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Author
Schutz, Stephen Richard

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Stephen Richard Schutz

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RESIDENTIAL ON SITE SOLAR HEATING SYSTEMS: A PROJECT EVALUATION USING THE CAPITAL ASSET PRICING MODEL

by

Stephen Richard Schutz

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Stephen Richard Schutz

Energy and Environment Division
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

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ABSTRACT

One of the major problems currently facing the United States is the high cost of energy. The importation of oil is causing a serious balance of payments problem which has led to a weakening of the U.S. dollar in overseas money markets. The escalation in energy costs has also contributed to inflation and inhibited economic growth. For these reasons it would be highly desirable for the United States to develop alternative, domestic energy sources.

One such energy source ready for immediate use on a commercial scale is solar energy in the form of On Site Solar Heating (OSSH) systems. These systems collect solar energy with rooftop panels, store excess energy in water storage tanks and can, in certain circumstances, provide 100% of the space heating and hot water required by the occupants of the residential or commercial structure on which the system is located. Such systems would take advantage of a free and inexhaustible energy source — sunlight.

The principal drawback of such systems is the high initial capital cost. The solution would normally be a carefully worked out corporate financing plan. However, at the moment it is individual homeowners and not corporations who are attempting to finance these systems. As a result, the terms of finance are excessively stringent and constitute the main obstacle to the large scale market penetration of OSSH.

This study analyzes the feasibility of OSSH as a private utility investment. Such systems would be installed and owned by private utilities and would displace other investment projects, principally electric generating plants. The return on OSSH is calculated on the basis of the cost to the consumer of the equivalent amount of electrical energy that is displaced by the OSSH system. The hurdle rate for investment in OSSH is calculated using the Sharpe-Lintner Capital Asset Pricing Model.

The results of this study indicate that OSSH is a low risk investment having an appropriate hurdle rate of 7.9%. At this rate, OSSH investment appears marginally acceptable in Northern California and unambiguously acceptable in Southern California. The results also suggest that utility investment in OSSH should lead to a higher degree of financial leverage for utility companies without a concurrent deterioration in the risk class of utility equity.

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INTRODUCTION

The energy crisis, ushered in by the 1973 Arab embargo, has become one of the most serious problems facing American business and the American economy. The rapidly increasing price of energy since 1973 has been an important cause of the recent inflationary spiral. Heavy dependence on imported oil has also resulted in serious economic and political problems for the United States. Therefore, it is universally recognized that a high priority must be given to the development of alternative, domestically available, energy sources.

Of all potential new energy sources, solar energy is perhaps the most attractive. Among the principal attractions of solar energy are the fact that it is essentially a limitless source of energy (based on present world-wide energy consumption levels), it is freely available domestically, it is environmentally benign, and the necessary technology for its utilization already exists. The principal disincentive mitigating against the use of solar energy is the fact that the existing technology requires a relatively large capital investment per installed British Thermal Unit (btu) of capacity. As a result, the main obstacle to the rapid substitution of solar-generated energy for fossil-fuel-generated energy is financial.

Of the many solar energy technologies currently available, the one most ready for immediate large scale implementation is On Site Solar Heating (OSSH). Experimental OSSH systems are already in use in certain areas of the country; but the total number of OSSH systems in operation and their total energy contribution is not yet significant.

Briefly, an OSSH system consists of an area of solar heat collector panels mounted on the roof of a home or building, a water storage tank, and a system of pipes and pumps to transfer the heat captured by the collector panels to the storage tank. Such systems can supply hot water or both hot water and space heating to a home or building. The schematic of such an OSSH system is shown in Fig. 1.

In order to provide space heating rather than just hot water heating, the OSSH systems must of necessity be larger and more complex. Because of the technological problems associated with larger and more complex systems, the engineering economics appear less favorable for the large OSSH hot water and space heating systems than for the smaller OSSH hot water only systems. For that reason, this report will deal solely with the smaller OSSH hot water only systems. It should be noted that were such systems to achieve an 80% market penetration, the daily energy savings, based on present residential hot water use, would be equivalent to roughly one million barrels of oil daily, or about 5% of present daily energy consumption.

The principal obstacle to the proliferation of OSSH systems is financial. For a system capable of providing 80% of the hot water needs for a family of three, the initial equipment and installation costs would be on the order of $1,500. In the current market, the initiative for the installation and ownership of OSSH systems must be taken by a homeowner who will typically seek to borrow the necessary capital from a bank or similar financial institution. In this financial transaction, as in all other financial transactions, the question of which risks shall be borne by whom and for what price must be addressed.

In the case of OSSH systems as in the case of swimming pools and other home improvements, repossession in the event of default is not feasible. Therefore a bank or other financial institution, in order to reduce the risks of default, would probably be willing to finance OSSH only through a second mortgage. The homeowner, on the other hand, would probably not wish to risk losing a home in order to finance OSSH and would probably attempt to secure such loans with less valuable assets. In the first case, where a bank loan is secured through a second mortgage, financing for OSSH could probably be obtained at interest rates only slightly higher than first mortgage rates. In the second case, where a loan is unsecured or secured with an asset less valuable than a home, financing for OSSH would probably carry an interest rate on the order of 15% to 20% if available at all.

Thus, in the current market, the cost of capital for OSSH depends on the type of asset a homeowner is willing to use to secure financing rather than on the characteristics of OSSH itself. In this report the risk/return characteristics of OSSH will be analyzed and, through the use of the Capital Asset Pricing Model (CAPM), an appropriate cost of capital for OSSH will be estimated. It will also be shown that this cost of capital and the accmpanying financing arrangements would be more acceptable to all parties concerned than any of the financing schemes currently available, thus promoting the market penetration of OSSH and its associated energy savings.

DISCUSSION OF CAPM

The Capital Asset Pricing Model as developed by Sharpe [1964], Lintner [1965] and others is an outgrowth of Portfolio theory as developed by Markowitz [1952], Tobin [1958] and others. Portfolio theory deals with the selection of individual assets to form portfolios which have, in a particular sense, optimal risk and expected return characteristics.

The starting point of Portfolio theory is usually taken to be the following set of equations:

$$(1) \qquad E(R_p) = \sum_{i=1}^{n} x_i \, E(R_i)$$

$$(2) \qquad Var(R_p) = \sum_{i=1}^{n} \sum_{j=1}^{n} x_i x_j \, C_{ij}$$

where $E(R_p)$ is the expected rate of return on the portfolio, x_i is the proportion of the portfolio held in security i, R_i is the rate of return on security i, $Var(R_p)$ is the variance of the portfolio rate of return, and C_{ij} is the covariance of the rates of return of securities i and j. A high expected return, of course, makes a portfolio more desirable. Likewise, a high variance makes a portfolio less desirable. Variance is frequently used as a measure of risk because a high variance indicates a large probability of actual return being lower than expected return. The fact that a high variance also indicates a large probability of actual return being higher than expected return does not adequately compensate for the downside risk.

Equation (1) and Eq. (2) indicate that for every portfolio there is a unique value of expected return and variance. Thus every portfolio can be represented as a point on a two-dimensional graph of expected portfolio return versus portfolio variance. Figure 2 is such a graph. Each dot in the figure represents the Standard Deviation/Expected Return or Risk/Expected Return characteristics of some particular portfolio or portfolios of risky assets. The curve AB in Fig. 2 is the efficient frontier of the set of feasible portfolios. It can be shown that this curve must be convex upward [Sharpe, 1970] and that it delineates the locus of points representing portfolios having the largest expected return for a given variance or, equivalently, the lowest variance for a given expected return.

In addition to risky assets, there are also riskless assets. Such assets can be represented by points along the vertical axis in a Standard Deviation/Expected Return plot. All riskless assets, however, would have to have the same expected return. If this were not true, market pressures would cause price adjustments until all riskless assets did have the same expected return. In Fig. 2 the risk/return characteristics of all riskless assets are represented by a single point on the vertical axis, R_f units above the origin.

Examination of Eq. (1) and (2) reveals that portfolios containing both riskless and risky assets have a particularly simple representation on Risk/Return graphs, such as pictured in Fig. 2. In the case of a portfolio consisting of one riskless asset and one risky asset where the proportion of the riskless assets in the portfolio is given by x_2, it is clear that x_2 is equal to $(1 - x_1)$. Thus the expected rate of return on such a portfolio is given by

(3) $$E(R_p) = x_1 R_F + (1 - x_1)\, E(R_r)$$

where $E(R_r)$ is the expected rate of return on the risky asset. The variance of the portfolio rate of return is given by

(4) $$Var(R_p) = (1 - x_1)^2\, C_{22}$$

Combining Eqs. (3) and (4), noting that standard deviation is defined as the square root of the variance, yields

(5) $$E(R_p) = R_F + \sigma_p \frac{E(R_r) - R_f}{\sqrt{C_{22}}}$$

where σ_p is the standard deviation of the rate of return on the portfolio.

Thus $E(R_p)$ is a linear function of σ_p. For σ_p equal to zero (a portfolio consisting solely of a riskless asset), the expected return is equal to R_F. For σ_p equal to the square root of C_{22} (a portfolio consisting solely of the risky asset), the expected return is equal to R_r. Thus, in the representation of Fig. 2, the locus of feasible portfolios is the set of rays extending from the representation of the riskless asset to the representations of each of the risky assets.

It is also clear that these rays can be extended indefinitely by investing a negative amount in the riskless asset (borrowing at the risk-free rate) or by investing a negative amount in the risky asset (selling short). In addition, the above analysis can be generalized by thinking of a portfolio of risky assets as a single risky asset and replacing $E(R_r)$ by the expected portfolio return $E(R_m)$, and $\sqrt{C_{22}}$ by the expected portfolio standard deviation, σ_m. Thus, by allowing portfolios to include riskless assets the efficient frontier becomes a straight line extending from the representation of the riskless asset and which is tangent to the original efficient frontier of portfolios consisting solely of risky assets. This ray is known as the Capital Market Line (CML) and the above geometry is shown in Fig. 2. Two critical properties of the CML are, 1) that no feasible portfolios can have risk/return characteristics that would plot above the CML, and 2) that the CML is a straight line.

From the above analysis it is clear that all investors strive to assemble portfolios that plot along the CML because, in terms of risk and return, it is not possible to achieve performance that exceeds this level. It is also clear that portfolios which plot along the CML all include the same relative proportions of the risky assets and differ only in the relative amounts of risky and riskless assets [Sharpe, 1970]. This portfolio is usually referred to as the Market Portfolio and has an expected return of $E(R_m)$ and a standard deviation of σ_m.

The properties of the CML discussed above in fact allows for the valuation of individual capital assets. The essential point of the analysis is illustrated in Fig. 3. Point M depicts the expected return/standard deviation characteristics of the market portfolio. Were a new security to be introduced into the market and were an infinitesimal amount of this new security added to the market portfolio by risky assets, the expected return/standard deviation characteristics of this portfolio would not change detectably. Were more and more of the new security added to the market portfolio, the representation of the new market portfolio would depart further and further from point M in Fig. 3. The curved lines passing through point M in Fig. 3 depict possible locii of points representing the new market portfolio. All such locii must pass through point M because a new market portfolio containing an infinitesimal amount of the new security would be essentially identical to the original market portfolio.

It should be noted, however, that the curves passing through points A and C contradict the principle that no portfolio having a risk/return representation superior to the CML can be assembled. Thus only the curve passing through point B, the curve that is tangent to the CML at point M, represents feasible risk/return characteristics. Stated quantitatively, at point M the curves have equal slopes.

The slope of the CML is constant and given by:

(6) $$S_{CML} = \frac{E(R_m) - R_f}{\sigma_m}$$ [Sharpe, 1970]

The slope of the locus curve at point M is given by:

(7) $$S_{LC} = \frac{[E(R_i) - E(R_m)]\sigma_m}{C_{im} - \sigma_m^2}$$ [Sharpe, 1970]

where $E(R_i)$ is the expected return on the new security, and C_{im} is the covariance between the new security rate of return and the market rate of return. Equations S_{CML} and S_{LC} yield

(8) $$E(R_i) - R_f = \left[\frac{E(R_m) - R_f}{\sigma_m^2}\right] C_{im}$$ [Sharpe, 1970]

Equation (8) is the Capital Asset Pricing Model (CAPM) and expresses the expected return on a security in terms of market parameters and the covariance of the security return with the market. Equation (8) can be rewritten as

$$E(R_i) = R_f + MPR \times b_i \tag{9}$$

where MPR, the market price of risk, is equal to $[E(R_m) - R_f]$ and b_i, sometimes referred to as the volatility, is equal to $[C_{im}/\sigma_m^2]$.

