Chapter I

ANALYTICAL METHODS

Chapter I.– ANALYTICAL METHODS

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Analytical Methods

INTRODUCTION

Chapters in volume I have established the technical feasibility of numerous techniques for converting sunlight into other useful forms of energy. The present discussion describes a variety of methods for measuring the value of these systems. It is important to recognize that many of the critical variables cannot be characterized with great precision and cannot be expressed in terms which permit easy comparison. Costs and benefits apply to different groups of investors and consumers (requiring a comparison between costs extracted from one group and benefits enjoyed by another), occur at different times, and occur in different areas (requiring a comparison between impacts on the profitability of individual firms, the environment, employment, national security, civil liberties, etc.). Such issues exceed the capabilities of conventional economic theory. The choice between alternative energy strategies must therefore ultimately reflect a political judgment and must be made without the comfort and guidance of mathematically precise forecasts. It would be dishonest to obscure the fact that such political judgments are necessary, and it is essential to be modest about the capabilities of analysis. All that is possible is to develop techniques for systematically evaluating aspects of the alternatives which can be quantified.

The perceived costs of solar energy depend strongly both on the perspective from which they are examined and on the methods used for evaluating them. It is fair to assume that investors are attracted to solar equipment only if they are able to earn rates of return comparable to those earned in other types of investments exhibiting Similar risks. The measure of merit, which is the primary basis for economic comparisons in this report, is the price paid by the ultimate consumer of energy. This price depends on the kind of equiptment used and on the economic expectations of the owner of the equipment. The following discussion develops a self-consistent technique for reducing the large number of variables which affect this price to an easily interpretable average consumer energy price.

The financial merit of investments can be assessed in a number of different ways. Methods vary in their sophistication, and alternative investments are often ranked differently depending on the method used. The techniques include a comparison of:

— initial capital investment;

—the "payback time, " or the time required for cumulative income to equal the initial investment;

—rates of return from the investment; and

—the "present value" of investments.

The techniques actually used to compare investments vary greatly and frequently involve a number of factors which are not easy to quantify. Critical decisions depend on the financial condition of the investor, his perception of the risk involved, the skill with which the proposed equipment is marketed, the availability of funding, his attitude toward diversifying his investment portfolio, and other psychological factors. The simple comparison of initial costs, for example, will almost certainly continue to be one of the most critical variables in making decisions, in spite of the fact that sophisticated analysis might show that decisions based on this comparison may be unwise. It is important, therefore, not to be mesmerized by quantitative measures of merit when attempting to assess the marketability of equipment.

The bulk of the analysis in this report is based on discounted cash-flow (or "present value") analysis — a systematic way of evaluating the profitability of different kinds of investments.

SOCIAL DISCOUNT THEORY

Before proceeding into the detailed analysis of private investment decisions, a brief review will be given of an entirely different technique for evaluating the cost of energy equipment. The "social" cost of energy —or the cost perceived by society as a whole— may differ greatly from the costs perceived by individual producers or consumers, even if the full costs of environmental damage and other immediate social disbenefits are identified and charged to the appropriate equipment owner. For example, today's market does not accurately reflect the cost of resources which are being depleted but are not now in short supply. This lack of foresight is encouraged by policies designed to keep prices artificially low (price regulations, concessionary tax policies, etc.). Another reason for the differences between private and social costs is the way in which any analyses made by private investors discount future costs and benefits with respect to present costs. The interest rate, which should be used to evaluate the real marginal productivity of capital from the point of view of society as a whole (the so-called "social discount rate"), is the subject of considerable dispute.

The value of societal costs computed in this way must be treated with great caution. If ranking energy alternatives with these simple discounting procedures results in very different priorities than the ranking which results from conventional financial analysis, however, it will be important to be able to understand whether the difference really implies that conventional financial decisions are resulting in a sacrifice of social benefits for short-term private gains. In this sense calculating a "societal cost" can serve as a kind of warning mechanism, but much work remains to be done after the warning has been received. It must be noted that this technique does not eliminate the difficulty of assigning a just value to goods or services, since all prices used in the calculation are estimates of prices in the open market; determining a real marginal cost to society for each item costed would give a better answer but there is no agreement about how to conduct such estimates.

It might be thought that the Federal Government would make decisions to maximize social benefits, but the argument of how to measure the real value of a Federal investment is more complex than the debate over techniques used to measure "social value." It could be argued, for example, that if the Government extracts capital from society, it must invest this capital so as to yield an effective rate of return equivalent to that which would be earned on the money in private hands. This is, in effect, the current policy of the U.S. Government. The basis for Federal procurement is dictated by the Office of Management and Budget, which has declared that the Government should invest funds in a manner which earns a rate of return equivalent to that earned by a typical private concern "before inflation and after taxes." This is declared to be 10.0 percent.[1]

[1] OMB Circular A-94.

It is clear, however, that this rigid formula maximizes social benefits only if it assumed that social benefits are maximized by private investment decisions. I n several European nations different discount rates are applied to projects on the basis of political judgments about the social merits of different technologies and the technique has been used in the past by the United States as an implicit subsidy to water projects, rural electrification, and other investments felt to be in the public's interest.

PRIVATE EVALUATION OF COSTS

This analysis provides quantitative measures of the financial attractiveness of solar energy measured from four separate perspectives:

1. An individual contemplating investing in equipment for his private residence.
2. A corporation which will include the cost of the solar energy in the price of the company's product or service (the corporation might own an apartment building, for example, and include energy costs in the rent, or it might own a manufacturing concern using solar energy to provide power for manufacturing processes).
3. Utility ownership (both private and municipal utilities are examined).
4. Federal, State, or municipal governments.

The economic perspectives of these four types of investors differ in a number of respects. Each has different expectations about the profitability of investing in solar equipment; has access to different types of financing; is subject to different rates of interest by lenders; has different tax status (tax rates and allowed deductions and credits differ); and each compares alternatives using techniques which differ greatly in sophistication. As a result, separate analysis is necessary to predict whether investors in each group would be attracted to solar energy. Separate analysis is also necessary to measure the impact of proposed policies on each type of owner since each group is influenced by incentives in different ways. There are also great differences between investors in the same category, and the categories themselves do not reflect the full complexity of the situation. The analysis which follows selects representative examples from each group.

