis of the on-site solar financial risk by comparing our results with data that indicates the financial risk of conventional technologies.

4.2.3 Preliminary Comparisons

The argument up to now may be summarized as follows. Utility companies are low beta assets. The California utilities we have studied vary from $\beta = 0.56$ to $\beta \approx 0.67$. The Standard and Poor Utility Index is closer to $\beta = 0.91$. Utility investment in on-site solar we have estimated would reduce the average cost of capital; beta for this investment being around 0.15. It remains to argue that conventional projects now being planned have financial risks that are considerably greater than the historical average. If this is true, then the diversifying effect of utility investment in on-site solar is even greater than what appears by looking at historical beta alone. We will begin to argue that conventional projects on the margin are high beta propositions by examining the implications of increased rates of return on equity for one of the California utilities we have studied.

In Section 3.2 we made a numerical estimate of the finance charge for utility investment in on-site solar using estimated values of CAPM parameters due to Whitcomb (ref. 9). We will use these parameter values to check whether our estimate of Pacific Gas and Electric Company beta is consistent with their allowed return on equity. The beta implied by CAPM, Whitcomb's estimated parameters and the allowed return on equity is calculated as follows:

Allowed Return on Equity = Risk-free Rate + β (Market Price of Risk)   (16)

Substituting into (16), we get $12.83 = 7.0 + \beta(8.82)$

$$\beta = .66$$

This compares to our estimate of $\beta = 0.56$. The agreement is reasonable, but not perfect. The value of return on equity is the latest approved value (ref. 22).

For illustrative purposes we consider PG&E's requested return on equity of 15.0% (ref. 23). This is associated with the financing requirements of a resource plan going out to 1996. Substituting this value into eq. (16) with everything else fixed, we find that $\beta = 0.91$. It is instructive to decompose this new beta into an historical and a marginal component to determine the risk of the new investments. To do this we need a capitalization weighting of the historical and marginal components. This means we need to know the number of new equity shares needed to finance the plan. One estimate of this has been made by W.R.Z. Willey (ref. 24) on the assumption that shares sell at 115% of book value. He estimates that new equity will represent 56% of existing equity by 1996 under this plan. We can

can calculate the marginal beta of PG&E (or the beta of its resource plan) as follows:

$$\text{Capital Weight (Historical } \beta) + \text{Capital Weight (Marginal } \beta) =$$
$$\text{Total Capital } (\beta = 0.91) \qquad (17)$$

Substituting into (17) we get
$$1.0 \ (.66) + .56 \ (\text{Marginal } \beta) = 1.56 \ (0.91)$$
$$\text{Marginal } \beta = 1.36.$$

This result, whose numerical precision is limited, demonstrates qualitatively that the financial risks of currently planned conventional technology is higher than historical levels. In comparison with on-site solar investment the deviation from historical levels of risk is about as great on the high side for conventional technology as solar is on the low side. We will pursue this theme in the following section where we take up consideration of the underlying determinants of risk for energy technology projects.

5.0 Determinants of Asset Betas

There is only a limited literature which is relevant to determining the incidence of financial risk and differential capital charges for energy technologies. General accounts of project valuation problem are typically so

abstracted from the particularities of energy investment that they do not offer a practical guide to the problem. On the other extreme there is an anecdotal literature on comparitive capital charges from which examples and some principles may be drawn. We will take these two strands up separately.

5.1 Elasticity of Expectations Model

Myers and Turnbull (ref. 25) have recently extended the multi-period version of CAPM to a model of asset valuation in which expectations are periodically revised in the light of new information. These revisions are modelled as a set of weights which are attached to the historical stream of cash flows which the asset generated in the past. If the last period is given all the weight in formulating the expected cash flow for the next period, then the asset is said to have an elasticity of expectations equal to one. Conversely, if the last period has zero weight in forecasting expected cash flow for the subsequent period, then expectations are inelastic.

The authors then proceed to derive asset valuation formulas which express beta in terms of the familiar CAPM parameters. Indeed their formula may be seen as another "raw" beta adjustment technique which is more tailored to project valuation than to security valuation. In equation (18) below we write the expression for beta when asset life is infinite. The authors have produced a table of values which gives explicit numerical results for fixed parameters and varying asset life. The table shows that eq. (18) is a reasonable first approximation for the lifetimes expected of energy projects.

$$\beta_{z,\text{adjusted}} = (r_f + \nu)/(1 - (\text{MPR}) \, \text{cov}(r_z, r_m))[\beta_{z,\text{raw}}] \qquad (18)$$

where r_f = risk-free rate
  ν = elasticity of expectations ($0 \leq \nu \leq 1$)
  MPR = market price of risk ($E(r_m) - r_f$)
  r_z = rate of return on asset z
  r_m = rate of return on the market.

The denominator in eq. (18) is typically a number less than one. So the adjustment to the raw beta measures the extent to which one can expect "surprises" in the cash flow generated by project z. Where the parameter ν is large, i.e. heavy weight is given to experience of the recent past, we

must have revised initial expectations, i.e. discounted them. In this
case the adjustment to the raw beta will tend to be a factor near to
or greater than one. Conversely, where no surprises are expected, where
initial expectations form a firm basis for the forecast of future cash flows,
the adjustment will reduce the raw beta. In the limit a "certain" situation
will reduce the raw beta by a factor equal to r_f, the risk-free rate of return.

While equation (18) is suggestive, it really only translates risk
adjustment from one set of conceptual categories to another. The elasticity
of expectations is difficult to measure, perhaps impossible to forecast. If
we can know it at all, it is only in retrospect and rather qualitatively at
that. That is, we can judge relative elasticities perhaps, but not absolute
magnitudes. Nonetheless, the Myers-Turnbull language does suggest a
way to interpret some data on the difference in capital charges associated
with coal versus nuclear electric generation investments. It is to this
more particular discussion that we now turn.

5.2 Coal vs. Nuclear: An Example of Capital Charge Differentials

In regulatory practice, technologies are differentiated by capital charge
rates. Only certain contributing factors are commonly distinguished, however,
and there is no uniform approach. For illustrative purposes we will reproduce
data in Table 2 below which shows one recent and detailed comparison of the
capital charges associated with coal and nuclear generation projects. Of
the utility risks listed in Section 4.2.2, only the lead time risk is included
explicitly in Table 2, where it is represented by the Construction Compound
Interest Factor (CCIF). In some versions of these calculations, CCIF is
treated as part of the present value of the capital investment (ref. 27).
Annual carrying charges then include only the components of return, deprecia-
tion and taxes. Even here, however, we see differences between coal and nuclear
in Table 2. Our problem is to construct an account of these differences that
is more general than anecdotal.

The Myers and Turnbull framework offers one possible line of argument.
The reasons cited in Table 2 for the higher carrying charges associated
with nuclear investments can be interpreted as evidence of revised expectations.
The higher depreciation charges associated with nuclear decommissioning costs

are expressed in accounting language as a negative net salvage value (ref. 26). It is doubtful if this component of cost was part of the original set of cost expectations used in initial estimates of the cost of nuclear power. The very term "negative net salvage value" is of recent vintage. Similarly the distinguished "financial risk" penalty of the nuclear investment can be understood as a change of expectations. Compared to coal combustion technology, nuclear can be seen as having more "surprises". As usual with this framework, "more" and "less" is hard to measure, especially to the precision of 0.2% differences in required return.