While Eq. (9) is amenable to numerical analysis, it does involve the quantity C_{im}, the covariance of the rate of return of security i with the rate of return on the market portfolio. Since the market portfolio is composed of thousands of securities, each of which will, in all likelihood, have a different correlation with security i, calculation of C_{im} would involve computing a weighted average of all of the thousands of relevant correlation coefficients.

A technique for greatly reducing the computational effort was developed by Sharpe [1963]. Essentially the market portfolio is treated as a single security. The advantage of this technique is the fact that rather than calculating thousands of correlation coefficients it is only necessary to calculate a single covariance. The disadvantage of this technique is accuracy. Empirical studies [Sharpe, 1963], however, suggest that the loss of accuracy is not severe.

Using the Sharpe [1963] model, the rate of return on an asset is given by

$$R_i = \alpha_i + \beta_i R_m + e_i \tag{10}$$

where α_i and β_i are simply regression coefficients, R_m is the rate of return on the market portfolio, and e_i is an error term. It can be shown that under the assumptions of the model, the regression coefficient β_i is equivalent to the quantity b_i in Eq. (9).

Thus it has been shown that in a market where investors are allowed to hold both risky and riskless securities, investors will seek to assemble efficient portfolios whose risk/return characteristics plot along a straight line. It has been further shown that to the holder of such an efficient portfolio, the value of a new asset is given by Eq. (9) where the parameter describing risk, b_i, can be estimated by the simple regression indicated by Eq. (10). Finally, it can be shown that in an efficient market, demand and supply pressures will cause the prices of individual securities to adjust in such a way as to maintain the relationship between risk and return as given by Eq. (9).

APPLICATION OF CAPM TO OSSH

The CAPM can be used in principle to evaluate any capital asset, although it is most commonly used to evaluate securities. The properties of securities are by and large independent of the properties of the holder. In the case of physical assets, however, the risk/return properties of an asset may in fact be a function of the properties of the holder. For example, a gasoline station owned by a vertically integrated oil company has different risk/return characteristics than an independently owned service station.

In the case of OSSH it is typically taken for granted that such systems are to be purchased by the owner of the home or building on which the system is to be installed. As was pointed out earlier, however, investment in OSSH by a homeowner is inefficient. This is essentially because the financial risks of the investment must be borne wholly by either the homeowner or the financial institution. There are ways, however, to diversify the financial risks of OSSH investment, thus permitting the financing of OSSH at lower cost. One such way to achieve this result would be to have private utility companies install and retain ownership of OSSH systems.

In the above scenario, OSSH systems are viewed as capital assets; much the same as coal-fired electrical generating plants, financed and owned by private utilities. Utility ownership of OSSH systems would effectively diversify the financial risks associated with individual systems and would permit more efficient and lower cost financing. This in itself, however, does not necessarily imply that utility companies should embark on such an investment program. Rather, it implies that OSSH is a better investment for utility companies than it is for individual homeowners. In this study the question of whether OSSH can be a sound investment for a private utility will be examined.

The evaluation of an investment, in the framework of the CAPM begins with Eq. (9). Equation (9) allows for the valuation of an individual security in terms of market parameters. It also, however, allows for the evaluation of an investment made by a firm. This is demonstrated by the following analysis.

Let the current risk and return parameters of a firm be β_c and R_c respectively. Equation (9) implies:

$$E(R_c) - R_f = MPR \times \beta_c \tag{11}$$

Assume that after making a capital investment those parameters of the firm become $\beta_{c'}$ and $R_{c'}$ respectively. If this investment did indeed have a favorable impact on the firm then it can be shown that

$$\frac{E(R_{c'}) - R_f}{\beta_{c'}} > \frac{E(R_c) - R_f}{\beta_c} \tag{12}$$

If the above inequality were to hold then demand for stock in the firm would increase, thus forcing up the price per share.

The parameters $R_{c'}$ and $\beta_{c'}$ can be rewritten as:

$$R_{c'} = R_c\left(\frac{C_c}{C_c + I}\right) + R_I\left(\frac{I}{C_c + I}\right) \tag{13}$$

where C_c is the initial equity of the firm, I is the additional equity used to finance the capital investment, and R_I is the net rate of return on the investment. Likewise:

$$(14) \qquad \beta_{c'} = \frac{\mathrm{Cov}\left\{\left[\left(\frac{C_c}{C_c+I}\right) R_c + \left(\frac{I}{C_c+I}\right) R_I\right], \left[\left(\frac{C_m}{C_m+I}\right) R_m + \left(\frac{I}{C_m+I}\right) R_I\right]\right\}}{\mathrm{Var}\left\{\left(\frac{C_m}{C_m+I}\right) R_m + \left(\frac{I}{C_m+I}\right) R_I\right\}}$$

where C_m is the total equity in the market, and R_m is the rate of return on the market porfolio.

The numerator of Eq. (14) can be broken into four terms. The first term contains a factor on the order of $C_c/(C_c + I)$ which for most firms and most investments is on the order of 0.9. The second term has a factor on the order of $I/(C_c + I)$ which should be on the order of 0.1. The third term contains a factor on the order of I/C_m which would be essentially zero. The fourth term contains a factor on the order of I^2/C_cC_m which is even smaller. Therefore in most situations it is reasonable to ignore these last two terms.

Applying a similar analysis to the denominator of Eq. (14) yields the following approximation for Eq. (14):

$$(15) \qquad \beta_{c'} \approx \left(\frac{C_c}{C_c + I}\right) \beta_c + \left(\frac{I}{C_c + I}\right) \beta_I$$

Substitution of Eq. (15) and Eq. (13) into Eq. (12) yields:

$$(16) \qquad \left\{ \frac{\left(\frac{C_c}{C_c+I}\right) E(R_c) + \left(\frac{I}{C_c+I}\right) E(R_I) - R_f}{\left(\frac{C_c}{C_c+I}\right) \beta_c + \left(\frac{I}{C_c+I}\right) \beta_I} \right\} > \frac{E(R_c) - R_f}{\beta_c}$$

Equation (16) can then be simplified and expressed as

$$E(R_I) - R_f > MPR \times \beta_I \tag{17}$$

The foregoing analysis demonstrates the equivalence of Eq. (17), Eq. (12), and an increase in value of the shares of a company. Thus, if the goal of management is to increase the price per share of corporate stock, then the CAPM provides a project evaluation criterion in the form of Eq. (17).

The CAPM is quite general and before it may be applied to specific cases, an appropriate framework must be selected. For example, as mentioned previously, the CAPM is most commonly used in the evaluation of corporate common stocks. In such an application the appropriate market portfolio would be the set of all corporate common stocks. However, there are many other securities available to the investor; examples of which are corporate bonds, gold and Persian rugs. It will be shown that the MPR and the value of β for individual securities is a function of the framework in which the CAPM is applied.

In most applications of the CAPM to corporate stock, a market index such as the Standard and Poor's price index of 500 stocks is used as a surrogate for the market portfolio of all corporate stocks. Let us treat this index of common stocks as a single security and evaluate it, using the CAPM, with respect to an arbitrary and broader set of securities such as suggested above. This implies

$$E(R_{ind}) - R_f = MPR \times \beta_{ind} \tag{18}$$

where R_{ind} is the rate of return on the stock index and β_{ind} is the volatility of the index with respect to the broader market portfolio.

Now consider an individual security having return R_i and volatility β_i. This implies

$$(19) \qquad E(R_i) - R_f = MPR \times \beta_i$$

If, however, the volatility of security i is referred to the index rather than to the broader market portfolio, then:

$$(20) \qquad \beta_i' \equiv \frac{Cov(R_i, R_{ind})}{Var(R_{ind})}$$

which implies

$$(21) \qquad \beta_i' = \frac{\beta_i}{\beta_{ind}}$$

and this

$$(22) \qquad E(R_i) - R_f = [E(R_{ind}) - R_f] \times \beta_i'$$

Equation (22) demonstrates the important fact that a security may be evaluated within the framework of any arbitrary set of risky assets. In the present analysis the framework used is the set of corporate common stocks whose return characteristics are closely approximated by the Standard & Poor 500 stock index.

Equation (17) indicates that the key to project evaluation is an estimate of the rate of return on investment and an estimate of β_I. In this study, published engineering economics data for OSSH will be used to calculate the Internal Rate of Return (IRR) for OSSH. These calculations yield $E(R_i)$ of Eq. (17). Estimating β_I for a new project is less straightforward. In this study β_I for OSSH is estimated by taking β_c (β for the typical utility company) to be a first order approximation of β_I. This estimate of β_I is then refined by the application of certain assumptions to the question of investment volatility.

The β value of a company is a measure of the volatility of return on the company's total capitalization. Therefore the β value of a company is a weighted average of its β value for long-term debt and its β value for equity. In the case of utility companies, the above calculation is complicated by the fact that utilities also issue preferred stock which is neither debt nor equity. For computational purposes it will be assumed that the typical utility capitalization is one-half debt and one-half common equity. With this assumption the β value of a utility company equals the arithmetic mean of the β value of common equity and the β value of long-term debt.

The β values for debt and for equity can be estimated by regressing their respective rates of return against the Standard & Poor's 500 stock index. The β values so calculated are sometimes referred to as technical β's. When performing a regression analysis to calculate a security's β, two parameters of the analysis must be chosen somewhat arbitrarily. They are, 1) the spacing of the data points, and 2) the time interval of data to be used. The first parameter addresses the question of whether to use hourly, daily, monthly, etc., rates of return for both the security and the index; the second parameter addresses the question of how long a time period should the analysis be carried out. If the second parameter is chosen to be too long, then the analysis will yield an historical average value of β that may have little relevance to its current value. On the other hand, if it is chosen to be too short, the analysis will have a large statistical error, thus giving a very imprecise value for β.

In the present analysis, monthly average rates of return were used and the analyses were carried out over 60-month intervals. These values were chosen for empirical reasons and also because other authors have employed similar parameters [Whitcomb,1978; Smith,1978]. The monthly average rates of return were calculated from the following:

$$R_t = \frac{P_{t+1} - P_t}{P_t} + D_t \qquad (23)$$

where P_t is the average price of the security during the month t and D_t is the dividend or interest yield for month t.

Tests were run to determine the effects of varying the interval of data over which β regressions were performed. The results of those tests for PG&E common stock returns is as shown in Fig. 7 for the Standard & Poor's utility index return in Fig. 8. As can be seen from the figures, increasing the time interval over which β is calculated reduces the (presumably) statistical scatter in the calculated values of β. However, the figures also suggest that the β values can change somewhat over a five year period.

It might also be noted that, as one might expect, there is more scatter and more evidence of temporal change in β for the individual utility stock (PG&E) than for the utility index [Lorie and Hamilton,1973]. Since these calculations of β will be used to estimate β for the OSSH investment, knowing the precise value of β for some particular time period is of secondary importance. Therefore, for the purposes of this study, the reduced statistical scatter present in the 60-month calculations make these values preferable to β values calculated over shorter time frames.

Sample regression analyses for PG&E stocks, SDG&E stock, and for the S&P utility stock index are shown in Figs. 4, 5 and 6, respectively. Each figure shows the monthly common stock return plotted against the return of the Standard & Poor stock index for the 60-month interval of January 1973 through December 1977. Also shown in the figures are the least squares fitted straight lines and their slopes, β. The computer programs for performing these analyses are discussed in Appendix 1. The results of similar regressions using overlapping 60-month intervals of data appear in Tables 1, 2 and 3. These tables indicate β and the standard error of β for 60 intervals, the first of which extends from January 1968 through December 1972, the second of which extends from February 1968 through January 1973, etc. The last 25 calculated β values for PG&E, SDG&E and the Standard & Poor utility index are plotted in Fig. 9. The horizontal axis in the figure indicates the terminations of the 60-month intervals.