Utilities' perspectives on energy costs are unique since while a utility's customers pay a price which represents the average cost and make investments on this basis, the utility will compare prospective new investments on the basis of higher marginal costs; the costs of electricity and the cost of fossil fuels from some new sources are significantly higher than the average or "imbedded cost" of energy from all generating sources. [2]

QUANTITATIVE EVALUATION OF FINANCING ALTERNATIVES

The cost of operating any kind of energy equipment can be divided into four broad categories:

1. **Capital** Costs.–These include the cost of paying investors for their funds, and any taxes and insurance which must be paid on tangible property. In most cases, all of these costs are directly proportional to the initial cost of the system.
2. **operating and Maintenance (O&M)** Costs. -These include costs of keeping equipment in repair, paying operators, etc., but do not include fuel costs.
3. **Energy** Costs.–These include the price paid-for all fossil fuels and electricity used by the equipment. In cases where energy can be sold to a utility, the owner's energy costs are reduced by the amount of income received from this source.

[2] Paul L. Joscow, "Inflation and Environmental Concern: Structural Change in the Process of Public Utility Price Regulation, " 17,2 (autumn *1974),* p 291,

4. **Replacement Costs.** -These include the cost of replacing those large pieces of equipment which wear out before the bulk of equipment in the system.

Most of the differences between owners are reflected in the cost of capital, since this this represents differences in tax status. It is shown later that the component of the average cost of energy to the final consumer, which is traceable to capital costs, can be written in linear form regardless of ownership. This capital cost is written in the following form:

average capital charges perceived by the final consumer of energy
= k_lX (initial cost of equipment)

The constant in this equation (k_l), called the "levelized fixed charge rate, " represents the ratio between the portion of consumer prices attributable to capital-related costs and the initial cost of equipment. Its value is shown in figures I-I and I-2 for several assumptions about ownership. The assumptions used to prepare these curves are shown in table I-I (the origin of these assumptions are discussed in a later section). The figures implicitly assume inflation, since the interest rates and rates of return expected reflect actual market rates.

Figure I-I shows the relationship between capital charges and the consumer's discount rate. Figure I-2 shows relationship between capital charges and the rate of return expected by a corporate owner. The capital costs charged to consumers by the corporate owner are assumed to be constant during the lifetime of the plant (this is usually called "normalized" accounting), and therefore the average cost of capital to the consumer is independent of the consumer's discount rate.

Figure I-1 .—Sensitivity of Capital Charges to Consumer's Discount Rate

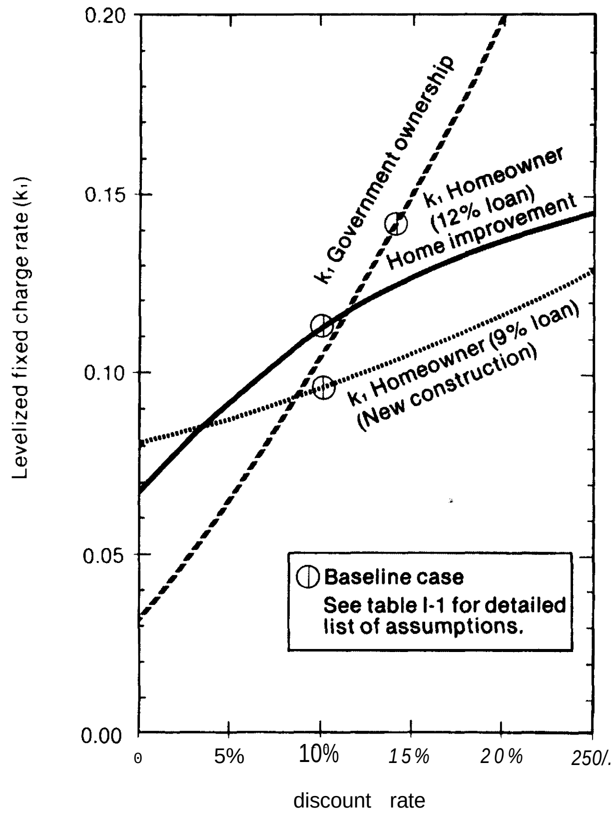

Figure 1-2.—Sensitivity of Capital Charges to Rate of Return for Corporate Owner

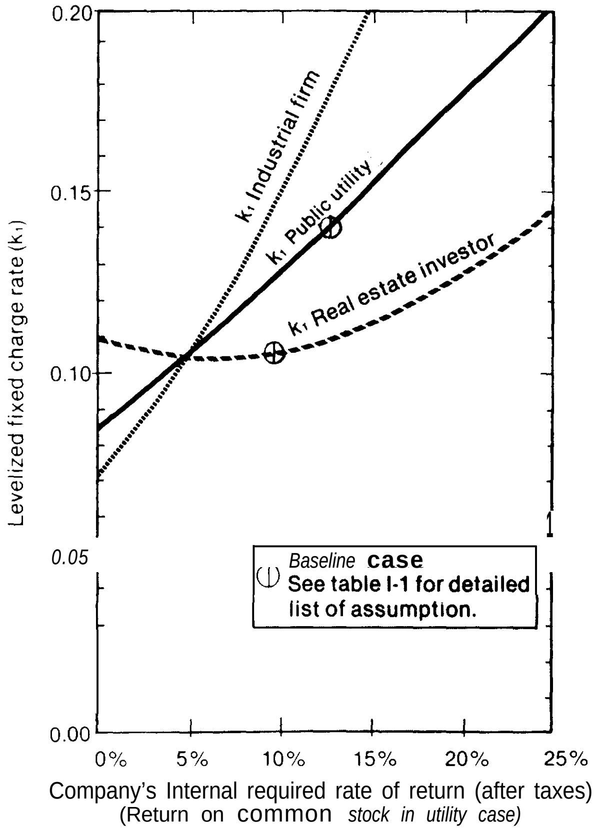

Table I-1.— Baseline Assumptions Used to Prepare Figures I.1 and I.2.