5.3 The Lemon Technology Problem

Up to now we have neglected the risk that on site solar systems will turn out to be inadequate on technical or engineering grounds. We can call this the risk of investing in a lemon technology. This risk applies to all technologies, of course, and is fundamentally just another aspect of our limited knowledge. We only discover that we have invested in a lemon after the fact. In the Myers and Turnbull language we adjust our expectations on the basis of new information. The critical parameter in this framework, the elasticity of expectations, measures among other things when we learn the bad news. The sooner the ill tidings arrive, the lower is this elasticity, and hence the lower the beta of the assets in question. This brings us back to the lead time risk which we discussed in sec. 4.2.2. A long lead time technology is one in which potential bad news is delayed. If the amount of capital committed to such projects is large the total risk to the firm goes up accordingly. Here again the small incremental nature of on site solar turns out to be an advantage compared to the large scale, long lead time technologies.

5.4 An Alternate Approach

A potentially more explanatory quantitive approach to assessing the underlying determinants of energy project risk premiums lies in a possible variant in the CAPM framework. By adapting CAPM we have in effect assumed that non-market related risk, sometimes called un-systematic or residual risk, is unimportant for project valuation. Project cash flow variances that are not market correlated show up in the rate of return. While this procedure

does relate market to non-market risk, the linkage is less clear and explicit than it might be. Indeed, many of the risks faced by a utility may not be systematic in the sense of CAPM. This possibility may be even more plausible for the marginal investment. For example, on site solar investment is vulnerable to the discovery of a better conversion technology. If that were to occur then there would be no escalation in the value of existing on site solar systems and possibly even a decline. To call this, or the risk of a reactor core meltdown a market related risk is stretching the meaning of the CAPM.

One variation on the CAPM is a model tested by Miller and Scholes (ref. 28) in which there is a term representing the unsystematic risk in an equation such as our (14). Although sampling problems make their conclusion less than clear cut, they found that this term was as significant a determinant of return as beta. Project cash flow variances can be estimated in a more or less straight-forward manner. These variances can in principle be separated into systematic and unsystematic components. Such an approach is probably more relevant on the case study level than the generic level because unsystematic risks are likely to vary considerably with region. Nonetheless this additional refinement on CAPM is probably the most promising path of development for the assessment of financial risks associated with energy projects. In the case studies which will follow as the next phase of investigation we will explore this possibility.

6.0 Conclusion

This study is a preliminary attempt to develop a basis for distinguishing the elements of risk in energy projects. Financial risk is linked to required returns is estimating the feasibility of energy investments. We have found that utility investment in on site solar involves relatively few financial risks. This conclusion is more robust in comparing investments on the margin than in comparison with the historical record. Our results should not be interpreted as a claim of precise numerical differences. The data on which our estimates are based is far too limited for that. We do claim that

our methods and qualitative conclusions are reasonable. Clearly, however, more reliable results can be achieved. In a period of rapidly rising capital requirements for energy and increasing uncertainty, it is desirable to develop an approach to distinguishing the financial risks of competing technologies. We hope to stimulate further work in both the specific application we have studied and in the general problem.

Table 2

Fixed Charge Rates[*]

Coal vs. Nuclear

1. Annual Carrying Charges (ACR)

	Nuclear	Coal	Reason for Difference
Return	10.78	10.58	Financial Risk
Depreciation	.94	.45	Negative Net Salvage Value
Taxes (federal)	2.65	1.91	
	14.37%	12.94%	

2. Construction Compound Interest Factor (CCIF)

1.57	1.25	Lead Time

3. Fixed Charge Rate (FCR = ACR XCCIF)

22.56%	16.18%

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APPENDIX 1

Derivation of CAPM

To prove $\quad \dfrac{\partial R_p}{\partial \sigma_p} = \dfrac{R_m - R_f}{\sigma_m}$ implies CAPM

Define $\quad R_p = X_i R_i + X_m R_m,$

Where $\quad X_i + X_m = 1.$ These are the shares of the asset i and the market portfolio m in the portfolio P.

Then $\quad \sigma_p^2 = X_i^2 \sigma_i^2 + X_m^2 \sigma_m^2 + 2 X_i X_m \, COV (R_i, R_m).$

Substitute $\quad X_m = (1 - X_i).$

Then $\quad \sigma_p = \left[X_i^2 \sigma_i^2 + (1 - X_i)^2 \sigma_m^2 + 2 X_i (1 - X_i) \, COV (R_i, R_m) \right]^{1/2}$

and $\quad \dfrac{\partial \sigma_p}{\partial X_i} = \dfrac{X_i (\sigma_i^2 + \sigma_m^2 - 2 \, COV (R_i, R_m)) + COV (R_i, R_m) - \sigma_m^2}{\sigma_p}$

Substitute $X_m = (1 - X_i)$ into expression for R_p and differentiate with respect to X.

$$\dfrac{\partial R_p}{\partial X_i} = R_i - R_m.$$

Then

$$\dfrac{\partial R_p}{\partial \sigma_p} = \dfrac{\partial R_p / \partial X_i}{\partial \sigma_p / \partial X_i}$$

$$= \dfrac{\left(R_i - R_m \right) \sigma_p}{\left[X_i \left(\sigma_i^2 + \sigma_m^2 - 2 \, COV (R_i \, R_m) \right) + COV (R_i, R_m) - \sigma_m^2 \right]}$$

We are interested in the value of this derivative at the point where the portfolio p consists only of the market portfolio m, i.e. whereas $X_i = 0$ and $\sigma_p = \sigma_m.$

Making these substitutions we obtain

$$\frac{\partial R_p}{\partial \sigma_p}\bigg|_{X_i = 0} = \frac{R_i - R_m}{(COV(R_i, R_m) - \sigma_m^2)/\sigma_m}.$$

Finally we equate this expression with the slope of the capital market line and derive the CAPM.

$$\frac{(R_i - R_m)\sigma_m}{COV(R_i, R_m) - \sigma_m^2} = \frac{R_m - R_f}{\sigma_m},$$

$$(R_i - R_m)\sigma_m^2 = (R_m - R_f)(COV(R_i, R_m) - \sigma_m^2),$$

$$R_i\sigma_m^2 = R_m\sigma_m^2 + R_m COV(R_i, R_m) - R_m\sigma_m^2 - R_f COV(R_i, R_m) + R_f\sigma_m^2,$$

$$(R_i - R_f)\sigma_m^2 = (R_m - R_f)COV(R_i, R_m),$$

$$R_i - R_f = (R_m - R_f)\frac{COV(R_i, R_m)}{\sigma_m^2}.$$

This expression is the CAPM.

APPENDIX 2

Risk Measure for Projects

Notation: Capital letters are returns in dollars. Small letters are rates of returns. Primes indicate the situation after investment I has been made.