The β values for the long-term debt component of utility capitalization was estimated by regressing the return on the Standard & Poor's high-grade bond index against the Standard & Poor's 500 stock index. This procedure was considered appropriate since the major risk factor in high-grade corporate bonds is the risk that increasing interest rates will reduce the market value of the bond. Therefore, utility bonds would be expected to have a volatility or β value comparable to that of other high-grade corporate bonds. The use of a bond index also reduces statistical uncertainties. The results of these regressions are given in Table 4. These results suggest that the β value of high-grade corporate debt lies in the range of 0.1 to 0.2. For computational purposes the β

value for utility debt is taken to be 0.15.

Examination of Fig. 9 indicates that in the recent past, typical values of β for California utility common stocks were in the range of from 0.5 to 0.7. The relativity high value of β for the Standard & Poor's utility index reflects the fact that several Eastern and Midwestern utilities, most notably Consolidated Edison Company of New York, have experienced recent difficulties [Senate Interior and Insular Affairs Committee, 1974]. Limiting discussion to the southwestern United States, it would appear reasonable to select, as typical of β for utility equity, values in the range of 0.5 to 1.0. For computational purposes the β value for utility equity is taken to be 0.75. Combining this β value with the β value for utility debt discussed above implies a β value of 0.45 for a typical utility company's total capitalization.

That utilities should have such low β values is due to the fact that utility companies are granted legal monopolies to provide commodities or services, the demand for which is highly inelastic in comparison to other goods and services traded in the market place. Thus it is not surprising that utility stocks would show less volatility than the stock market in general. In fact, it is almost surprising that utilities have β values as high as 0.45.

The main reason that utilities do not have a zero β is the fact that there is some uncertainty as to whether the utility company will achieve the allowed rate of return set by public regulatory agencies by charging the rates set by public regulatory agencies. This risk will be referred to as market risk. This risk is made more serious by the fact that regulatory procedures are cumbersome and time consuming. Thus, after problems are first discovered, regulatory lag ensures that considerable losses (or gains) will result before corrective actions can be taken.

There are three distinct types of market risks faced by utilities. First, there is the risk of incorrectly estimating future demand; second, there is the risk of incorrectly estimating future costs; third, there is the risk that the allowed rate of return, while achieved may be too low by market standards. This latter risk is analogous to the risk faced by the purchasers of long-term bonds. For example, a $1,000 bond bearing a 4% coupon rate would not command a $1,000 price in today's market. In fact, it would be roughly as valuable as a $500 bond bearing an 8% coupon rate. Thus the value of fixed income securities declines as interest rates rise.

These risks may be enumerated as: 1) future demand uncertainty, 2) future cost uncertainty, and 3) future cost of capital uncertainty. Conventional utilities are strongly affected by demand uncertainties. The lead time between the planning of a new electric generation facility and its completion ranges from about three years for a gas turbine plant to ten or more years for a nuclear facility. Thus capital is raised to purchase assets with which to supply future demand and provide future revenues. In the past, demand forecasts have proved to be very accurate. However, since 1973 such forecasts have been far less accurate. This is due to the fact that while market demand is highly price-inelastic in the short run, it is quite elastic in the long run. For example, capital improvements such as home insulation will affect long-run demand. This has left utilities with excess capacity which regulatory agencies have been reluctant to support through the rate structure.

Utilities have also suffered recently from unexpected increases in the costs of capital equipment and of fuel. Once again, despite the fact that utilities are regulated monopolies, due to regulatory lag, rate adjustments have not kept pace with recent cost escalations, resulting in utility companies not achieving their allowed rates of return on investment. Finally, utility stocks, like fixed income securities, perform poorly in periods of rising cost of capital. This is due, once again, to regulatory lag. Once the allowed rate of return for a utility is set by a regulatory agency it is usually fixed for a period on the order of one year. If, in that time period, the market rate of return were to improve considerably, then the price of utility stock will be forced downward. This will, however, improve its rate of return performance. These three risks result in a utility capitalization β value on the order of 0.45.

The problem of uncertain demand or, alternatively, of excess cap capacity, results from the long lead times associated with conventional heating energy systems. A natural gas system requires the construction of pipeline networks; electrical heating systems require power generation facilities. The need for such facilities must be estimated years in advance. Needless to say, the further in advance the forecast must be made the more uncertain are the results with regard to both estimated capacity requirements and also estimated capital costs. Thus the chief cause of excess capacity and excess capital expenditure risk is the long lead time inherent in conventional heating energy systems.

OSSH, however, has a lead time of weeks or months rather than years. In fact, by being physically located at the demand site, OSSH has an almost zero demand/excess capacity risk. This is because the demand for heating and hot water energy is essentially a function of the physical dimensions of the structure only. Even the demand for hot water energy is principally a function of structure dimensions since large homes are usually occupied by large families, etc. A potential source of risk is vacancy. A regression analysis of occupany rate against market return indicates the correlation not to be significantly different from zero. Therefore, OSSH would have a much smaller demand/excess capacity risk than conventional heating energy investments.

As stated above, utilities face risks associated with the uncertainty of the uncertainty of future costs for capital equipment and for the fuel. OSSH would have a very small cost escalation uncertainty because the systems are installed so quickly (a few weeks) that there is little time for cost overruns. In addition fuel costs would be zero with certainty. There would be, of course, other costs risks, particularly with respect to maintenance costs. However, the magnitude of this risk would be much smaller than the fuel cost risks associated with conventional heating energy systems. Therefore OSSH would have a much smaller cost escalation risk than conventional heating systems.

The cost of capital risk faced by utilities results from the fact that power generating facilities are very long term assets. Perhaps the most extreme examples are the hydroelectric stations which have anticipated lifetimes on the order of hundreds of years. The risk faced by utilities is that long-term investment decisions made when interest rates are low will appear unprofitable when interest rates are high. Such a course of events would have a depressing effect on stock prices. Thus the principal parameter determining the cost of capital risk is the expected lifetime of the physical asset. In the case of OSSH, the expected lifetimes are on the order of 15 to 20 years. This is short in comparison to conventional utility assets but long in terms of financial asets. Therefore it would not be unreasonable to assess the cost of capital risk associated with investment in OSSH as comparable to that associated with investment in conventional heating energy assets.

There is, however, one other risk that must be examined in connection with OSSH. The principal risk that mitigates against homeowner-financed OSSH is default risk. It is the risk that the homeowner cannot or will not service his debt. This possibility forces up interest rates or, alternatively, leads to unacceptable risks to be borne by the homeowner. However, were title to OSSH to be retained by a utility company, the likelihood, and hence risk, of homeowner default could be expected to be greatly reduced for the following reason. Were OSSH financing arranged by a homeowner through a bank or similar financial institution, the only recourse for the lender, in the event of default, would be the cumbersome process of foreclosure. In the case of utility-owned OSSH the penalties for default would presumably include prompt termination of all other utility services; including the electrical backup to the OSSH system. Because of the extremely negative consequences that would result from utility service termination (homes would become essentially uninhabitable), very few utility customers fail to pay their bills. In the western states the utility uncollectable rate has been consistently below 1% [Electrical World, 1977].

For completeness, the consequences of housing vacancies must be considered. When houses or apartments are vacant the utility company does not receive its expected cash flow from OSSH or, for that matter, any other of its services. The vacancy rate for single-family houses nationwide is on the order of 1% and is quite stable. The vacancy rate for multi-unit residential buildings in the western United States varies between four and eight percent. However, for the suspension of cash flows due to housing vacancy to be considered a risk in the framework of the CAPM, it must be shown that the housing vacancy rate varies in a systematic way with respect to the market portfolio. In order to determine if that were so, a regression of western states multi-unit housing occupancy rates [U.S. Department of Housing and Urban Development, 1968-1977] versus the Standard & Poor 500 stock index was performed. Quarterly data from 1968 through 1977 blocked into six-year subintervals was used. The results of that regression are shown in Table 5. These results indicate that the relevant regression coefficient is not significantly different from zero. Thus the effect on OSSH of vacancy-induced cash flow interruptions would be to lower the value of expected return ($E(R_I)$) in Eq. (9) but not to raise the value of risk (β_I) in that equation.

The conclusion of the above analysis is that from the point of view of a utility company, the risk of customer non-payment is small and is independent of the equipment used to provide service. Thus ownership of OSSH by utilities rather than by individuals eliminates what is now by far the greatest risk associated with OSSH — default risk.

Based on the foregoing analysis it would appear that the market risks associated with OSSH are smaller than for conventional heating energy generation investments. This implies that the β value for OSSH is expected to be smaller. The β value for conventional utility assets was estimated to be on the order of 0.45. OSSH is expected to have substantially lower demand/excess capacity as well as cost escalation risks. It is expected to have roughly the same cost of capital risk. Default risk is not a major consideration for utility-owned OSSH.

If it is assumed that to a first approximation the three risks applicable to conventional utility assets all contribute equally to β, then OSSH, facing only cost of capital risk, could be expected to have a β value on the order of 0.15. As stated above, having mainly a cost of capital risk, OSSH is, in so far as a risk class, similar to fixed income securities such as corporate bonds. As was shown previously, the β value for corporate bonds is on the order of 0.15. While this striking numerical agreement cannot be considered proof of the foregoing analysis, it is, however, extremely reassuring and increases confidence in the value of β_I for OSSH estimated above.

Next, it is necessary to make some estimate of R_f, the risk-free interest rate, and MPR, the market price of risk. It should be noted that the actual current values of these parameters may not be the appropriate values to substitute into Eq. (17). For example, since 1968, stocks in general have not performed well. In fact, over certain intervals their performance has been so poor as to imply a negative MPR. For the purposes of this study, Whitcomb's [1978] thesis regarding the proper time frame over which to estimate MPR will be adopted. His estimate of MPR, based on a 52-year data set, lies in the range between 7.85% and 8.82%. Whitcomb's [1978] thesis regarding the appropriate value of R_f will also be adopted. His estimate of the value of R_f, relevant to current financial decisions, lies in the range between 6.3% and 7.0%. For computational purposes the central values in these ranges will be used. Thus the value of MPR is taken to be 8.3% and the value of R_f is taken to be 6.7%. The above values for β_I, MPR and R_f, when substituted into Eq. (17), lead to the following conclusion. Investment in OSSH should result in an increase in the total value of the firm (utility company) and hence be made when the expected return on OSSH investment exceeds 7.9%.

PROJECT EVALUATION

In the previous section of this report, the CAPM was used to determine the minimum rate of return on OSSH investment consistent with maintaining the total value of the firm (utility company). That rate of return was calculated to be 7.9%. This rate can be interpreted as a hurdle rate or as a cost of capital against which investment projects must be compared. The significance of the preceding analysis is that the calculated rate of return is an estimate of the "correct" hurdle rate appropriate to utility OSSH investment based on the specific risk characteristics of OSSH.

The next step in capital budgeting/project evaluation is the comparison of the expected rate of return on the investment with the hurdle rate. Determination of the expected rate of return on the investment requires the estimation of cost and policy parameters. Examples of cost parameters include the initial materials and labor costs and yearly maintenance costs. Examples of policy parameters include the allowed utility rate structure for OSSH-derived energy as well as the circumstances under which utility-owned OSSH would be permitted. The above issues are important ones which must be addressed before utility-owned OSSH can be implemented.

For the purposes of this report, a particular set of parameter estimates has been chosen to make a generic evaluation of utility-owned OSSH. The simplest, least expensive and perhaps the most promising OSSH system is the hot-water-only system. However, even such a modest OSSH system offers the potential for reducing the nation's demands on conventional energy sources by 5%. The expected return, $E(R_I)$, is taken to be the expected Internal Rate of Return (IRR) for the project over its anticipated lifetime. Dollar values for initial investment and yearly expenses (maintenance) were those of Southwest Energy Management, Inc. [1978]. Evaluation of the yearly gross revenues is not quite so straightforward.