	Federal Government	Homeowner (new construction)	Homeowner (home improvement)	Real estate investor	Industry	Public utility	Municipal utility
Required rate of return	.16	variable	variable	.10	.20	—	0
Down payment fraction	1.0	.25	0	.25	.70	0	0
Interest on loan or bonds	—	.09	.12	.10	.10	.09	0.06
Debt fraction	0	.75	1.0	.75	.30	.53	1.00
Earnings on pfd stock	—	—	–	—	—	.09	0
Fraction of pfd stock. .	o	0	o	o	“o	.122	0
Earnings of common stock	—	—	—	—	—	.13	0
Fraction of common stock	0	o	0	o	0	.348	0
Depreciation:		–	—	DDB	SL	DDB	.
Depreciation period. . .		—	—	15	30	30	–
Marginal income tax rate (combined Federal & State)	0	.35	.35	.50	.50	.50	o
Life/term of loan (yrs). .	30	30	10	30	30	30	30
Property tax rate	0	.02	.02	.02	.02	.02	.02’
insurance rate	0	.0025	.0025	.0025	.0025	.0025	.0025
Investment tax credit rate	0	0	0	0	.10	.10	0
Inflation rate. ., ...	0	.055	.055	.055	.055	.055	.055
Salvage value ($).	0	0	0	0	0	0	0
Depreciation of replacement .	—	—	—	DDB	SL	DDB	—

SL = Straight-line depreciations DDB = Double. declining balance depredation . Payments in lieu of taxes
NOTE All costs are levelized over 30 years

The routine operating and maintenance (O&M) costs of a system are written in the following form:

average O&M costs perceived by energy consumer
$= k_2 X$ (O&M cost in first year of the system's operation)

where the constant k_2 depends on the consumer's discount rate, the life expectancy of the system, and on the average rate of inflation. It is assumed that operating costs do not change in constant dollars for the life of the system. This represents a considerable simplification of real cases, since the costs of maintaining and repairing real systems vary from year to year and overall maintenance costs tend to increase as the system ages. The approximation used here is necessary, however, since it is difficult or impossible to estimate the maintenance schedules reliably, particularly for untested or hypothetical systems.

The fuel costs are written in the following form:

average energy costs perceived by consumer
$= k_3 X$ (energy costs in the first year of the system's operation)

where k_3 depends on the life expectancy of the system, the consumer's discount rates, and assumptions about the rate at which energy from conventional sources increases in price.

The replacement costs are somewhat more complex, since they depend on the number and schedule of replacements.

Using the terms defined here, the levelized annual cost of energy to the ultimate consumer of that energy (which is called PRICE) can be written in the following form:

PRICE $= k_1 \times$ (initial price of equipment)
$+ k_2 \times$ (initial O&M costs)
$+ k_3 \times$ (initial energy costs)
$+$ (levelized replacement costs)

The remainder of this discussion is directed towards a detailed analysis of the value of these constants for a variety of assumptions about ownership, costs of capital, and regulatory policy.

SOME BASIC EQUATIONS

The present value of all consumer energy expenses can be computed as follows:

$$\text{PRESENT VALUE }(d) = \sum_{t=0}^{N} \frac{[\text{energy-related expenses in year } t]}{(1+d)^t} \qquad (1)$$

where N is the lifetime of the system in years. (Table I-2 contains a dictionary of variables used in this section and can be used for reference.) The function PRICE was defined previously to be the average cash outlay which, if paid in equal amounts during the life of the system, would result in the same present value as the actual cash flow. This can be computed from the previous function as follows:

$$\text{PRICE }(d) = \text{CRF}(d,L) \times [\text{PRESENT VALUE }(d)] \qquad (2)$$

$$\text{CRF}(d,L) = \frac{d(1+d)^L}{(1+d)^L - 1} \qquad (3)$$

where CRF(d,L] is a constant called the "capital recovery factor. " (The name results from the fact that CRF(d,L) is also the ratio between the annual payments on a loan and the initial value of the loan if it is for L years and pays an interest rate d.) The price function is very closely related to the present value of an investment calculated using conventional techniques.

Federally Owned Equipment

A variety of techniques are used to evaluate Federal investments. The following discussion will follow the procedures suggested for use in internal planning by OMB Circular A-94. This procedure requires the estimate of both discounted costs and benefits, but since the benefits are assumed to be identical for all systems compared only the procedure for evaluating costs will be outlined.

Table I-2.—Symbols Used in Financial Analysis

a = accelerated depreciation multiplier (a = 1 for straight line; a = 2 for double-declining balance)

B(r,LN,t) = interest paid during year t on $1.00 of debt paying interest r over LN years (defined in equation 12)

CRF(d,L) = capital recovery factor for a loan with interest d payable over L years (defined in equation 3)

d = consumer's discount rate

d' = consumer's discount rate in constant dollars (1 +d') = (1 + d)/(1 + i)

D(a,DP,t) = permitted depreciation of $1.00 of initial investment in year t given a permitted depreciable lifetime of DP and an accelerated depreciation multiplier of a (defined in equation 22)

DEP(a,DP,R) = net present value of depreciation with accelerated depreciation multiplier a, depreciation period DP, and discount rate R (defined in equation 29)

DP = depreciation period

E(t) = payments for energy made during year t (evaluated in constant dollars valued at the first year of the system's operation)

f = fraction of initial value of system financed with mortgage

FIX = fixed charge made by a utility or other industry to cover levelized capital expenses and yield the desired rate of return

f_b = fraction of utility plant financed with bonds

f_c = fraction of utility plant financed with common stock

f_p = fraction of utility plant financed with preferred stock

i = annual rate of inflation

IN = fraction of capital value of plant paid for insurance annually

INCOME(t) = gross receipts received by a system owner during year t of a system's operation

ITC = investment tax credit (fraction of capital value of plant deducted from taxes in first year of operation)

K_o = installed initial cost of equipment including inflation and interest during construction. K_o is evaluated in dollars valued at the first year of the system's operation

K(t) = capital expended during year t of **a** plant's construction (evaluated in dollars valued at the first year of the system's operation)

k, = multiplier for determining the capital-related component of the levelized PRICE paid by customers for energy from the initial installed cost •

k_2 = multiplier for determining the energy component of the levelized PRICE paid by customers for energy from the energy cost in the first year of the system's operation*

ks = multiplier for determining the routine maintenance component of the levelized PRICE paid by customers from the cost of routine maintenance in the first year of the system's operation"

k_4(t) = multiplier for determining the contribution of a major replacement made during year t to the levelized PRICE paid by customers given the *cost* **of the replacement in year t measured** in dollars valued during the first year of the system's operation*

L = period over which system costs are measured

LN = period of loan

M_o = routine operating costs in the first year of the system's operation

M(t) = major replacements made during year t of the systems operation (measured in dollars valued at the first year of the system's operation). For most **years** M(t) will be zero

N = the system's life in years

N_c = number of years required to construct a large plant or system

N_r = life of major replacements

PV(d) = present value of a cash flow given a discount rate d (defined in equation 1)

PRICE = levelized annual price charged to the customer

PT = fraction of initial capital value of the equipment paid annually for property tax

r = interest rate paid on mortgages

R = commercial and industrial required rate of return

R_u = utility's permitted rate of return (defined in equation 32)

r_b = interest rate paid by utilities on bonds

= return paid by utilities on common stock

= return paid by utilities on preferred stock

S(R,LN) = annual amount paid by utilities into a sinking fund to retire debt at the end of LN years assuming that the fund is invested at a return of R (defined in equation 35)

t = the year of system operation under consideration

T = net income tax rate (defined in equation 11)

T, = Federal income tax rate

T_s = State income tax rate

TAX(t) = income tax paid in year t

ð(t) = a switch function used for convenience, b(t) = O unless t = O in which **case** ð(0) = 1

"NOTE: On the $k_1, k_2, k_3,$ and k_4 (t) multipliers, no primes indicate Federal financing, one prime indicates homeowner financing, two primes indicate conventional commercial financing, three primes Indicate utility financing using normalized accounting, and four primes indicate utility financing using flow-through accounting.