Start with CAPM:

$$E(r_c) - r_f = \left[E(r_m) - r_f \right] \beta_c$$

After undertaking a desirable project I, we have

$$E(r_c') - r_f > \left[E(r_m) - r_f \right] \beta_c'$$

$$\boxed{\frac{E(r_c') - r_f}{\beta_c'} > \frac{E(r_c) - r_f}{\beta_c}} \qquad 1.$$

$$r_c = \frac{R_c}{C_c} \; ; \; r_c' = \frac{R_c + R_I}{C_c + I}$$

$$r_m = \frac{R_m}{C_m} \; ; \; r_m' = \frac{R_m + R_I}{C_m + I}$$

$$\beta_c = \frac{Cov\ (r_c,\ r_m)}{Var\ (r_m)} \; ; \beta_c' = \frac{Cov\ (r_c',\ r_m')}{Var\ (r_m')}$$

$$r_m' = \frac{R_m}{C_m} \left(\frac{C_m}{C_m + I} \right) + \frac{R_I}{I} \left(\frac{I}{C_m + I} \right) = r_m \left(\frac{C_m}{C_m + I} \right) + r_I \left(\frac{I}{C_m + I} \right)$$

$$r_c' = \frac{R_c}{C_c} \left(\frac{C_c}{C_c + I} \right) + \frac{R_I}{I} \left(\frac{I}{C_c + I} \right)$$

$$\boxed{r_c' = r_c \left(\frac{C_c}{C_c + I} \right) + r_I \left(\frac{I}{C_c + I} \right)} \qquad 2.$$

The new rate of return is the capitalization weighted average of the new project and the company before the project.

$$\beta_c = \frac{\text{Cov}\left\{\left[\left(\dfrac{C_c}{C_c+I}\right) r_c + \left(\dfrac{I}{C_c+I}\right) r_I\right] , \left[\left(\dfrac{C_m}{C_m+I}\right) r_m + \left(\dfrac{I}{C_m+I}\right) r_I\right]\right\}}{\text{Var}\left\{\left(\dfrac{C_m}{C_m+I}\right) r_m + \left(\dfrac{I}{C_m+I}\right) r_I\right\}}$$

Examine Numerator:

$$\text{Cov}\left\{\ \right\} = \frac{C_c C_m}{(C_c+I)(C_m+I)} \text{Cov}(r_c, r_m) + \frac{I C_m}{(C_c+I)(C_m+I)} \text{Cov}(r_I, r_m)$$

$$+ \frac{C_c I}{(C_c+I)(C_m+I)} \text{Cov}(r_c, r_I) + \frac{I^2}{(C_c+I)(C_m+I)} \text{Var}(r_I)$$

Notice that the last three terms include the covariances identified in Eq. (6) Sec. 2.4, but they are weighted by capitalization. We will approximate this entire expression for the case in which the investment I is 10% of the firm's capitalization.

Assume: $I \ll C_m$

$$\frac{I}{C_c} \sim .1$$

$$\frac{C_c C_m}{(C_c+I)(C_m+I)} \sim \frac{C_c}{C_c+I} \sim .9$$

$$\frac{I C_m}{(C_c+I)(C_m+I)} \sim \frac{I}{C_c+I} \sim .1$$

$$\frac{C_c I}{(C_c+I)(C_m+I)} \sim 0$$

$$\frac{I^2}{(C_c+I)(C_m+I)} \sim 0$$

$$\text{Cov}\left\{ \begin{array}{c} \\ \end{array} \right\} \underset{\sim}{\sim} \frac{C_c}{C_c+I} \ \text{Cov}\ (r_c,\ r_m) + \frac{I}{C_c+I} \ \text{Cov}\ (r_I,\ r_m)$$

Examine demominator:

$$\text{Var}\left\{ \begin{array}{c} \\ \end{array} \right\} \frac{C_m^2}{(C_m+I)^2} \ \ \text{Var}\ (r_m) + \frac{I^2}{(C_m+I)^2} \ \ \text{Var}\ (r_I) + \frac{2C_m I}{(C_m+I)^2} \ \ \text{Cov}\ (r_m,\ r_I)$$

Using previous approximations:

$$\text{Var}\left\{ \begin{array}{c} \\ \end{array} \right\} \ \underset{\sim}{\sim} \ \text{var}(r_m)$$

$$\beta_c' \ \underset{\sim}{\sim} \ \frac{\left(\dfrac{C_c}{C_c+I}\right) \ \text{Cov}\ (r_c,\ r_m) + \left(\dfrac{I}{C_c+I}\right) \ \text{Cov}\ (r_I,\ R_m)}{\text{var}\ (r_m)}$$

$$\boxed{\beta_c' \ \underset{\sim}{\sim} \ \left(\frac{C_c}{C_c+I}\right)\beta_c + \left(\frac{I}{C_c+I}\right)\beta_I} \qquad\qquad 3.$$

Thus, the new beta for the company is the capitalization weighed average of the original beta and the project beta. In this approximation the project beta, $\beta_I = \dfrac{\text{Cov}(r_I,\ r_m)}{\text{VAR}\ (r_m)}$ and we can neglect the higher order terms.

Finally, we

Substitute 2. and 3. into 1.

$$\left\{ \frac{\left(\dfrac{C_c}{C_c+I}\right) E(r_c) + \left(\dfrac{I}{C_c+I}\right) E(r_I) - r_f}{\left(\dfrac{C_c}{C_c+I}\right) \beta_c + \left(\dfrac{I}{C_c+I}\right) \beta_I} \right\} > \frac{E(r_c) - r_f}{\beta_c}$$

Project is desirable if:

$$\left\{ \left(\frac{C_c}{C_c+I}\right) \ E(r_c) \ \beta_c \ + \ \left(\frac{I}{C_c+I}\right) \ E(r_I) \ \beta_c \ - \ r_f \ \beta_c \right\} > \left\{ \left(\frac{C_c}{C_c+1}\right) \ \beta_c E(r_c) \right.$$

4.

$$\left. + \ \left(\frac{I}{C_c+I}\right) \ \beta_I \ E(r_c) \ - \ \left(\frac{C_c}{C_c+I}\right) \beta_c \ (r_f) \ - \ \left(\frac{I}{C_c+I}\right) \ \beta_I \ r_f \right\}.$$

Simplifying,

$$\left(\frac{I}{C_c+I}\right) \ E(r_I) \ \beta_c \ - \ \left(\frac{I}{C_c+I}\right) \ r_f \ \beta_c \ > \ \left(\frac{I}{C_c+I}\right) \ \beta_I \ E(r_c) \ - \ \left(\frac{I}{C_c+I}\right) \ \beta_I \ r_f.$$

This reduces to

$$\left(E(r_I) \ - \ r_f \right) \ \beta_c \ > \ \left(E(r_c) \ - \ r_f \right) \ \beta_I \ = \ \left(E(r_m) \ - \ r_f \right) \ \beta_c \ \beta_I \ .$$

Therefore, if the project's excess return satisfies (5) it is desirable

$$\left(E(r_I) \ - \ r_f \right) \ > \ \left(E(r_m) \ - \ r_f \right) \ \beta_I \qquad (5).$$

This equation is identical to eq. (7) in section 2.4.