There are several alternative ways to view the revenue stream resulting from an OSSH investment. For the purposes of this report the expected revenue stream is viewed as follows. From the point of view of the utility, an OSSH system is a capital asset whose gross revenues are simply the product of the amount of energy supplied multiplied by the rate per unit of energy set by the appropriate public regulatory agency. Furthermore, OSSH systems typically require back-up systems to provide energy during periods of cloud cover. Therefore it will be assumed for the purposes of this analysis that OSSH hot-water-only systems will be installed by utility companies only in areas where oil or natural gas back-up systems are not feasible. This would apply to many parts of the country where recent shortages have resulted in the installation of such systems being restricted or inadvisable. Therefore it will be assumed that OSSH systems will be provided with electric heating back-up systems and that the rate per unit of energy for both solar and back-up electricity will be the rate per unit of electrical energy. The above assumption is quite far reaching although not unreasonable.

Internal rates of return based on the above model appear in Table 5. For computational purposes, figures appropriate to a single-family residential OSSH system requiring a 20% electrical back-up were used [Southwest Energy Management, Inc., 1978]. The initial cost of such a system is taken to be $1500, the 1978 estimated maintenance expense is taken to be $60, the yearly inflation of the maintenance is taken to be 5%. Two sets of figures for yearly solar energy usage and 1978 electric rates were used. One set of figures is appropriate to areas of low demand and relatively low electric rates, such as encountered in the San Francisco Bay Area, while the other set of figures is appropriate to regions of California having high demand and high electric rates, as is found in the San Diego area. The differences in the figures result from demographic differences between the two areas and from the fact that a substantial fraction of Northern California electrical energy is inexpensive hydroelectric energy. The yearly inflation in electrical rates is taken to be 10.1%. Finally, because the tax status of utility-owned OSSH systems is unclear, the IRR in Table 5 are calculated for three possible tax treatments. These are 1) no tax, 2) 48% tax, and 3) 48% tax with a 55% investment tax credit in the first year.

DISCUSSION AND CONCLUSIONS

These results now allow for the evaluation of OSSH in the context of the CAPM as embodied by Eq. (17). Equation (17) implies that the OSSH investment should be accepted if the expected rate of return on investment exceeds R_f, the risk-free rate, plus the risk premium appropriate to OSSH. The risk premium or the product of MPR times β_I (for OSSH) is estimated to be 8.3% times 0.15, or 1.2%. When combined with R_f the model sets a hurdle rate of 6.7% + 1.2%, or 7.9% for the acceptance of the OSSH investment. Comparison with the expected rates of return for OSSH investment given in Table 5 very clearly indicates that OSSH is a marginal proposition in northern California but a sound investment in southern California.

There are several interesting corollaries of the above analysis that merit discussion. Perhaps the most important is the fact that OSSH would appear to have a substantially lower β than conventional utility assets. In fact it can be argued that OSSH investments are in the same risk class as bonds. If this is indeed the case it would appear logical that utilities would seek to finance OSSH through debt rather than equity. This is because the expected increase in the β value of equity, as the debt-to-equity ratio were increased, would be offset by the decrease in the β value of total capitalization as the utility acquired lower β OSSH assets.

Viewed alternatively, since physical assets are not necessarily traded in an efficient market, it is possible to earn extra normal profits in the asset market that are not attainable in efficient markets. It would appear that OSSH could provide such profits. This is because expected return on OSSH depends on engineering economics and not on the actual market risk of the investment. Through financial leveraging (debt financing), a utility could increase its return on equity without increasing the risk on equity by investing in OSSH. The net effect would be to force up the price per share of equity allowing for better terms on future equity financing. For capital-intensive industries such as utilities this is of critical importance.

The advantage of OSSH can also be viewed in the following way. Conventional utility assets, with the notable exception of hydroelectric stations, have variable fuel costs. OSSH, however, having zero fuel costs in effect has a higher degree of operating leverage. When fuel costs rise, public regulatory agencies allow for rate increases which have the effect of containing the increase to the break-even point for conventional power generating assets. The effect on OSSH systems, which have no fuel costs, is simply to lower the break-even point, thus rendering them more and more profitable as fuel prices and electric rates rise. In addition, OSSH faces a more inelastic demand than do conventional power-generating assets. It is these two factors that make investment in OSSH appear so promising.

APPENDIX I.

COMPUTATION OF TECHNICAL β

The technical or historical β values of the various indices and securities were calculated on the Lawrence Berkeley Laboratory CDC-7600 computer using computer programs developed for this study. A listing of the main program, BETAS, appears in Fig. A1 and listings of the relevant subroutines appear in Fig. A2.

Program BETAS has, as its inputs, the number of data points to be processed (the number of months of data to be processed), the monthly average security and index prices, the average monthly security and index dividend or interest yield, and the average monthly risk-free rate (90-day Treasury Bill discount rate).

The program then combines the rates of capital appreciation with the monthly dividend or interest yields to give the monthly average rates of return on the inputted indices and/or securities. The program then computes the regression coefficients $\hat{\alpha}$ and $\hat{\beta}$ using the formulas

(A.1) $$\beta = \frac{\left(\Sigma\, x_i y_i / N\right) - \bar{x}\bar{y}}{\left(\Sigma\, x_i^2 / N\right) - \bar{x}^2}$$

(A.2) $$\alpha = \bar{y} - \beta\bar{x}$$

The output quantity β is the so-called technical β. The program is designed so that the input data set can be subdivided into sequential subsets. In this study the initial data set consisted of ten years of data. These data were then analyzed in sequential blocks of 60 months of data.

Subroutine STDERR computes the standard errors of the regression coefficients α and β using the formulas

(A.3) $$S_{\alpha}^{2} = \left[\frac{\sum (y_i - \alpha - \beta x_i)^2}{N - 2}\right]\left[\frac{\sum x_i^2}{N\sum (x_i - \bar{x})^2}\right]$$

(A.4) $$S_{\beta}^{2} = \left\{\frac{\sum (y_i - \alpha - \beta x_i)^2}{[N - 2]\left[\sum (x_i - \bar{x})^2\right]}\right\}$$

Subroutine CAPAP calculates the rate of capital appreciation as the result of monthly price changes, and to this adds the monthly dividend or interest yield using the formula

(A.5) $$R_t = \frac{P_{t+1} - P_t}{P_t} + D_t$$

Subroutines VPROD calculates the vector product of the rates of return of the two input data sets using the formula

(A.6) $$PROD = \sum_{i=1}^{n} x_i y_i$$

This subroutine also calculates the arithmetic and geometric mean returns using the formulas

(A.7) $$\bar{R}_{arith} = \frac{1}{n} \sum_{i=1}^{n} x_i$$

(A.8) $$\bar{R}_{geom} = \left[\prod_{i=1}^{n} (1 + x_i)\right]^{1/n} - 1$$

APPENDIX II

CALCULATION OF INTERNAL RATES OF RETURN

The internal rates of return used in this study were calculated on the Lawrence Berkeley Laboratory CDC-7600 computer using computer programs developed for this study. A listing of the main program IROR and the relevant subroutines appear in Fig. A3.

Program IROR has as its inputs the initial cost, the expected yearly load, the base year electrical rates, the expected base year maintenance expense, the expected lifetime of the OSSH system, the projected inflation rate, and the projected energy cost escalation rate over and above the inflation rate. The output of the program is the IRR.

Function PRESVL computes the present value of the net operating revenue stream discounted at a given discount rate. Function PVTAX is similar to function PRESVL and computes the after-tax (taken to be 48%) present value of the revenue stream. Straight line depreciation expensing is assumed.

TABLE 1. Pacific Gas and Electric

β		$S.E._{\beta}$
.70942	+/-	.159
.75597	+/-	.160
.75833	+/-	.161
.79572	+/-	.166
.79742	+/-	.165
.77183	+/-	.163
.76716	+/-	.165
.78017	+/-	.165
.79885	+/-	.166
.75579	+/-	.168
.76242	+/-	.160
.74399	+/-	.155
.75316	+/-	.157
.73550	+/-	.158
.73533	+/-	.155
.74923	+/-	.153
.74253	+/-	.153
.75427	+/-	.156
.69503	+/-	.155
.67709	+/-	.149
.70014	+/-	.141
.70384	+/-	.140
.72705	+/-	.141
.68573	+/-	.139
.70780	+/-	.134
.73035	+/-	.128
.66592	+/-	.136
.65941	+/-	.137
.54979	+/-	.140
.56154	+/-	.142
.56145	+/-	.142
.52939	+/-	.136
.50268	+/-	.137
.52013	+/-	.132
.52172	+/-	.129
.45438	+/-	.124
.46128	+/-	.120
.46429	+/-	.119
.46590	+/-	.119
.47843	+/-	.119
.47827	+/-	.120
.48218	+/-	.120
.48497	+/-	.119
.47824	+/-	.120
.49737	+/-	.122
.50728	+/-	.120
.51501	+/-	.123
.53848	+/-	.124
.53279	+/-	.125
.53401	+/-	.122
.54527	+/-	.122
.54453	+/-	.122
.54470	+/-	.122
.54550	+/-	.121
.54940	+/-	.122
.54070	+/-	.122
.55073	+/-	.122
.55023	+/-	.118
.56574	+/-	.119
.55394	+/-	.118
.56014	+/-	.115

TABLE 2. San Diego Gas and Electric

β		S.E.$_\beta$
.61846	+/-	.197
.67473	+/-	.194
.67623	+/-	.195
.73129	+/-	.200
.71537	+/-	.200
.68788	+/-	.196
.68219	+/-	.195
.70706	+/-	.191
.73276	+/-	.191
.75712	+/-	.188
.80144	+/-	.180
.82897	+/-	.175
.85547	+/-	.179
.83460	+/-	.180
.80057	+/-	.180
.81997	+/-	.177
.81552	+/-	.177
.82365	+/-	.181
.88809	+/-	.175
.80815	+/-	.173
.71397	+/-	.165
.71302	+/-	.164
.69671	+/-	.159
.69060	+/-	.158
.68763	+/-	.151
.68672	+/-	.142
.67264	+/-	.141
.66545	+/-	.142
.62191	+/-	.148
.63361	+/-	.150
.63454	+/-	.150
.62910	+/-	.142
.64238	+/-	.144
.65410	+/-	.137
.65578	+/-	.135
.61153	+/-	.135
.63294	+/-	.131
.66913	+/-	.133
.69179	+/-	.128
.68330	+/-	.128
.67512	+/-	.127
.67385	+/-	.127
.67496	+/-	.126
.66873	+/-	.128
.68469	+/-	.126
.70718	+/-	.125
.69659	+/-	.128
.69596	+/-	.130
.65218	+/-	.125
.67164	+/-	.118
.68687	+/-	.116
.68797	+/-	.115
.68603	+/-	.115
.68960	+/-	.114
.69171	+/-	.113
.69607	+/-	.113
.69526	+/-	.113
.68293	+/-	.115
.67286	+/-	.116
.66456	+/-	.115
.66977	+/-	.113

TABLE 3. Utilities Index

β		$S.E._{\beta}$
.75286	+/-	.105
.76040	+/-	.106
.75417	+/-	.105
.79081	+/-	.107
.78581	+/-	.107
.77780	+/-	.106
.77718	+/-	.105
.79242	+/-	.107
.81096	+/-	.108
.81027	+/-	.107
.83098	+/-	.102
.81996	+/-	.099
.83911	+/-	.103
.83309	+/-	.103
.80566	+/-	.103
.83307	+/-	.102
.86204	+/-	.108
.85774	+/-	.112
.84583	+/-	.109
.80775	+/-	.106
.80447	+/-	.100
.83144	+/-	.106
.82962	+/-	.105
.80932	+/-	.104
.89592	+/-	.108
.87316	+/-	.103
.84217	+/-	.102
.83816	+/-	.103
.82980	+/-	.108
.84514	+/-	.112
.84570	+/-	.111
.84414	+/-	.109
.84889	+/-	.110
.86253	+/-	.109
.86592	+/-	.108
.84117	+/-	.109
.84348	+/-	.105
.85060	+/-	.104
.85375	+/-	.105
.86361	+/-	.105
.85918	+/-	.104
.85845	+/-	.104
.86750	+/-	.103
.85919	+/-	.104
.86949	+/-	.103
.86969	+/-	.102
.87501	+/-	.103
.90524	+/-	.104
.89593	+/-	.105
.90544	+/-	.102
.90953	+/-	.102
.91096	+/-	.101
.90997	+/-	.101
.91208	+/-	.101
.91382	+/-	.101
.92022	+/-	.101
.92387	+/-	.101
.92012	+/-	.101
.90409	+/-	.101
.90679	+/-	.101
.91027	+/-	.100