The expenses occur in four separate categories:

CAPITAL-RELATED EXPENSES

The initial capital investment is called K_o. Since all of this investment is assumed to be made in the first year, no discount is applied and therefore the levelized capital costs can be written as follows:

$$\text{LEVELIZED CAPITAL COSTS} = k_1 K_o \tag{4}$$

$$k_1 = \text{CRF}(d,L)$$

where CR F(d,L) is the capital recovery factor defined previously, L is the period over which the system costs are evaluated and d is the Federal discount rate. (The OMB circular states that for planning purposes, the Government should use d = 10.0 percent, if all expenses are expressed in constant, uninflated dollars.)

ENERGY EXPENSES

Energy expenses must be discounted to present value using the discount rate. If the cost of energy in constant dollars in a year t is called E(t), then the levelized energy expense is given by:

$$\text{LEVELIZED COST OF PURCHASED ENERGY} = k_2 E(1) \tag{5}$$

$$k_2 = \text{CRF}(d,L) \sum_{t=l} \frac{E(t)}{E(1)} \left(\frac{1+i}{1+d}\right)^t$$

where i is the rate of inflation.

O&M EXPENSES

For simplicity, it is assumed that the routine operating and maintenance expenses (excluding energy costs) will not change during the life of the system if these expenses are expressed in constant dollars. If these constant expenses are called MO, the levelized annual O&M expenses are given by:

$$\text{LEVELIZED OPERATING COSTS} = k_3 M_o \tag{6}$$

$$k_3 = \text{CRF}(d,L)/\text{CRF}(d',L)$$

$$d' = (1 + d) / (1 + i) - 1$$

REPLACEMENT EXPENSE

It may be necessary to replace major components during the life of the system. If the cost of replacements made in the year t (less the salvage value of the component replaced) is called M(t), the levelized value of replacement costs can be computed as follows:

$$\text{LEVELIZED REPLACEMENT COSTS} = \sum_{t=1}^{t=L} k_4(t)\, M(t) \tag{7}$$

$$k_4(t) = \text{CRF}(d,L) \left(\frac{1+i}{1+d}\right)^t \tag{8}$$

(Note that M(t) is zero for most years.)

PRICE

The total levelized costs of providing energy services can then be written as follows:

$$\text{PRICE} = \tag{9}$$

$$k_1 K_O + k_2\, E(1) + k_3 M_o + \sum_{t=l}^{L} k_4(t)\, M(t)$$

Homeowner Financing

A calculation of the effective price paid by a homeowner for energy generated by a solar device which he owns requires adding a number of complexities to the case just described, although the overall components of cost fall into the same four categories and the final formula for levelized cost can also be reduced to a simple linear equation identical to equation (9).

CAPITAL-RELATED EXPENSES

The capital-related charges for a homeowner fall into four basic categories:

Payment on a mortage.—It is assumed that the homeowner will finance a solar unit on a new home with the same mortage used to purchase the rest of the house, and that systems retrofitted to existing homes are financed with "home improvement loans" covering the full value of the improvement. If it is assumed that the loan covers a fraction (f) of the equipment and that an interest rate (r) must be paid for a period of (LN) years, the annual mortgage payments are given by:

$$\text{ANNUAL MORTGAGE PAYMENTS} = f\,K_o\,CRF(r,LN) \quad (10)$$

Income taxes.–The homeowner will be able to deduct the interest paid on the equipment and property taxes from his income when he computes his taxes. It is assumed that the owner pays a net income tax rate T. Since State taxes are deductible from Federal taxes the net tax rate T can be computed from the Federal tax rate T_f and the State tax rate T_s as follows:

$$T = T_f(1-T_s) + T_s = T_f + T_s - T_f T_s \quad (11)$$

The interest in year t on the loan value fK_o will be given by:

$$\left(\text{INTEREST ON MORTGAGE PAID IN YEAR } t\right) = fK_oB(r, LN, t) \quad (12)$$

$$B(r,LN,t) = [(1+r)[-(r-CRF(r,LN)) + CRF(r,LN)]$$

Property taxes.—It is assumed that property taxes are charged at a rate which is directly proportional to the initial value of the installation, and that these payments are given by:

$$\text{PROPERTY TAXES} = PT\ K_o \quad (13)$$

where PT is the property tax rate.

Insurance.–It is assumed that the owner pays insurance on the equipment at a rate directly proportional to the initial value of the installation and that these payments are given by:

$$\text{INSURANCE PAYMENTS} = IN\ K_o \quad (14)$$

Using this notation, a down payment of $(1-f)K_o$ will be made in year O and the total annual capital-related costs during year t can be expressed as follows: (15)

$$\text{CAPITAL CHARGES}(t) = K_o[(1-f)\ CRF(d,L) + fCRF(r,LN) - Tf(1+r)^{t-1}(r - CRF(r,LN) + CRF(r)LN) + (1-T)PT + IN]$$

and the levelized capital charges can then be expressed as follows:

$$\text{LEVELIZED CAPITAL CHARGES} = k_1 K_o \quad (16)$$

$$k_1' = CRF(d,L)\left[(1-f) + f(1-T)\frac{CRF(r,LN)}{CRF(d,LN)} - \frac{fT}{1+r}\,\frac{r-CRF(r,LN)}{CRF(d',LN)} + \frac{(1-T)PT}{CRF(d,L)} + \frac{IN}{CRF(d,L)}\right]$$

$$d' = (1+d)/(1+r) - 1$$

ENERGY EXPENSES

The levelized cost of fuel and electricity purchased by a homeowner can be expressed in terms of the price paid for these items during the first year of the system's operation E(l). The equations are identical to the ones developed in the previous case:

$$\text{LEVELIZED COST OF PURCHASED ENERGY} = k'_2 E(1) \quad (17)$$

$$k'_2 = CRF(d,L)\sum_{t=1}^{L}\frac{E(t)}{E(1)}\left(\frac{1+i}{1+d}\right)^t$$

O&M EXPENSES

If the cost of routine annual operating and maintenance expenses (not including the cost of purchased energy) during the first year the system operates is called M_o, the cost of O&M in the year t will be equal to $(1+i)^t M_o$ where i is the rate of inflation. The levelized cost of O&M can then be expressed as follows:

$$\text{LEVELIZED O\&M COSTS} = k_3' M_o \quad (18)$$

$$k'_3 = k_3$$

where k_3 was defined in equation (6).