APPENDIX 3

The Procedure used in the Calculation of the
Systematic Risk Measure β

The Capital Asset Pricing Model presumes that associated with each
and every capital asset there is an expected rate of return denoted by r,
and a systematic risk measure denoted by β. The expected rate of return de-
pends on the amount and timing of expected future cash flows, and on the
initial cost of the asset. The systematic risk measure depends on the degree
to which the asset return co-varies with the average return on all assets.
(i.e. with the economy as a whole). More precisely, β is defined by:

$$\beta_i = \frac{\text{Covariance } (r_i, r_M)}{\text{Variance } (r_M)} \qquad (1.)$$

Where the subscript i denotes a particular asset and the subscript M de-
notes the market average.

The two different techniques commonly used to evaluate β are referred
to as the fundamental and the technical methods respectively. The funda-
mental method is based on the following definitions:

$$\text{Covariance } (R_i, R_m) = \sum_n P_n \times (R_{in} - \bar{R}_i) \times (R_{mn} - \bar{R}_m)$$

$$\text{Variance } (R_m) = \sum_n P_n \times (R_{mn} - \bar{R}_m)^2 \qquad (2.)$$

Where n denotes a possible state of the economy, P_n denotes the estimated
probability of that state eventuating, R_{in} denotes the estimated rate of re-
turn on asset i in economic state n and R_{mn} denotes the estimated market aver-
age rate of return in economic state n.

The technical method for evaluating β is based on the fact that the def-
inition of β_i as given by Equation 1 is also the formula for the coefficient
of a simple regression. Thus β_i can be calculated from a regression of past

values of r_i on past values of r_m. The above formulation is referred to as the Market Model and the underlying regression equation takes the form:

$$R_i = \alpha_i + \beta_i R_m + e_i, \tag{3.}$$

where α_i is the regression intercept term, and e_i is a stochastic error term.

The data set used spanned the interval from January 1968 to December 1977. The composite market and composite utilities' index rates of return were calculated from the respective Standard and Poor's monthly-average price and yield indices. The rates of return for individual utilities were based on published common stock price and dividend data. In the case of individual stocks, the monthly returns was calculated by adding the monthly price change gain to the monthly dividend return. The above relations can be expressed as:

$$r_i(t) = d_i(t)/12 + \frac{P_i(t+1) - P_i(t)}{P_i(t)} \tag{4.}$$

Where $d_i(t)$ is the yearly average dividend yield of stock i, $P_i(t)$ is the average price of stock.

The computations were carried out using 60 month sub-blocks of data with the first sub-block spanning the interval from January 1968 to December 1972 and subsequent sub-blocks spanning 60 month intervals commencing with February 1968, March 1968, etc. The calculations of β for each asset i were therefore performed on 61 sub blocks in all. The results of these calculations appear in Figures A1 through A4.
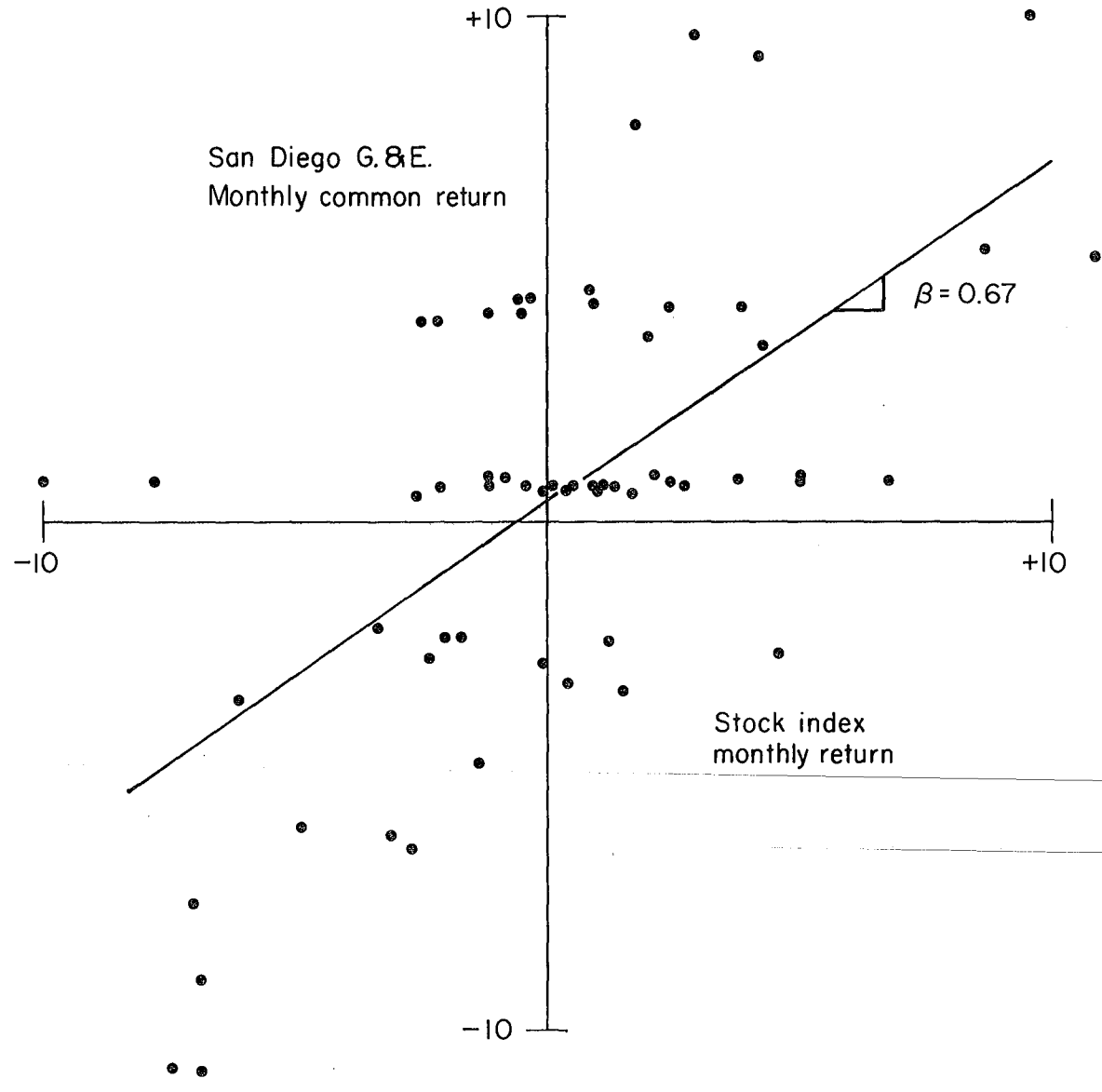
A1

Variation of Beta Over Time (60 month intervals)