TABLE 4. Bond index

β	S.E.$_β$
.15008	.055
.15840	.055
.15728	.055
.17689	.056
.17872	.055
.17757	.055
.17711	.055
.20163	.055
.20255	.056
.21570	.055
.19821	.053
.17535	.050
.17454	.051
.17362	.050
.16172	.050
.16871	.049
.17069	.049
.16424	.050
.16557	.049
.16510	.047
.17071	.044
.17042	.043
.17404	.043
.15270	.041
.14767	.039
.13989	.037
.13508	.037
.13626	.037
.13042	.039
.12821	.037
.12809	.037
.12852	.036
.12392	.037
.12260	.036
.12359	.036
.09826	.033
.09861	.030
.09814	.030
.10151	.030
.10649	.030
.10595	.031
.10616	.032
.10695	.032
.10666	.032
.10722	.032
.10779	.032
.11863	.030
.13287	.034
.13222	.034
.13560	.034
.13791	.034
.13816	.034
.13865	.034
.13956	.034
.13953	.034
.13884	.034
.13772	.035
.14005	.035
.13964	.035
.13970	.036
.13987	.036

TABLE 5. Multi-unit residence occupancy rates.
(western states)

β	$S.E._{\beta}$
.00203	.00752
.00168	.00694
.00315	.00520
.00498	.00497
.00650	.00553
.00588	.00562
.00408	.00512
.00450	.00515
.00814	.00457
.00746	.00404
.00952	.00388
.00626	.00366
.00394	.00396
.00301	.00412
.00496	.00393
.00536	.00398
.00455	.00385
.00350	.00389
.00402	.00418
.00283	.00493
.00336	.00505
.00233	.00511
.00161	.00532

TABLE 6

Region	Investment lifespan (years)	IRR (no tax)	IRR (48% tax)	IRR (48% tax and 55% tax credit)
S.California[a]	10	14.50	8.75	25.50
S.California	15	20.00	13.25	29.50
S.California	20	22.25	15.25	30.75
N.California[b]	10	--	--	3.50
N.California	15	6.00	3.75	11.50
N.California	20	10.00	6.75	15.00

[a] For Southern California, 80% of load taken to be 4800 Kwh at 1978 electric rate of 4.5¢/Kwh.

[b] For Northern California, 80% of load taken to be 2800 Kwh at 1978 electric rate of 4.0¢/Kwh.

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FIGURE CAPTIONS

Fig. 1. Schematic representation of an On Site Solar Heating System.

Fig. 2. Representation of securities portfolios in Standard deviation/Expected return space showing efficient frontier and Capital Market Line.

Fig. 3. Representation of the portfolios consisting of the Market portfolio plus varying amounts of one new security in Standard deviation/Expected return space.

Fig. 4. The monthly rate of return on PG&E common stock versus the monthly rate of return on the Standard & Poor 500 index in the interval January 1969 through December 1973.

Fig. 5. The monthly rate of return on SDG&E common stock versus the monthly rate of return on the Standard & Poor 500 index in the interval January 1969 through December 1972.

Fig. 6. The monthly rate of return on the Standard & Poor utilities' index versus the monthly rate of return on the Standard & Poor 500 index in the interval January 1969 through December 1973.

Fig. 7. The β values for PG&E stock calculated using differing data intervals.

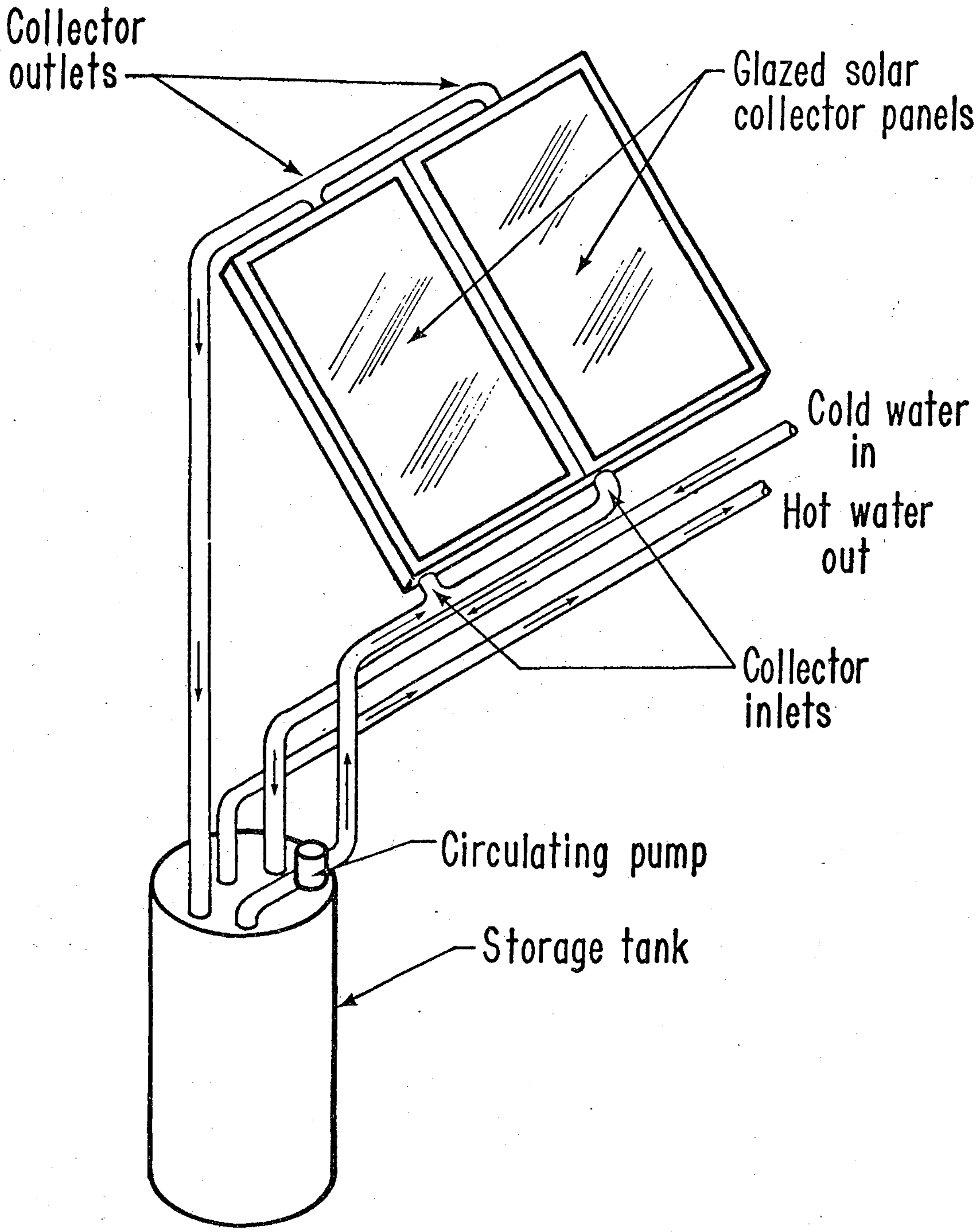
Fig. 8. The β values for the Standard & Poor utilities' index calculated using differing data intervals.

Fig. 9. The β values for PG&E stock, SDG&E stock and the Standard & Poor utilities' index for 60-month intervals terminating between December 1975 and December 1977.

Fig. A1. Computer program BETAS.

Fig. A2. Subroutines used with computer program BETAS.

Fig. A3. Computer program IROR and its accompanying subroutines.



XBL 7810-6550

Fig. 1. Schematic representation of an On Site Solar Heating System.

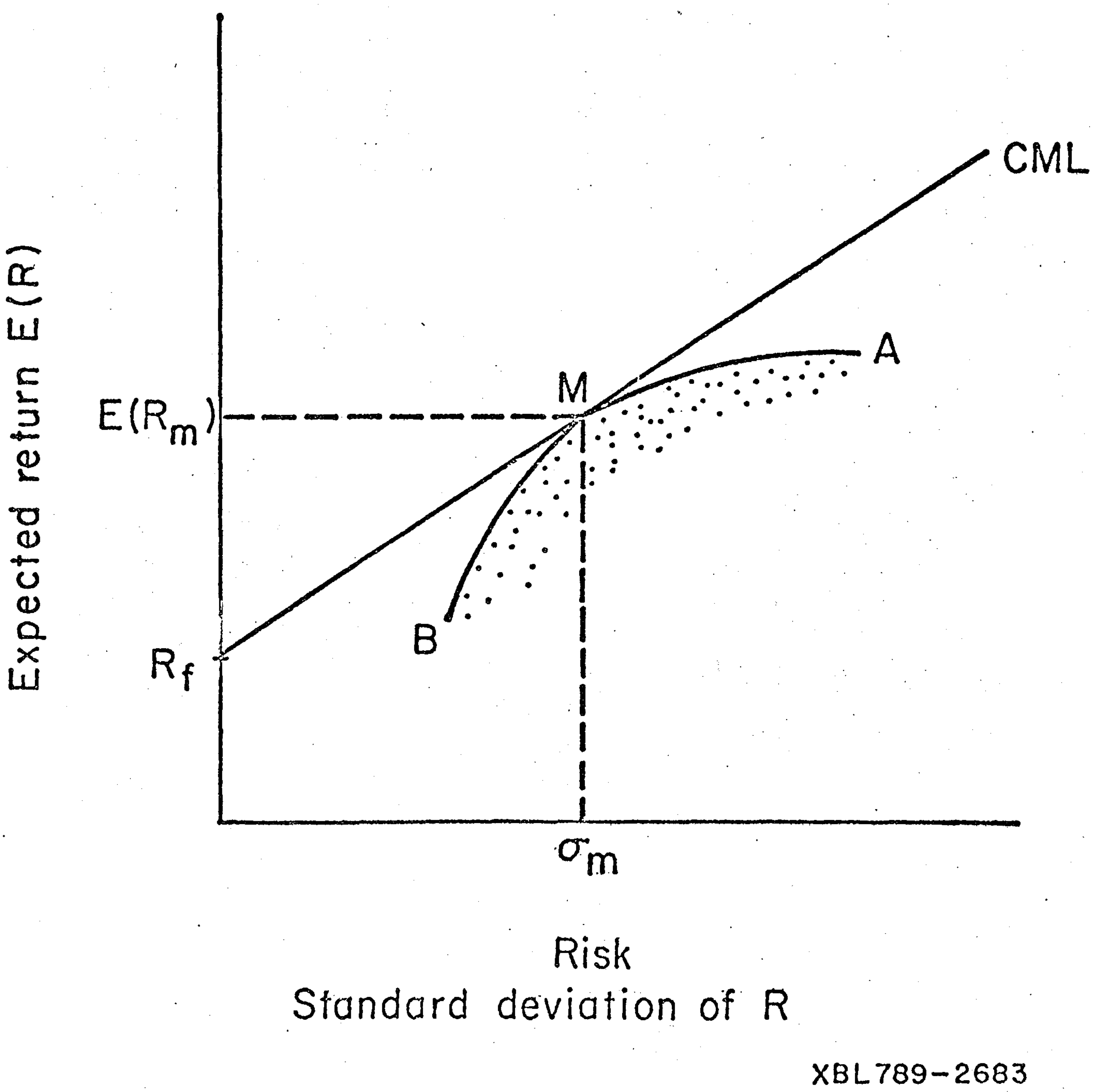
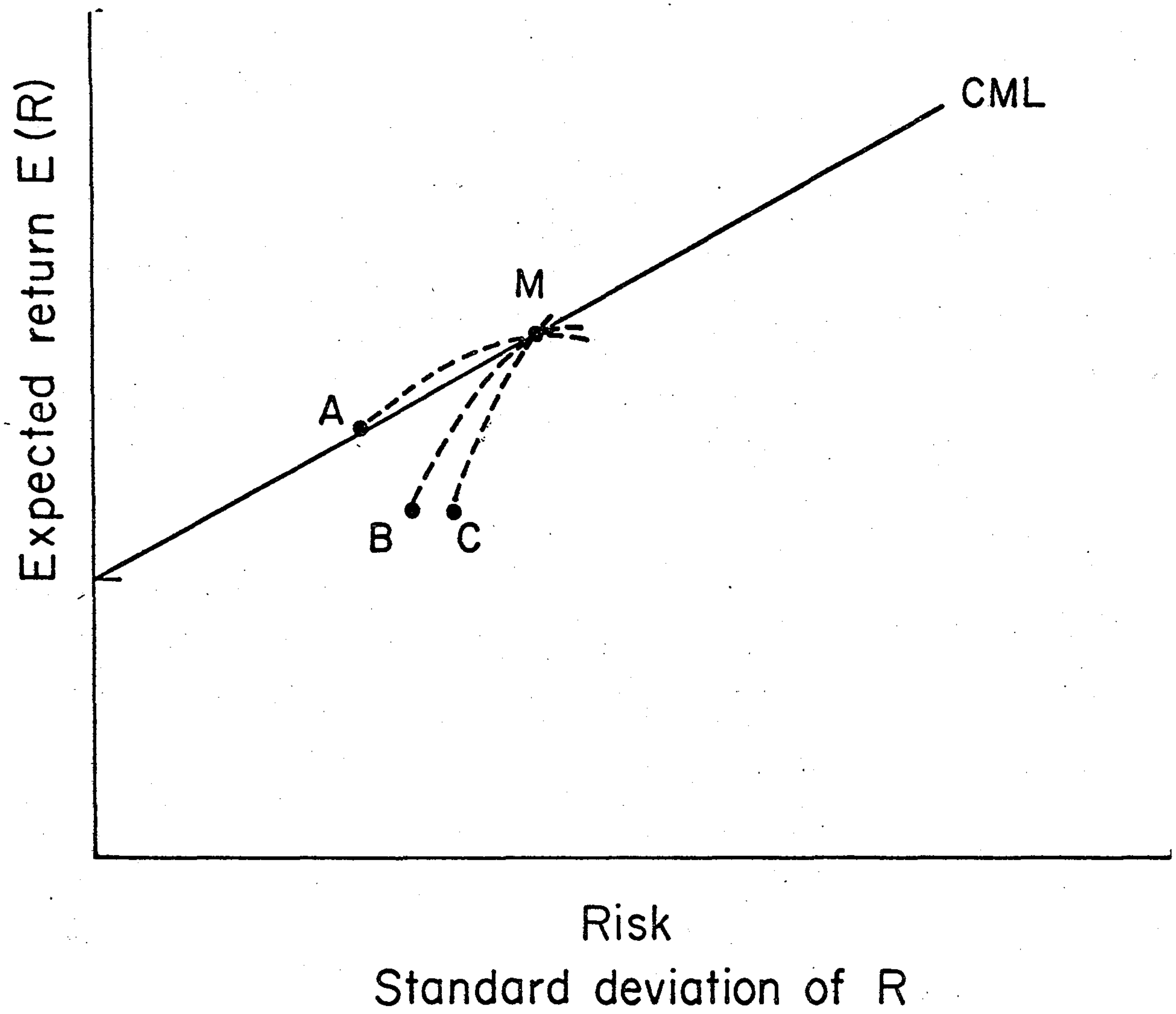