REPLACEMENT EXPENSES

It is assumed that the homeowner does not take out a loan to replace components of his onsite system but simply pays for new components out of existing savings. The levelized replacement costs can then be expressed in terms of the cost of items replaced each year.

$$\text{LEVELIZED REPLACEMENT COSTS} = \sum_{t=1}^{L} M(t)k'_4(t) \qquad (19)$$

$$k'_4(t) = \text{CRF}(d,L)\left[\frac{(1+i)}{(1+d)}\right]^t \qquad (20)$$

PRICE

The levelized price the homeowner pays can then be written as:

$$\text{PRICE} = k'_1K_0 + k'_2E(1) + k'_3M_0 + \sum_{t=1}^{L} k'_4(t)M(t) \qquad (21)$$

Commercial and Industrial Financing

The following discussion estimates the price which is charged by firms other than utilities for energy services. It is impossible to construct a single procedure for evaluating the financing of all private firms, since each has different sources of financing, is in a different tax position, and has different financial objectives. The procedure described below provides a simplistic way of evaluating:

- The price which an owner of an apartment building charges for energy services (lighting, miscellaneous electricity, heating, cooling, and hot water).
- The amount the price of a manufactured item is increased to pay for energy used by a manufacturing concern.

CAPITAL-RELATED EXPENSES

In computing the price, it is assumed that equipment owners expect a fixed rate of return on their equity and that all operating and maintenance costs (including the cost of purchasing fossil fuels and electricity) are passed along directly to the customer. If the investment in novel energy equipment is perceived to involve a greater risk, the expected rate of return will probably be higher than those expected from other areas of the same industry.

There are three major differences between the financial analysis made for the homeowner and the analysis which must be made for commercial and industrial firms:

- Depreciation of energy equipment, fuel, and operating costs can be subtracted from gross income for tax purposes.
- Investment tax credits may be available.
- Insurance payments are tax deductible.

Depreciation.-The type of depreciation permitted by the IRS depends both on the type of business and on the nature of the equipment involved. A ruling must be made both on the system's lifetime for depreciation purposes and on whether an accelerated depreciation technique will be permitted.

If a new building derives more than 80 percent of its revenues from apartment rental income, and if it has only a single owner, the heating and cooling equipment in the unit can presently qualify for "double declining balance" depreciation. Buildings with more than one owner are permitted only a 1.25 declining balance. Most new industrial equipment can also qualify for double declining balance for tax purposes if its expected life is greater than 3 years. A ruling by IRS on solar equipment must be made. For a first approximation it will therefore be assumed that the equipment is treated like conventional heating and cooling systems for tax purposes. These assumptions can be changed if other rulings are made by IRS, and possibilities are examined in the policy discussion.

The depreciation in year t will be called $D(a, DP,t)K_o$ where a = 2 for double declining balance, a = 1.25 for 1.25 declining balance, etc. Double-declining balance depreciation will be assumed in most cases. This means that the owner can deduct twice the straight-line depreciation calculated on the basis of the depreciated value of the equipment in the year the depreciation is claimed (e.g. if a $100 asset has a 10-year life, the first year deduction is 2 x $100/10 = $20, the second year deduction is 2 x (100 – 20)/10, and so on. It is permissible to shift from an accelerated depreciation technique whenever there is an advantage in doing so. It is assumed that the investor will make such a shift.

D(a,DP,t) can be written explicitly as follows:

$$D(a,DP,t) = \begin{cases} (a/DP)\,(1-a/DP)^{t-1} & t < t_o \\ (1-a/DP)^{t_o-1}/(DP-t_o+1) & t \geq t_o \end{cases} \qquad (22)$$

t_o = the first year for which t is greater than or equal to 1 + DP (l-l/a)

A shift is made to straight-line depreciation when t = t_o. Notice that if a = 1 the shift is made at the first year and the depreciation is a simple straight line for the entire system lifetime.

Tax Credits.–Some of the equipment being examined may qualify for an investment tax credit. This credit can only be taken in the first year of the system's operation, and has been 10 percent of qualifying capital for the past few years. When tax credits are allowed, the calculations assume that the owner is permitted a single-tax credit equal to ITC x K_o during the first year of operation. The constant ITC is the ratio of the credit obtained to the initial capital value of the equipment (K_o).

Insurance Deductions.—Insurance payments can be subtracted from gross income for tax purposes.

PRICE

The price charged by the owner of the energy equipment can be calculated from: (1) the annual payments which must be made to cover capital and operating costs (the payments made in year t are called OUTLAYS(t)); (2) the gross income received (income); and (3) the taxes paid (TAX(t)). These items can be evaluated as follows:

$$OUTLAYS(t) = \begin{cases} (1-f)K_o \quad \text{when } t=0 \\ K_o[PT+IN+fCRF(r,LN)] + (1+i)^t[M_o+M(t)+E(t)] + TAX(t) \text{ when } t>0 \end{cases} \qquad (23)$$

where f = fraction of project financed by debt

$$TAX(t) = T(INCOME(t) - (1+i)t(Mo+M(t) + E(t)) - K_o(fB(r,LN,t) + D(a,DP,t) + PT + IN) - (\text{deductions for major replacements})] - K_o ITC\,\delta(t-1) \qquad (24)$$

$$\delta(t) \equiv \begin{cases} 1 & \text{when } t = 0 \\ 0 & \text{otherwise} \end{cases}$$