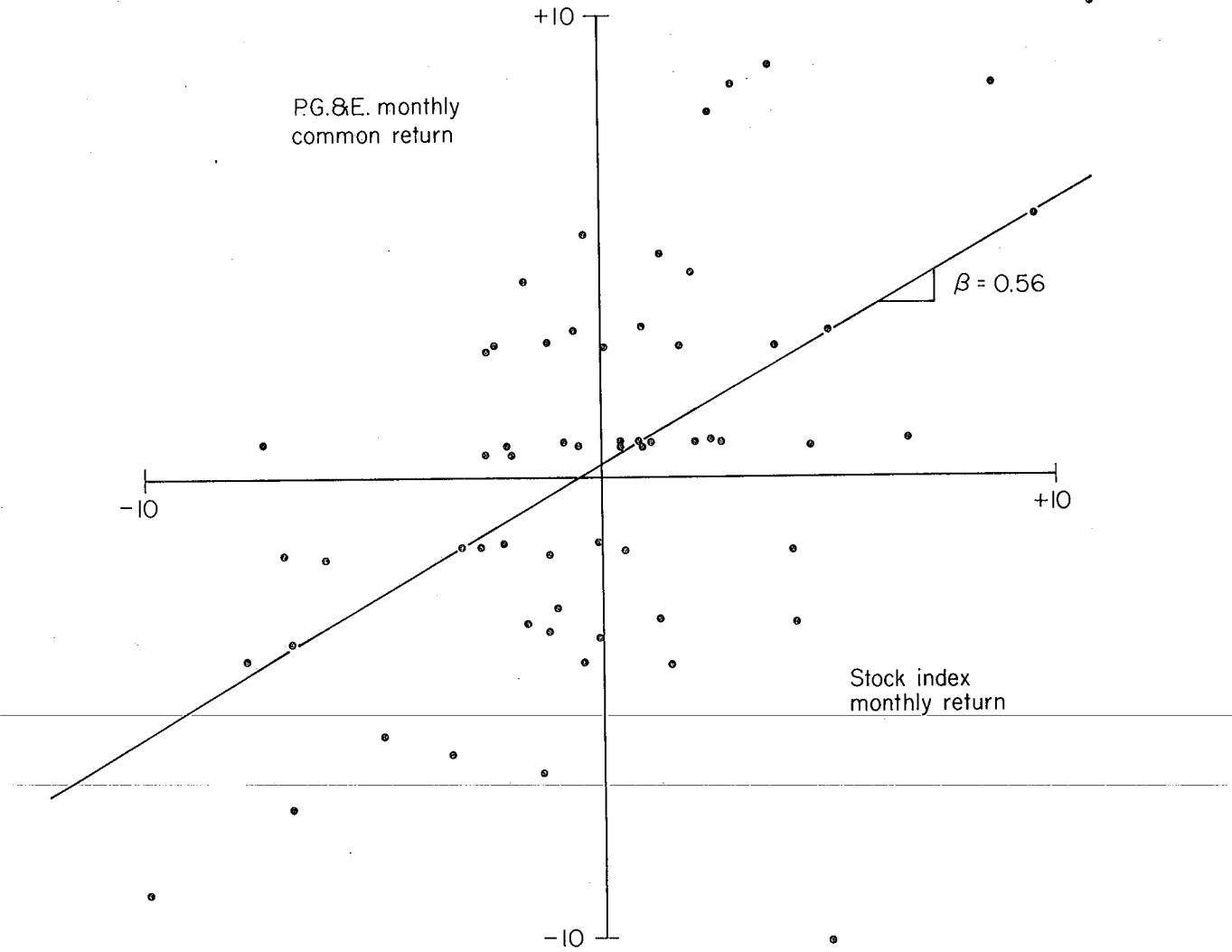
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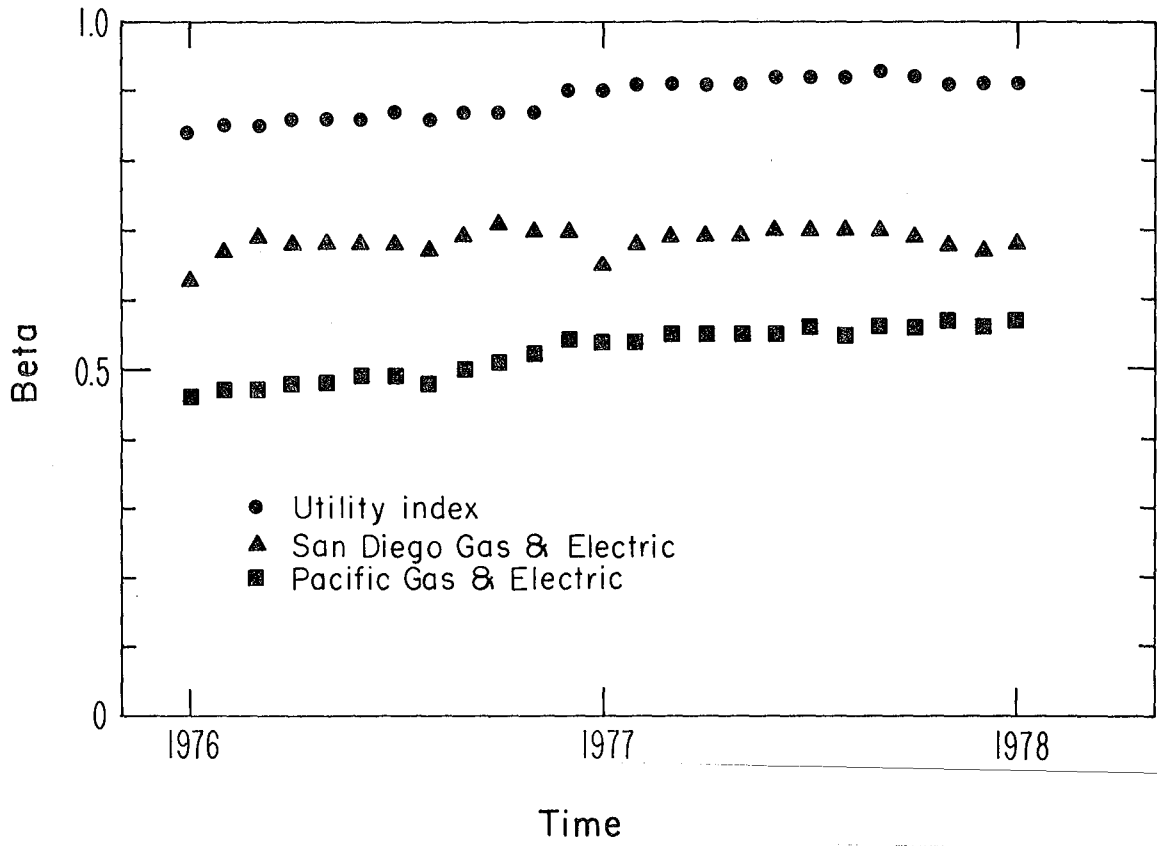
A2