Fig. 2. Representation of securities portfolios in Standard deviation/Expected return space showing efficient frontier and Capital Market Line.



XBL 7810-6549

Fig. 3. Representation of the portfolios consisting of the Market portfolio plus varying amounts of one new security in Standard deviation/Expected return space.

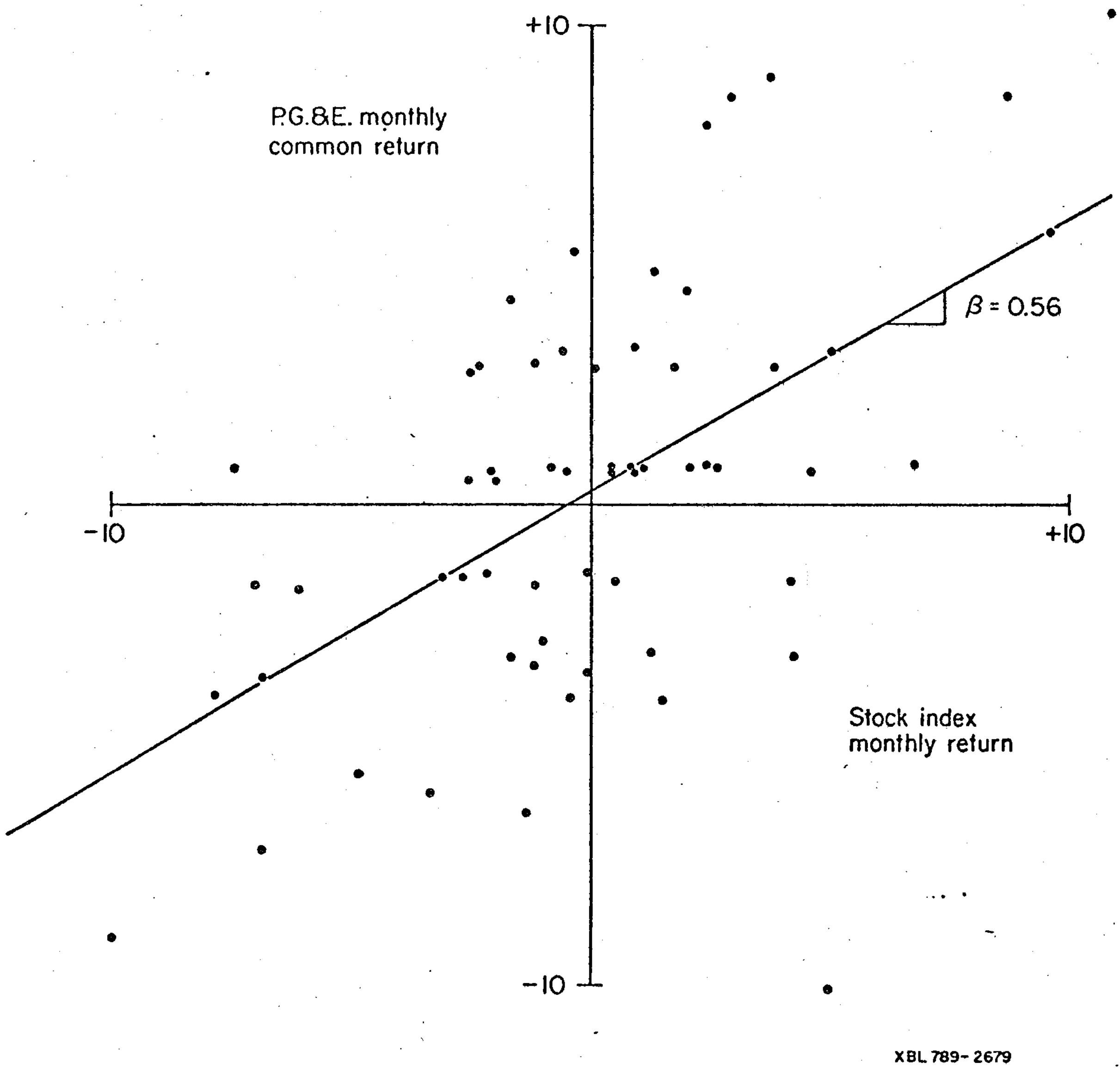


Fig. 4. The monthly rate of return on PG&E common stock versus the monthly rate of return on the Standard & Poor 500 index in the interval January 1969 through December 1973.

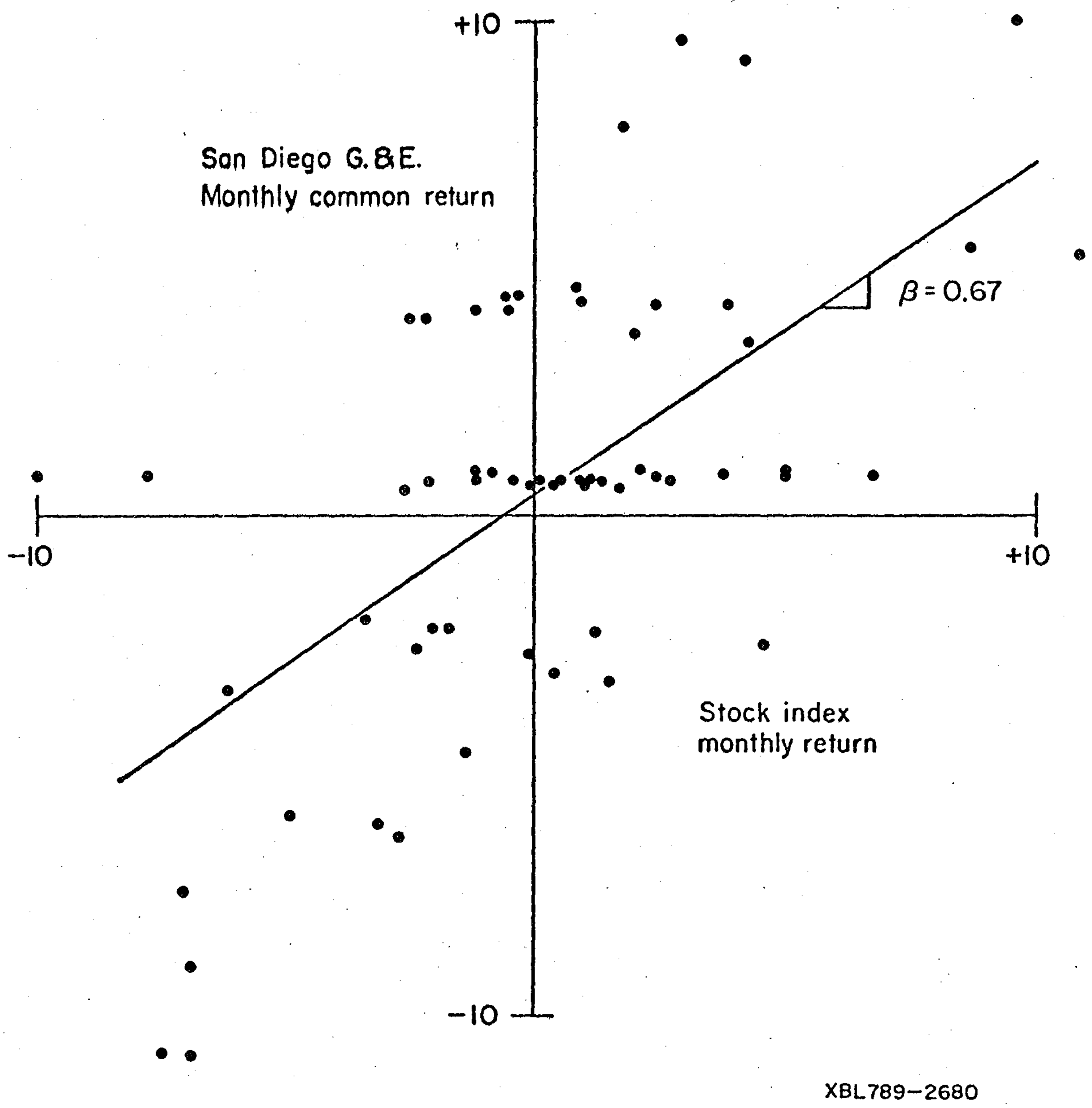


Fig. 5. The monthly rate of return on SDG&E common stock versus the monthly rate of return on the Standard & Poor 500 index in the interval January 1969 through December 1972.