As shown, the tax is reduced by K_oITC in the first year of operation. It is assumed that the income from the project consists of a constant charge for capital which permits the owner to earn his desired rate of return. The desired rate of return is called R and the constant capital charge is called FIX. It is also assumed that all operating costs, including the cost of purchased fuels, are passed along to customers in the year in which they are incurred. The routine annual operating costs (excluding the cost of purchased energy) are called MO; the cost of major items replaced during year t is called M(t) which in most years is zero); and, the cost of energy purchased in the year t is called E(t). All of these costs are expressed in constant dollars valued in the initial year of the system's operation. The income derived from an investment in energy equipment during year t can then be written as follows:

$$INCOME(t) = FIX + (1+i)'(Mo+E(t)) \qquad (25)$$

where i is the assumed rate of inflation. By definition, if the owner charges rates which yield an income equal to INCOME (t), the owner is earning a rate of return R on his investment, and the present value of all cash flows discounted using the owner-desired rate of return R is zero. It can be shown that:

$$FIX = k_1''K_0 + \sum_{t=1}^{L} k_4''(t)M(t) \tag{26}$$

$$k_1'' = \frac{CRF(R,L)}{1-T}\left[(1-f) + f(1-T)\frac{CRF(r,LN)}{CRF(R,LN)} - \frac{fT}{1+r}\,\frac{r-CRF(r\ LN)}{CRF(R',LN)} - \frac{ITC}{1+R} - T \times DEP(a\ DP,R)\right] + IN + PT \tag{27}$$

$$R' = (1+R)/(l+r)-1 \tag{28}$$

The net present value of depreciation D(a, DP, t) over the depreciation period DP is DE P(a,DP, R) and can be written as:

$$DE\,P(a,DP,R) = \begin{cases} o & \text{if } d = o \\ \dfrac{1}{DP[CRF(R,DP)]} & \text{if } a = 1 \\ (a/DP)\,\dfrac{1-\left[\dfrac{1-a/DP}{1+R}\right]^{to-1}}{R + a/DP} + \left[\dfrac{(1-a/DP)^{to-1}}{(DP-to+1)}\right]\left[\dfrac{(1+R)^{DP+1-to}-1}{R(1+R)^{DP}}\right] & \text{if } a > 1 \end{cases} \tag{29}$$

$$t_o = \text{first integer greater than or equal to } 1 + DP(1-1/a) \tag{30}$$

$$k_4''(t) = \frac{CRF(R,L)}{1-T}\left(\frac{1+i}{1+R}\right)^t \times \left[1 - \frac{ITC}{(1+R)} - T \times [DEP(a,DP,R)]\right] \tag{31}$$

The levelized price paid by customers is readily calculable once FIX is known since:

$$PRICE = FIX + CRF(d,L)\sum_{t=1}^{L}\left|\frac{[M_o + E(t)]\ (1+i)t}{(1+d)^t}\right| \tag{32}$$

$$PRICE = k_1''K_o + k'_2E(l) + k'_3M_o + \sum_{t=1}^{L} k_4''(t)M(t) \tag{33}$$

Utility Financing

The financing of utility projects is a complex process. Projects are of enormous scale, many sources of funds are used, and a network of regulations govern accounting procedures. Financing varies greatly from region to region because of different rulings by the State public utility commissions which monitor utility financing. Furthermore, public and privately owned utilities are financed in very different ways. The following discussion presents a series of simplified methods for approximating utility accounting. A standardized procedure for computing utility costs has been developed in two recent analyses, and the methods developed here are a somewhat simplified version of these procedures. [3,4]

CAPITAL-RELATED EXPENSES

Rate of Return.–The major difference between investments made by utilities and in-

[3] *The Cost of Energy From Utility-Owned Solar Electric Systems: A Required Revenue Methodology for ERDA/EPRA Evaluations*, June 1976 (ERDA/J PL-101 2-76/3).

[4] E PRI Technical Assessment Group, *Technical Assessment Guide*, August 1977.

vestments made by the smaller organizations discussed previously is the source of funds used for construction and operations. utilities have three primary **sources of funds: common stock, preferred stock, and bonds.** The fraction **of a given facility financed by each of these sources are called f_c, f_P, and f_b, respectively. The rate of return which a utility must earn to meet its obligations (R_u) can be computed from those fractions and from the rates of return which must be paid for each source of capital (these are called r_c, r_P, and r_b). Note that debt service is tax deductible, whereas stock dividends are not.**

$$R_u = (1-T) r_b f_b + r_c f_c + r_p f_p \tag{34}$$

There is some dispute in the utility community about whether to reduce the cost of debt by the factor I-T as shown in equation (34).

The rates which can be earned by utilities are controlled by public utility commissions in each locality, and the return earned by holders of common stock varies as a function of the rulings of these commissions and the prevailing economic climate. For the purposes of the analysis which follows, it is assumed that the utilities are permitted to earn returns equivalent to the average return paid over the past decade. In the case of a municipal utility, the facility would be financed entirely from bonds and no taxes would be paid. Therefore in this case $R_u = r_b$ where r_b is the interest earned on the municipal bonds issued to finance the project.

Sinking Fund.– **It is assumed that the utility pays its stockholders and noteholders a uniform return on their investments during the life of the plant and returns the entire principal borrowed when the loan is retired. In order to provide for this final payment the utility must set aside a "sinking fund, " which accumulates an amount equal to the capital borrowed by the utility by the time the plant is decommissioned. If the utility can earn an amount R on the funds set aside for this purpose, an adequate sinking fund can be developed if an amount $S(R,LN)K_o$** is **set aside each year where:**

$$S(R,LN) = \frac{R}{(1+R)^{LN} - 1} \tag{35}$$

It is assumed in this analysis, that the rate R that the utility can earn on the funds in the sinking fund is equal to R_u.

Plant Construction. -In the equations presented *Up* **to this point, it is assumed that the capital has been paid in one sum in year t = O. utility devices,** on the other hand, may **be so** large that they require many years to construct. Investors will expect a return on their investment during the construction period even though the plant is not earning revenue. **Utilities are currently permitted to charge customers for the cost of capital tied up during construction only after the plant begins to generate power. (The allowances vary from one regulatory jurisdiction to another.) This is done by including an "allowance for interest used during con**struction" in the value of capital on which the utilities are permitted to earn a return, **For ratemaking purposes,** therefore, the **capital value of the plant (K_o) used to compute the price charged to customers includes the cost of capital up to the time that the plant enters service. If the outlays for labor and equipment during year t are called K(t) (where K(t) is given in constant dollars valued in the year the plant begins operating), the value of the plant on which a return can be earned (K_o) can be approximated as follows:**

$$K_o = \sum_{t=-N_c}^{0} K(t) \left[\frac{1+i}{1+R_u}\right]^t \tag{36}$$

where N_c is the number of years required to construct the plant.