Beta for Standard and Poor's Utility Index

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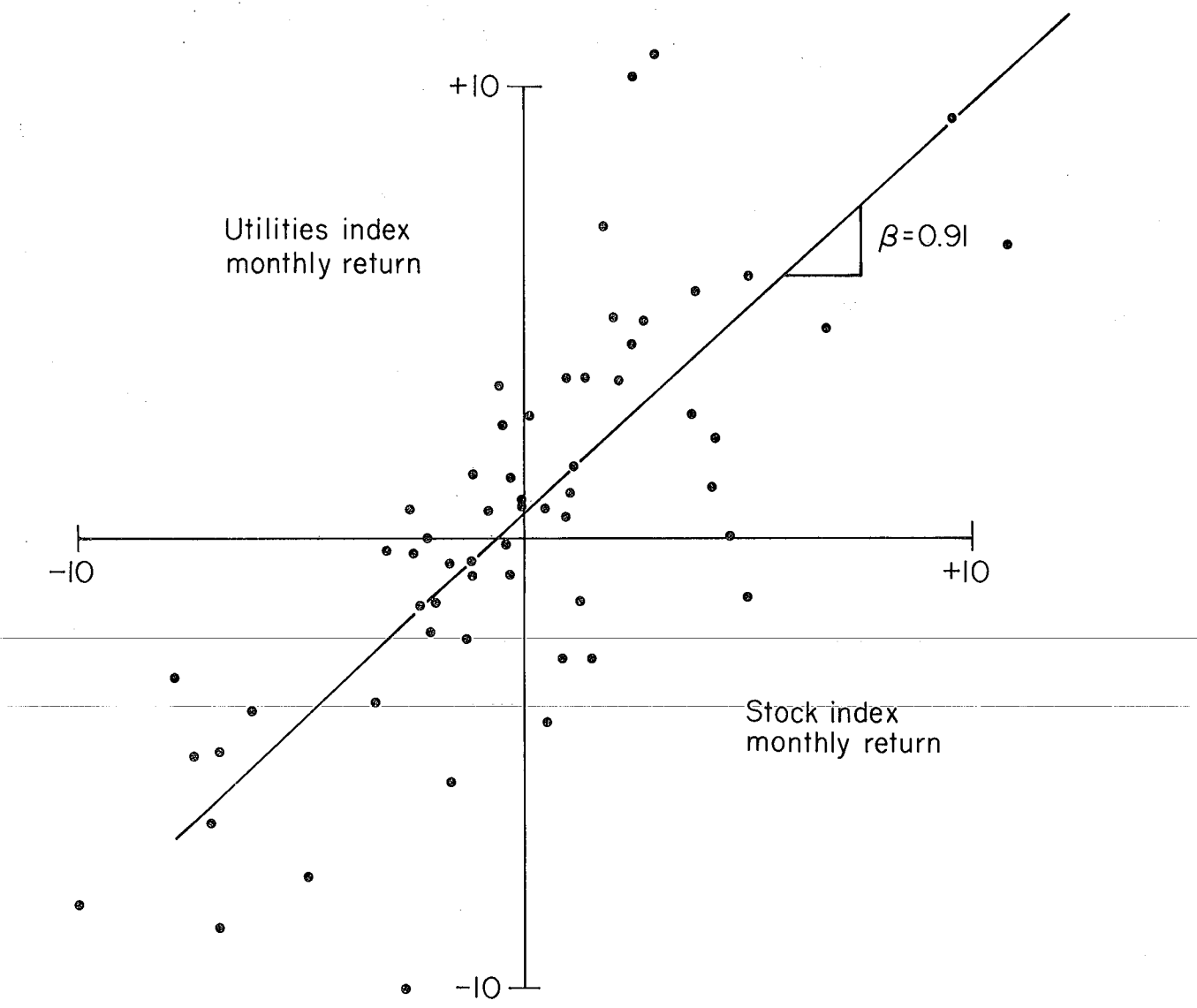
A3

San Diego Gas & Electric Co. Beta

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A4

Pacific Gas & Electric Co. Beta

XBL 789-2679

APPENDIX 4

The Stability of Technical β

As discussed in Appendix 3, the β's used in this study were calculated from regressions, using historical data, of the assets' rate of return on the market rate of return. In effect, historical data were used as a sample from which sample β's were calculated. As with all statistical estimations, the precision with which the sample estimator reflects the true parameter (in this case β) improves with increasing sample size. On the other hand, increasing the sample size, in this case, means using data from future into the past. Thus the sample size must be large enough to give a meaningful estimate of β but not extend so far back into the past that the results reflect past rather than current values of β.
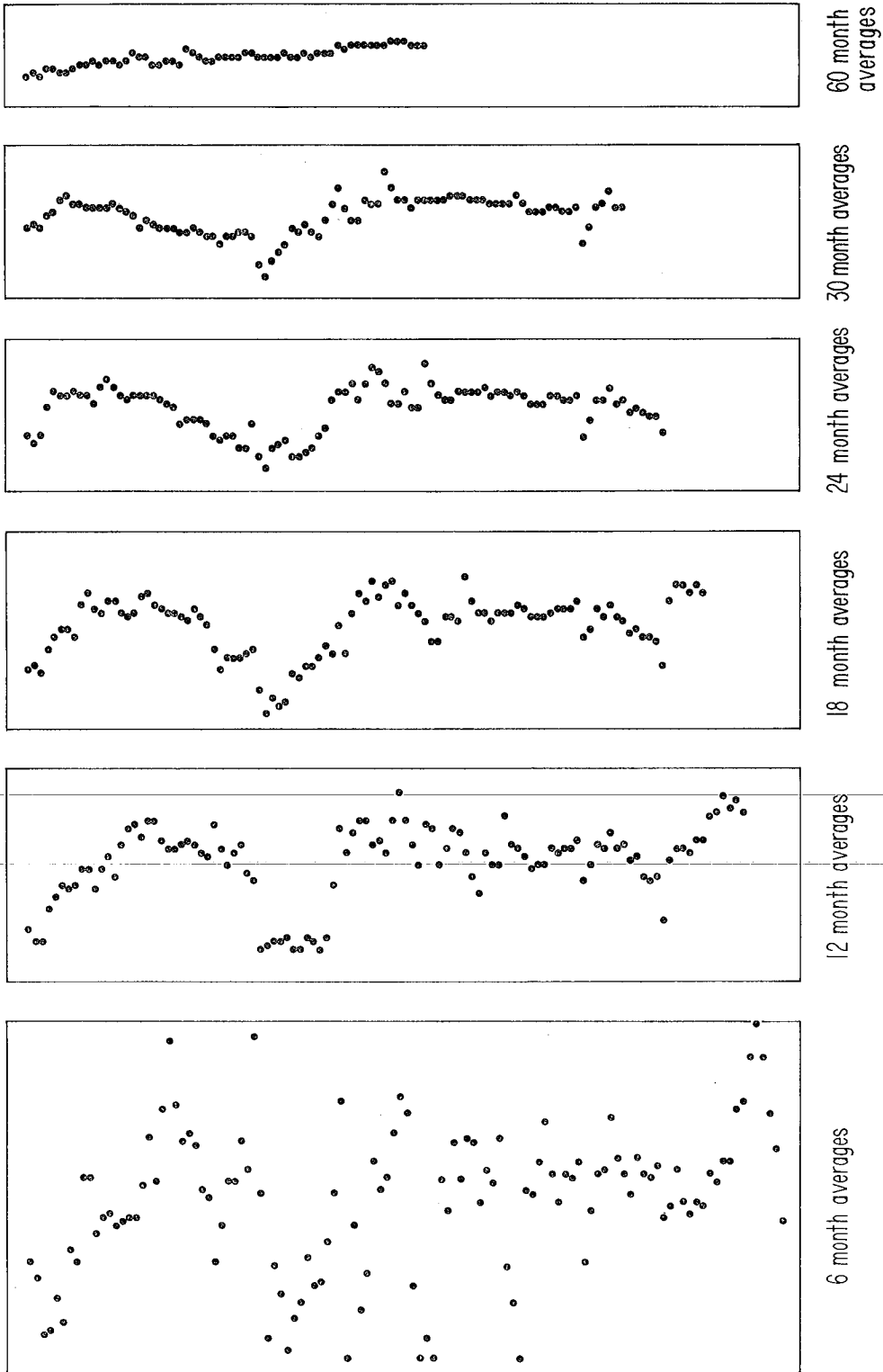
Thus, choosing the appropriate sample size involves a tradeoff between statistical precision and temporal accuracy. In this study β's were calculated from sample intervals of 6 months, 12 months, 18 months, 24 months, 30 months and 60 months. Figures A5 and A6 show the values of β calculated for Pacific Gas and Electric Company common stock and for the Standard and Poor's 40 stock utilities index using differing sample intervals.