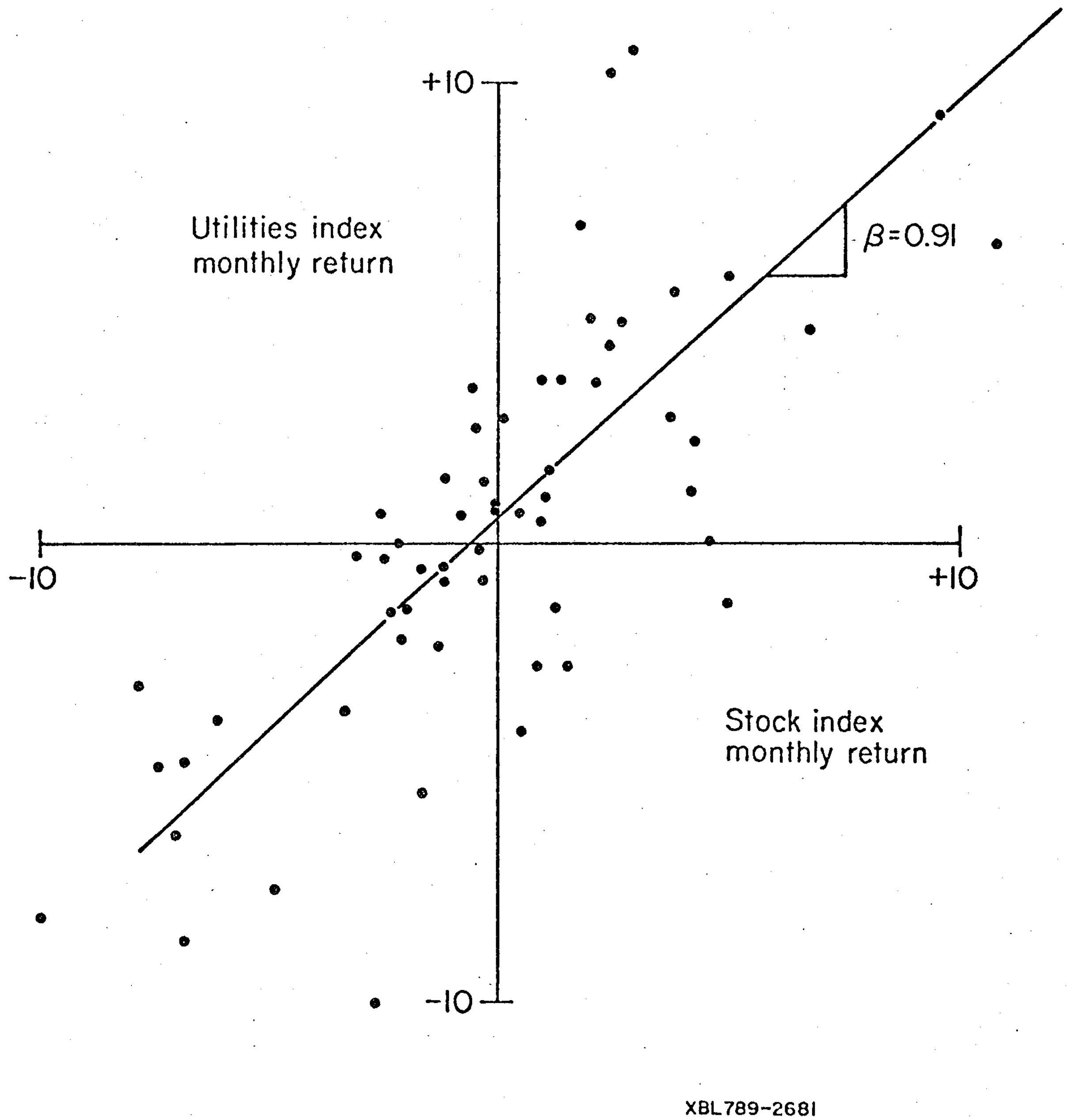


Fig. 6. The monthly rate of return on the Standard & Poor utilities' index versus the monthly rate of return on the Standard & Poor 500 index in the interval January 1969 through December 1973.

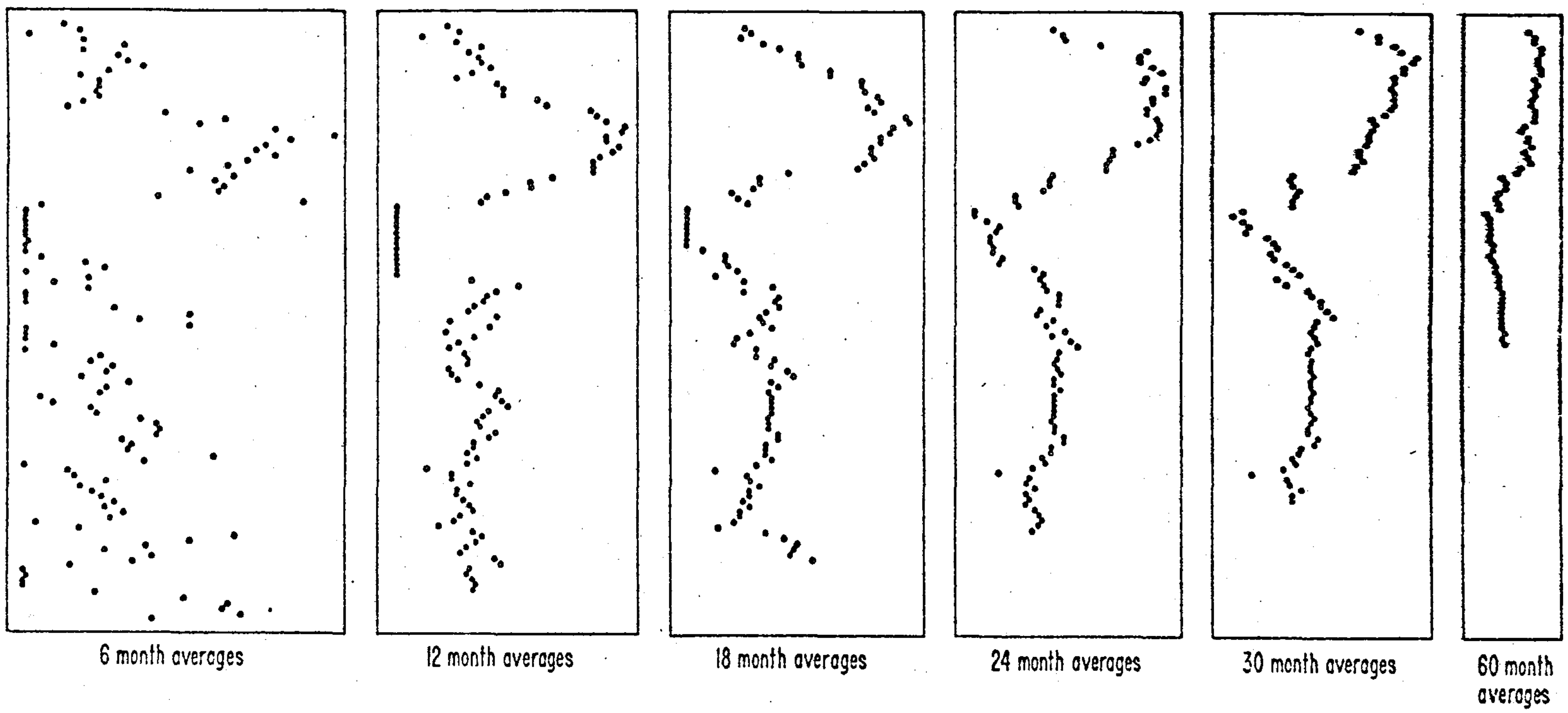


Fig. 7. The β values for PG&E stock calculated using differing data intervals.

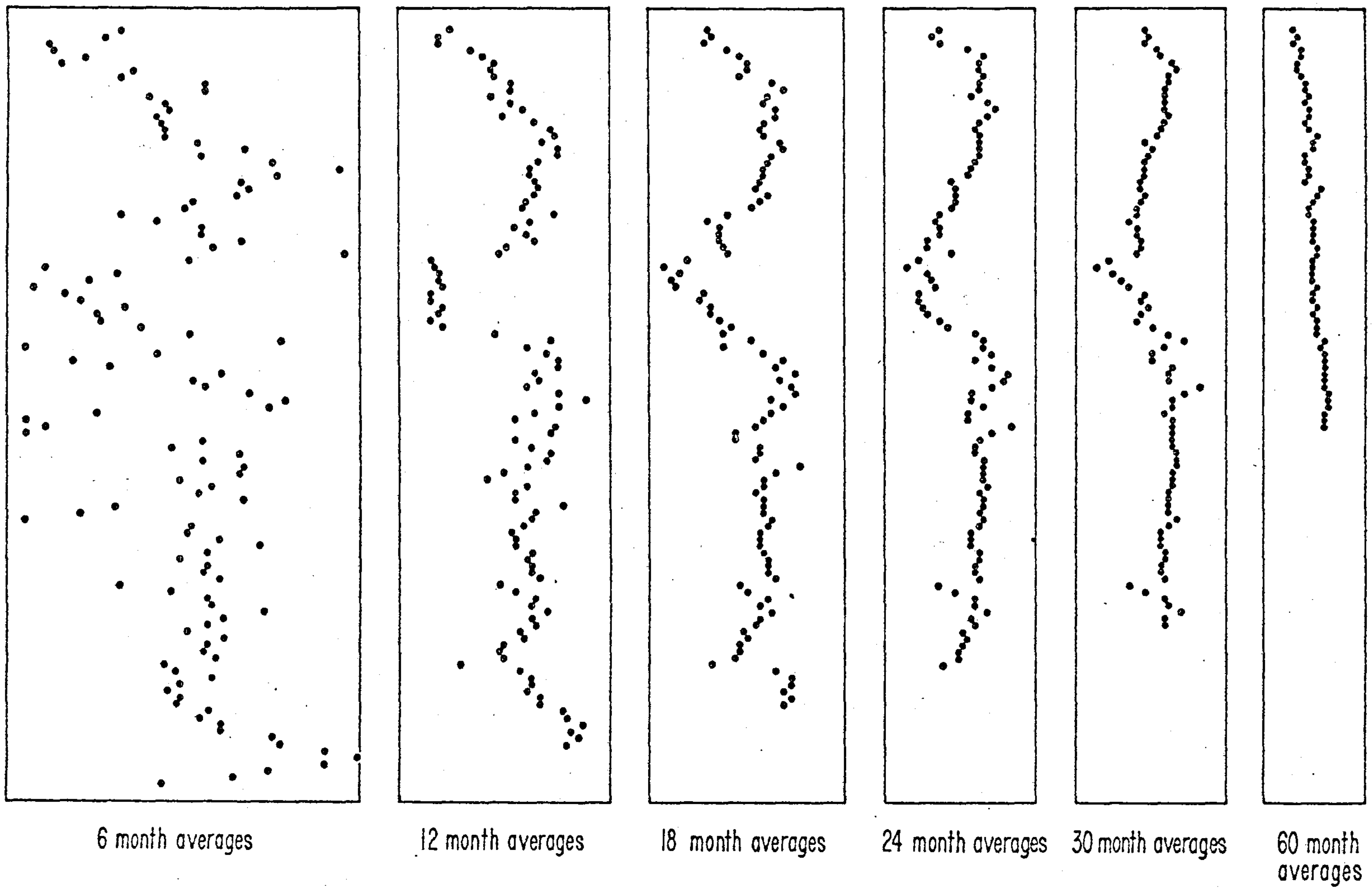


Fig. 8. The β values for the Standard & Poor utilities' index calculated using differing data intervals.