PRICE

Using this notation, it is possible to

develop a simplified analysis of the flow of utility assets:

$$\text{OUTLAYS}(t)=K_o[PT+IN+f_b r_b+f_c r_c+f_p r_p+ S(R_u,LN)]+TAX(t)+(1+i)^t(M_o+M(t)+E(t)) \tag{37}$$

$$\begin{aligned}TAX(t)=T[&INCOME(t)-(1+i)^t(M_o+M(t)+E(t))\\&-K_o(f_b r_b+PT+IN+D(a,DP,t))\\&-\text{(deductions from major replacements)}]\\&-K_o ITC\,\delta(t-1)\end{aligned} \tag{38}$$

In this case PT includes ad valorem and all other taxes not based on income. Using methods described earlier it can be shown that:

$$FIX'=k_1'''K_o+\sum_{t=1}^{L}k_4'''(t)M(t) \tag{39}$$

$$k_1'''=PT+IN+\frac{R_u+S(R_u,LN)}{1-T}-\frac{RF(R_u,L)}{1-T}\times\left[T\times DEP(a,DP,R_u)-\frac{ITC}{1+R_u}\right] \tag{40}$$

$$k_4'''(t)=\frac{CRF(R_u,L)}{1-T}\left(\frac{1+i}{1+R_u}\right)^{t_o}\left[1-\frac{ITC}{1+R_u}-T\times DEP(a,DP,R_u)\right] \tag{41}$$

With this notation the PRICE charged by the utility for power is given by:

$$PRICE=k_1'''K_o+k_2'''E(1)+k_3'''M_o+\sum_{t=1}^{L}k_4'''(t)M(t) \tag{42}$$

where

$$k_2'''=k_2'$$
$$k_3'''=k_3'$$

Throughout this analysis it has been assumed that utilities will use the rate of return R_u to discount future cash flows. In fact, however, a recent survey of privately owned utilities conducted by Consolidated Edison Company of New York revealed that only about 20 percent of the companies surveyed used this formulation. The remainder used a rate of return which did not reduce R_u by the tax savings resulting from debt financing. This technique is used because it results in a conservative analysis of future risks. The higher discount rate places a penalty on near-term capital investments and discounts future savings more heavily.

The price charged by the utility depends on the accounting procedures required by local utility commissions. The two types most commonly used are discussed below:

NORMALIZED ACCOUNTING

Most privately owned utilities employ a procedure called "normalized" accounting. In this procedure, customers are charged a fixed price for capital in much the same way as the conventional industrial procedures discussed in the previous case. The utility is, however, permitted to charge a rate for capital as though it were depreciating its facilities using "straight-line" depreciation techniques, with the taxes actually paid based on an accelerated depreciation schedule. Since all depreciation techniques result in the same total amount of depreciation, customers end up paying the same total amount for electricity with this procedure as if the utilities charged them on the basis of the actual accelerated depreciation. This procedure, however, permits collecting more money from customers early in the plant's life and results effectively in a zero-interest loan from the customer to the utility. (These funds are used to finance new construction but cannot be included in the utility's rate base.) Accounting procedures vary and the calculations which follow are only intended to approximate the methods actually employed by utilities.

An approximation of the income resulting from normalized accounting is given by:

$$\text{INCOME}(t) = \text{FIX}' + (1+i)t\ IM_o + E(t)] \tag{43}$$

A number of simplifications have been introduced into this accounting procedure. The same capital value, K_o, is to represent several different capital quantities:

- –The value which must eventually be repaid to stockholders and bondholders and for which a sinking fund must be established,
- –The depreciable value of the plant for tax purposes,
- –The value of the plant which is eligible for investment tax credits,
- –The value of the plant for ratemaking purposes, and
- –The insured value of the plant.

In practice, all of these values are different. For example, in most cases, actual interest outlays during construction are deducted from income taxes in the year they occur. This "interest during construction" cannot be included in the depreciable value of the plant when it enters operation and does not qualify for an investment tax credit. This value can be included in the value of the plant for ratemaking purposes, however.

Another example is the value of the land on which the plant is sited. This is part of the value of the plant for ratemaking purposes and its value must be included in the sinking fund, but land is not depreciable and cannot be used as a part of the depreciable value of the plant for tax purposes. These distinctions are not large enough to affect the results of the approximate calculations used here. The major difference between the normalized accounting approach and the standard procedure developed for unregulated industry is that the fixed capital charge (in the case of normalized accounting) does not anticipate a return on the capital accumulated from accelerated depreciation early in the plant's life.

FLOW-THROUGH ACCOUNTING

Approximately 25 percent of the utilities in the United States use a procedure by which all of a utility's costs, other than construction costs are passed directly to the consumer in the year they are incurred. With this technique, called "flow-through accounting," capital charges passed to customers will be smaller than the normalized procedure early in the plant's life (when the maximum advantages of depreciation and tax credits are permitted and are higher than the normalized charges later in a plant's life). In this case, the income each year must be sufficient to cover expenses and

$$\text{INCOME}(t) = K_o \left[\left[PT + IN + \frac{R_u + S(R_u, LN) - T \infty D(a, DP, t)}{(1 - T)} \right] \right] + (1+i)^t (M_o + E(t) - K_o \times ITC\delta(t-1)) \tag{44}$$

– expenses for major replacements

Using this formulation of income with the annual outlays computed earlier, the levelized annual value of the total cost of energy perceived by customers is given by:

$$\text{PRICE} = k_1'''' K_o + k_2'''' E(1) + k_3'''' M_o + \sum_{t=1}^{L} k_4''''(t)\, M(t) \tag{45}$$

where

$$k_1'''' = PT + IN + \frac{R_u + S(R_u, LN)}{(1 - T)} - \frac{CRF(d, L)}{(1 - T)} \left[T \times DEP(a, DP, d) + ITC/(1 + d) \right] \tag{46}$$

$$k_4''''(t) = \frac{CRF(d,L)}{1-T} \left[\frac{1+i}{1+d}\right]^t \times \tag{47}$$

$$\left[CRF(d,N_r)[R_u + S(R_u,N_r)] - T \times DEP(a,N_r,d) - \frac{ITC}{1+d}\right]$$

$$k_2'''' = k_2'$$

$$k_3'''' = k_3'$$

MUNICIPAL UTILITIES

Municipal utilities typically finance 100 percent of their plants with tax-exempt bonds which in most cases can be sold with interest rates considerably below the rates charged for commercial bonds. (This advantage cannot be enjoyed if the creditworthiness of the municipality has been subject to question.) Municipals are not required to pay property taxes on their equipment, but typically make "payments in lieu of taxes" which are roughly equivalent to the amounts paid by privately owned utilities.[5] The only quantities affected are k_1 and k_4. For the case of municipal utilities, equations (40) and (41) can be written as follows:

$$k_{1m} = PT + IN + CRF\,(r_d, L) \tag{48}$$

$$k_{4m}\,(t) = CRF(r_d, L) \left(\frac{1+i}{1+r_d}\right)^t$$

[5] *The Cost of Ene gy From Utility-Owned Solar Electric Systems,* p. III-10.