From the data it is clear that increasing the size of the sample interval reduces the statistical scatter in the calculated values of β. It would also appear that the underlying values of β did change significantly over the 10 year interval spanned by the data set. Thus, the appropriate length of the sample interval must be chosen with the above trade off in mind.

For the purposes of this study it was decided that a 60 month sample interval would be appropriate. This is also the sample interval used by Whitcomb (1978). Figures A5 and A6 show that for this sample interval the statistical scatter in the data is small compared to the numerical values of β. The figures also show that there is less statistical scatter when using the utilities index data than in the individual securities' data. This is due to the fact that fluctuations present in individual data points tend to be smoothed out when individual securities data are combined into an index.
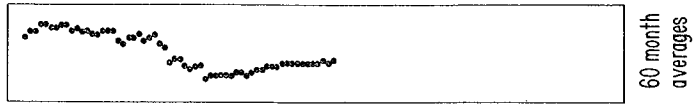
A5
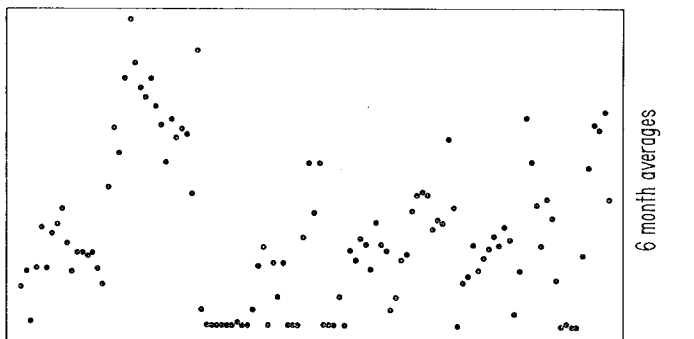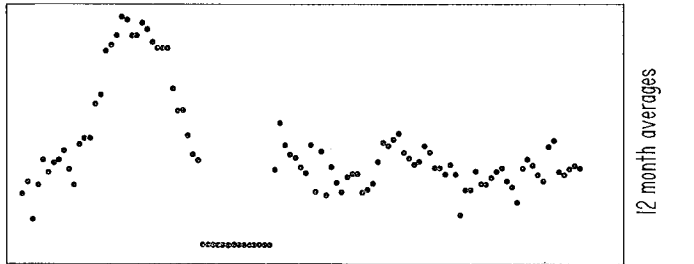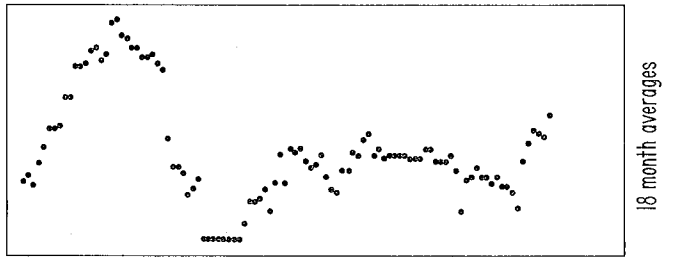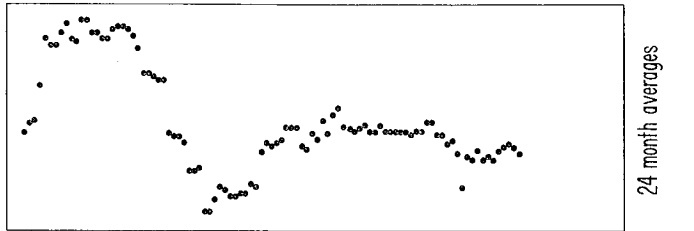Beta Scatter as a Function ofAveraging Interval: Utilities Index

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A6

Beta Scatter as a Function of Averaging Interval: Pacific Gas & Electric

60 month averages

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30 month averages

24 month averages

18 month averages

12 month averages

6 month averages
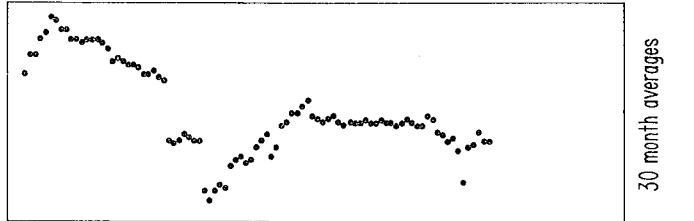
APPENDIX 5

Determination of β for On Site Solar Heating

Of the two techniques discussed in Appendix 3 for determining the β of a capital asset, only the fundamental technique can be applied directly to new capital investments. The technical method can, however, be applied indirectly to estimate the β of new capital projects. This is accomplished by identifying existing capital assets having risk characteristics similar to those expected in the new capital investment. In effect one estimates the β of a new investment by using the technical β of existing assets having similar risk properties as proxies for the new project beta.

As discussed in the text, the excess capacity risk associated with On Site Solar Heating could be expected to be small and would result almost exclusively from housing units, for which the investment in On Site Solar Heating Systems was made, going unoccupied. To determine the magnitude of this risk, a regression of housing occupancy rates on the Standard and Poor's 500 composite stock index rates of return was performed. The vacancy rates used in the regression were the quarterly vacancy rates for rental units for the western United States published by the Department of Housing and Urban Development. The results of the analysis are reproduced in Figure A7, and indicate that, to any reasonable confidence level, the regression coefficient of occupancy rate on market rate of return is zero. Therefore, while the amount of unused capacity will certainly not be zero, it should not vary in a systematic way with the market. Thus, excess capacity risk would affect the expected rates of return of On Site Solar Heating systems, but would not contribute to the systematic risk, β.

The major market risk in the On Site Solar Heating investment results from the long term nature of the investment. Whenever a long term investment is undertaken there is always the risk that better uses for that capital will be found in the future. This is evidenced by the fact that long term interest rates, even for riskless government securities, are higher than short term interest rates.

In order to determine the value of β that reflects this long term interest rate associated with the On Site Solar Heating investment, the Standard and Poor's High Grade Corporate Bond Index was selected as a reasonable proxy. The bonds rates of return is given by:

$$R(t) = \frac{d^*(t)}{12} + \frac{P^*(t+1) - P^*(t)}{P^*(t)} \quad (5)$$

Where $d^*(t)$ is the virtual dividend yield assuming a four percent coupon rate, $P^*(t)$ is the conversion price of the bond index at time t. The conversion price is the price of a hypothetical four percent coupon, twenty years to maturity of a bond that would have the same yield to maturity as the Standard and Poor's sample. The results of the regression of bond index rates of re-return on market rates of return are given in Figure A8.