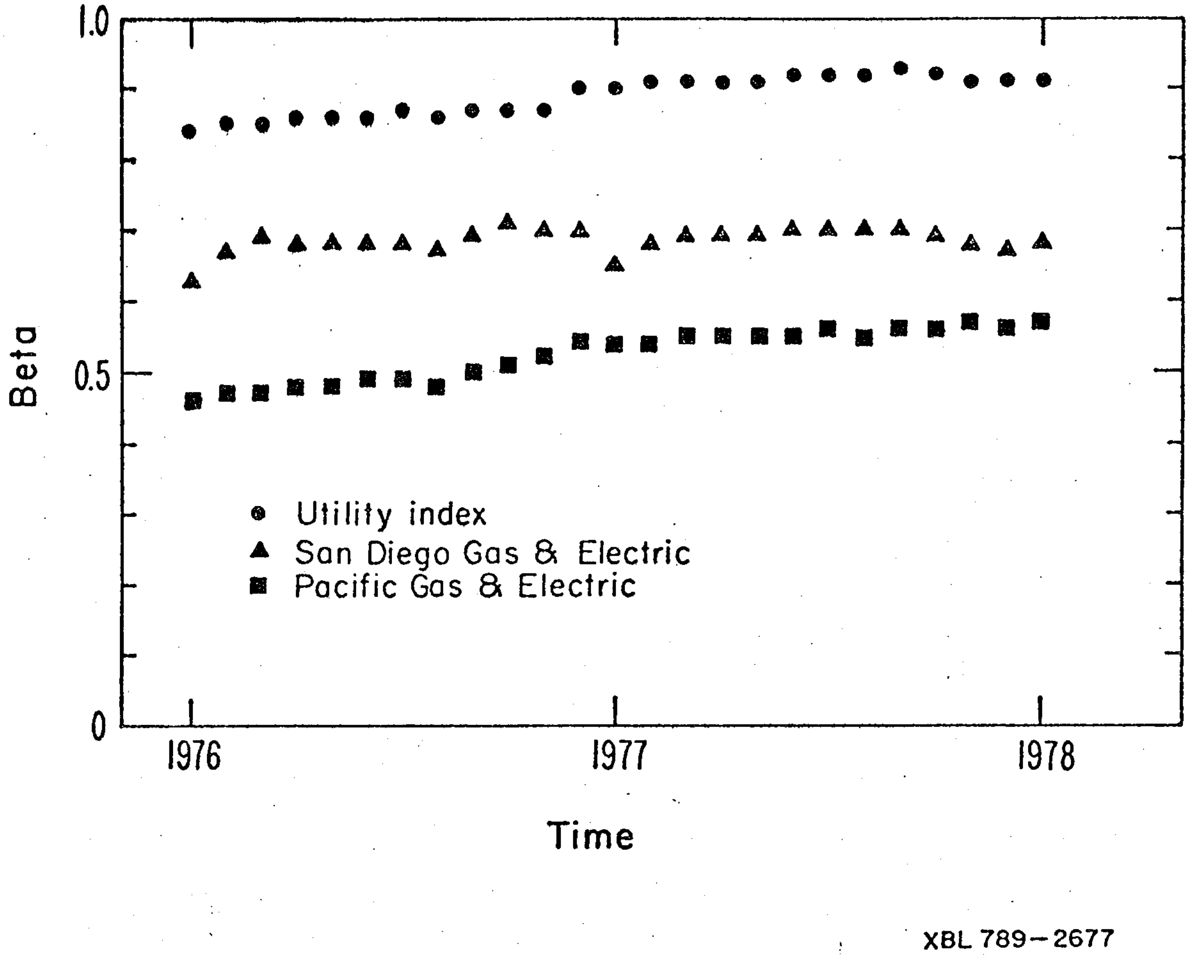


Fig. 9. The β values for PG&E stock, SDG&E stock and the Standard & Poor utilities' index for 60-month intervals terminating between December 1975 and December 1977.

```
      PROGRAM BETAS (INPUT,OUTPUT,TAPE5=INPUT,TAPE6,TAPE7)
      DIMENSION STKYLD(250), STKPRC(250)
      DIMENSION PLOT(100)
      REAL      INDYLD(250), INDPRC(250)
      REAL INDBAR
      REAL INTRTE(250)
      REAL INTBAR
      DATA BLANK,B/1H ,1HB/
      WRITE(6,1)
      WRITE(7,919)
1     FORMAT(1H1)
      DO 2 I = 1,250
      STKYLD(I) = -1201.
      STKPRC(I) = -1201.
      INDYLD(I) = -1201.
      INDPRC(I) = -1201.
      INTRTE(I) = -1201.
2     CONTINUE
      DO 100 J = 1,100
      PLOT(J) = BLANK
100   CONTINUE
      READ(5,900) NDATA
      READ(5,901) (INDYLD(I),I= 1,NDATA)
      READ(5,901) (INDPRC(I),I= 1,NDATA)
      READ(5,901) (STKYLD(I),I= 1,NDATA)
      READ(5,901) (STKPRC(I),I= 1,NDATA)
      READ(5,901) (INTRTE(I),I=1,NDATA)
      WRITE (6,902)  (INDYLD(J),J = 1,NDATA)
      WRITE (6,903)  (INDPRC(J),J = 1,NDATA)
      WRITE (6,904)  (STKYLD(J),J = 1,NDATA)
      WRITE (6,905)  (STKPRC(J),J = 1,NDATA)
      CALL CAFAF(INDYLD,INDPRC)
      CALL CAFAF(STKYLD,STKPRC)
      WRITE(6,906) (INTRTE(J), J=1,NDATA)
      DO 700 INUM = 1,2
      WRITE (6,902)  (INDYLD(J),J = 1,NDATA)
      WRITE (6,904)  (STKYLD(J),J = 1,NDATA)
      DO 600 N = 1,10
      READ(5,900) ISTART,INTVAL
      WRITE(6,950) ISTART,INTVAL
      WRITE(7,950) ISTART,INTVAL
      WRITE(6,899)
      IF(ISTART .EQ. -1) GO TO 601
      ISTART = ISTART - 1
      DO 500 J = 1,250
      ISTART = ISTART + 1
      CALL VPROD(INDYLD,INDYLD,ISTART,INTVAL,XX,INDBAR,INDRET)
      CALL VPROD(STKYLD,INDYLD,ISTART,INTVAL,XY,STKBAR,STKRET)
      IF (XY .EQ. -1000001..OR. XX .EQ. -1000001.)GO TO 501
      IF( (XX-INDBAR*INDBAR) .EQ. 0. ) STOP
      BETA = (XY-INDBAR*STKBAR)/(XX-INDBAR*INDBAR)
      ALPHA = STKBAR - BETA*INDBAR
      CALL STDERR(STKYLD,INDYLD,STKBAR,INDBAR,ALPHA,BETA,ISTART,
     1INTVAL,SALPHA,SBETA)
      INT = 50.*BETA
      IF (INT .LE. 1) INT = 1
      IF (INT .GE. 100) INT = 100
      PLOT(INT) = B
      WRITE(7,951)  BETA,SBETA,PLOT
      WRITE(6,913) INDRET,STKRET,ALPHA,SALPHA,BETA,SBETA
      PLOT(INT) = BLANK
500   CONTINUE
501   CONTINUE
600   CONTINUE
601   CONTINUE
      DO 650 K = 1,NDATA
      INDYLD(K) = INDYLD(K) - INTRTE(K)
      STKYLD(K) = STKYLD(K) - INTRTE(K)
650   CONTINUE
700   CONTINUE
899   FORMAT(15X,6HINDBAR,10X,6HSTKBAR,17X,5HALPHA,40X,4HBETA)
900   FORMAT(I3,I2)
901   FORMAT (12F5.1)
902   FORMAT(7H0INDYLD/(12F10.2))
903   FORMAT(7H0INDPRC/(12F10.2))
904   FORMAT(7H0STKYLD/(12F10.2))
905   FORMAT(7H0STKPRC/(12F10.2))
906   FORMAT(7H0INTRTE/(12F10.2))
913   FORMAT(1X,3F20.5,5H +/- ,F6.3,15X,F20.5,5H +/- ,F6.3)
919   FORMAT(1H1)
950   FORMAT(1H1,I3,I2)
951   FORMAT(1X,F6.3,3H+/-,F6.3,5X,100A1)
      END
```

Fig. A1. Computer program BETAS.

```
      SUBROUTINE STDERR(V1,V2,V1BAR,V2BAR,ALPHA,BETA,ISTART,INTVAL,
     1SALPHA,SBETA)
      DIMENSION V1(250), V2(250)
      IFIN = ISTART + INTVAL - 1
      SUM = 0.
      C = 0.
      D = 0.
      DO 50 I = ISTART,IFIN
      SUM = SUM + (V1(I)-ALPHA-BETA*V2(I))**2
      C = C + (V2(I) - V2BAR)**2
      D = D + V2(I)**2
50    CONTINUE
      SE = SUM/(INTVAL-2)
      SALPHA = (SE*D)/(INTVAL*C)
      SALPHA = SQRT(SALPHA)
      SBETA = SE/C
      SBETA = SQRT(SBETA)
      RETURN
      END
```

```
      SUBROUTINE CAPAP(V1,V2)
      DIMENSION V1(250),V2(250)
      DO 100 I = 1,250
      IF (V2(I+1) .LE. -1200.)  RETURN
      IF(V1(I) .LE. -1201.)  RETURN
      V1(I) = ((V2(I+1) - V2(I))*1200.)/V2(I) + V1(I)
100   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE VPROD (V1,V2,ISTART,INTVAL,PROD,V1BAR,V1RET)
      DIMENSION V1(250),V2(250)
      RINTVL = INTVAL
      ROOT = 1./RINTVL
      SUMV1 = 0.
      V1RET = 1.
      PROD = 0.
      IFIN =ISTART + INTVAL - 1
      DO 101 I = ISTART,IFIN
      IF (V1(I) .LE. -1201..OR. V2(I) .LE. -1201.)  GO TO 200
      SUMV1 = SUMV1 + V1(I)
      V1RET = V1RET*(1.+V1(I)/1200.)
      PROD = PROD + V1(I)*V2(I)
101   CONTINUE
      V1BAR = SUMV1/INTVAL
      V1RET =(V1RET**ROOT-1.)*1200.
      PROD = PROD/INTVAL
      RETURN
200   PROD = -1000001
      RETURN
901   FORMAT(3F10.0)
      END
```

Fig. A2. Subroutines used with computer program BETAS.

```
      PROGRAM IROR(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
      COMMON/R/LOAD,BYC,BYME,IR,EER
      COMMON/I/LFTME
      COMMON/TAX/DEP
      REAL IRR,IR,LOAD
      READ (5,910)  ITAX
      IF(ITAX .EQ. 0) WRITE(6,990)
      IF(ITAX .EQ. 1) WRITE(6,991)
      WRITE(6,949)
      DO 300 I = 1,10
      READ(5,901) COST,LOAD,BYC,BYME,LFTME,IR,EER
      IF(LFTME .EQ. 0)      GO TO 300
      IF(COST .LE. 0.) GO TO 801
      RLFTME = LFTME
      DEP = COST/RLFTME
      DO 200 J = 1,120
      RJ = J-1
      IRR = 0. + RJ/400.
      IF(ITAX .EQ. 0)  TEST=PRESVL(IRR)-COST
      IF(ITAX .EQ. 1)  TEST= PVTAX(IRR)-COST
      IF(TEST .LE. 0.)  GO TO 250
200   CONTINUE
      WRITE(6,925)
      GO TO 300
250   CONTINUE
      WRITE(6,950) COST,LOAD,BYC,BYME,LFTME,IR,EER,IRR
300   CONTINUE
801   CONTINUE
850   CONTINUE
901   FORMAT(4F10.0,I2,8X,2F10.0)
910   FORMAT(I1)
925   FORMAT(11H IRR GT .20  )
949   FORMAT(1H0/6X,4HCOST,6X,4HLOAD,8X,3HBYC,7X,4HBYME,3X,5HLFTME,
     18X,2HIR,8X,3HEER,17X,3HIRR)
950   FORMAT(1H ,2F10.0,F10.3,F10.0,5X,I2,3X,2F10.3,10X,F10.4)
990   FORMAT(7H1NO TAX   )
991   FORMAT(16H148 PER CENT TAX  )
      END



      FUNCTION PRESVL (IRR)
      COMMON/R/LOAD,BYC,BYME,IR,EER
      COMMON/I/LFTME
      REAL IRR,IR,LOAD
      PV = 0.
      DO 100 N = 1,LFTME
      PV = PV+(LOAD*BYC*((1.+IR+EER)**N) - BYME*((1.+IR)**N))/
     1((1.+IRR)**N)
100   CONTINUE
      PRESVL = PV
      RETURN
      END



      FUNCTION PVTAX(IRR)
      COMMON/R/LOAD,BYC,BYME,IR,EER
      COMMON/I/LFTME
      COMMON/TAX/DEP
      REAL IRR,IR,LOAD
      PV = 0.
      DO 100 N = 1,LFTME
      X =      (LOAD*BYC*((1.+IR+EER)**N) - BYME*((1.+IR)**N))
      X = 0.52*X+0.48*DEP
      PV = PV +X/((1.+IRR)**N)
100   CONTINUE
      PVTAX =  PV
      RETURN
      END
```

Fig. A3. Computer program IROR and its accompanying subroutines.

TECHNICAL INFORMATION DEPARTMENT
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720