We have chosen this regression to represent the long-term interest rate risk because it is the latest value calculated over the five-year averaging interval. The choice of this averaging interval is consistent with out other regression estimates for beta's. Nonetheless, as Appendix 4 indicates the scatter of beta estimates varies considerably with the averaging interval used. To put the value β - 0.14 in some perspective we will reproduce in Table A5-1 below some other regression estimates of the corporate bond index beta as a function of averaging interval. These data show the same phenomena we have seen in Appendix 4. As the averaging interval decreases, the range of variation grows in the estimated value as do the standard errors. It should also be noted that the latest value estimated shows considerable variation. Thus, while it is not obvious which of the many values to rely on, at least for the longer averaging intervals the average of high and low estimates is consistent with the adopted value of β = 0.14. Some kind of "average of the averages" is the appropriate choice for a project beta estimate. Still the data are not wholly inconsistent with solar beta estimates of even twice our adopted value. This change would not alter our qualitative conclusion that on-site solar risks are low for utility investment, but it might increase the estimated finance charge to as much as 9.5%.

A7

Housing Occupancy Rate Regressed on
Stock Market Index Rate of Return

11A

INDBAR	VACBAR	ALPHA	BETA	SE
6,67282	94,21111	94,19754	,00203	,00752
6,92655	94,24443	94,23283	,00168	,00694
7,59393	94,32778	94,30383	,00315	,00520
5,23099	94,32222	94,29611	,00498	,00497
4,69761	94,27222	94,24171	,00650	,00553
5,68975	94,25556	94,22211	,00588	,00562
4,29382	94,28889	94,27137	,00408	,00512
3,32049	94,26667	94,25171	,00450	,00515
2,19909	94,15000	94,13209	,00814	,00457
-,35932	94,11667	94,11935	,00746	,00404
3,47695	94,10000	94,06690	,00952	,00388
0,63731	94,04444	94,01540	,00626	,00366
4,31896	93,97222	93,95519	,00394	,00396
1,31375	93,87778	93,87382	,00301	,00412
4,33125	93,88333	93,86187	,00496	,00393
5,86060	93,92778	93,89628	,00536	,00398
4,98741	93,90556	93,88287	,00455	,00385
3,39017	93,90000	93,88814	,00350	,00389
4,20243	93,93333	93,91644	,00402	,00418
2,73937	94,06111	94,05335	,00283	,00493
1,34830	94,08333	94,07880	,00336	,00505
1,54571	94,12778	94,12418	,00233	,00511
2,58903	94,27222	94,26806	,00161	,00532

A8

Bond Index Rate of Return Regressed on Stock Market
Index Rate of Return
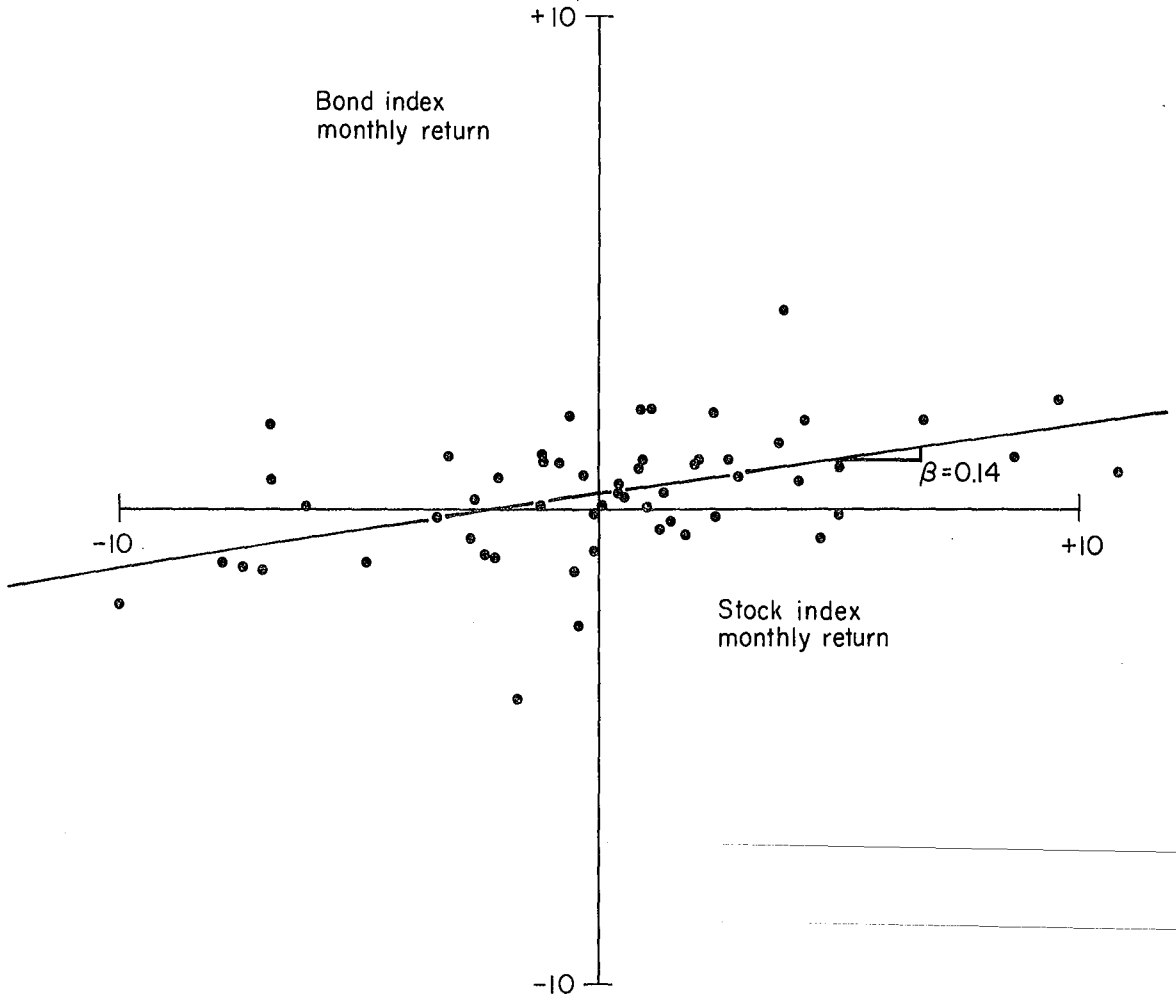
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Table A5-1

High Grade Corporate Bond Index Beta - Range of Variation
as a Function of Averaging Interval

5 year Sliding Average

    High   =   0.223 $\pm$ 0.054

                                Final = 0.145 $\pm$ 0.036

    Low   =   0.107 $\pm$ 0.030

2.5 year Sliding Average

    High = 0.304 $\pm$ 0.066

                                  Final = 0.231 $\pm$ 0.071

    Low   = 0.008 $\pm$ 0.059

2 year Sliding Average

    High = 0.342 $\pm$ 0.071

                                  Final = 0.337 $\pm$ 0.138

    Low = 0.025 $\pm$ 0.071

1.5 year Sliding Average

    High = 0.432 $\pm$ 0.158

                                  Final = 0.432 $\pm$ 0.158

    Low =-0.083 $\pm$ 0.091

1 year Sliding Average

    High = 0.621 $\pm$ 0.174

                                  Final = 0.252 $\pm$ 0.209

    Low =-0.132 $\pm$ 0.140

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