BASELINE ASSUMPTIONS

In order to keep the number of variables in this study down to manageable proportions, it was necessary to fix a number of quantities at the onset. The following quantities are held constant throughout the study.

INFLATION

All costs in this study are expressed in constant 1976 dollars. To compute costs in years other than 1976, an inflation rate equal to 5.5 percent is assumed.

HOMEOWNER FINANCING

If lending institutions accept solar equip ment as having no greater risk than conventional space-conditioning equipment, or if solar devices represent only a small fraction of the total loan, the cost of solar devices can be included in the loan package financing the rest of the building, with rates of interest no different from those paid on nonsolar buildings. 1n such circumstances, loans made for installing solar equipment on existing structures could be expected to cost no more than conventional market home-improvement or modernization loans.

If bankers feel that homeowners are assuming substantial risk by investing in solar equipment, loans will be more difficult to obtain or will be obtained under terms less favorable than mortages charged for other types of equipment. A recent survey indicated that in such situations lenders are not likely to raise interest rates, but will insist on a larger down payment (or smaller loan-to-value ratios). ' A similar policy would result if lenders felt that solar equipment represented a high technical risk or would be plagued by breakdowns and repair bills. It is difficult to determine the circumstances under which lenders would accept solar equipment until the technology has conclusively proven itself through operating ex-

[6] *Evaluation of Alternative Incentives for Overcoming Mortgage Market Constraints on the Commercial Acceptance and Use of Residential Solar Energy Technologies,* NSF Grant APR75-18360, *Interim Report, Dec 31,1975*

perience, In practice, the loan policies of individual lenders depends strongly on the credit-worthiness of individual borrowers, prevailing attitudes about the worth of various solar devices, and other intangibles,

Choosing a typical value for interest paid on home mortgages is difficult because rates have fluctuated substantially in recent years The analysis in this report assumes that an interest of 9 percent is paid on a loan covering 75 percent of the value of the house. The average interest rate paid for new homes in the United States in 1975 was 9.01 percent (including initial fees and charges), and the average loan-to-purchase-price ratio was 76.1 percent. [7] It is assumed that loans made for "home improvements" will average three percentage points above the rate for new purchases.

Income Taxes

It is assumed that the purchaser of solar equipment for single family homes has a taxable income (after deductions) of approximately $18,000. Standard Federal tax tables for joint filing show taxes on incremental income at this level are paid at a rate of 28 percent. This is higher than the average U.S. income in 1976 but approximates the taxable income of owners of detached residences.

State taxes vary widely, and several States have no State income taxes of any sort. The average rate of State tax payments for an individual with an income in the range shown above is approximately 6.5 percent. [8] Thus, the total tax paid by the individual in question on incremental income is assumed to be 34.5 percent.

Property Tax

It is assumed that the homeowner pays property taxes to State and local governments at a rate of 7 percent based on an assessed valuation of 30 percent of market value. This results in a net property tax rate of 0.02 on the capital value of the house and solar equipment. [9,10]

Insurance

It is assumed that the homeowner can insure this solar equipment at rates equivalent to ordinary property insurance which is $.25 per $100 of value.

RENTAL PROPERTIES

Statistics on the techniques used to finance rental property are difficult to assemble. Terms vary widely because of the different financial options of individual owners and investing organizations. The situation is complicated further by the fact that most buildings are financed with several notes, each with different interest rates and maturity dates. Publicly available data on the financing of rental property does not appear to have been compiled with as much thoroughness as data on single family residential debts. Some data is available from the American Council of Life Insurance, which has compiled data on loans for residential buildings with values greater than $100,000 made to owners of multifamily apartments. In 1975, the average interest on such loans was 10.09 percent, in 1976, the average interest was 969 percent, and the rate fell to 9.33 percent in 1977 The average "loan-to-value" ratio was 75 percent. [11] The computations which follow will assume that in a "baseline" case, the apartment owners will finance 75 percent of the property with a loan paying 10 percent.

In some cases, apartment owners can be expected to be reluctant to broaden their investments and purchase energy-generating

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[7] *NEWS, Mar 19, 1976, Federal* Home Loan Bank Board, table I

[8] *Statistical Abstract* of *the United States,* Department of Commerce, p 268 (Note Some State taxes were approximated when only a range of values for tax rates were shown)

[9] *State and Local Finances – Significant Features, ACIR 1973-74*

[10] *1972* Council of Governments *Report*

[11] *Statistics prepared by the American Council of Life Insurance provided to OTA* by Betty Bancala (ACLA), *Mar 12, 1978*

equipment which they may feel is outside the conventional boundaries of their business. In an effort to isolate themselves from fluctuating energy prices and the possible effects of rent control, apartment owners have frequently avoided owning and operating even conventional energy equipment such as central boilers and air-conditioners. Separate heating and cooling units have been installed in each apartment, and the utilities bill individual customers directly. This practice is encouraged in the administration's National Energy Plan.

Expected Rate of Return

Owners of real estate must earn enough on their investment to compensate for the added risk of these ventures as compared to more secure and, in the case of apartment properties, more liquid investments. The yield on equity invested in real estate depends heavily on the income tax position of the investor, the favorability of financing, the reception of risk, and expectations about the resale value of the property. The value of real estate has increased rapidly in recent years, and a significant fraction of the "rate of return" expected from such property has come in this form. An investment company's expected return will vary widely as a result of all these variables, and a single value cannot fairly represent the market. It is necessary to examine a number of possibilities in this area, and the following discussion is intended to provide at least some direction in choosing rates of return. An analysis of returns experienced by owners of apartment, office, and retail property in the Washington, D. C., area during the period 1968-74 indicates that returns of approximately 8.5 percent (after taxes) were experienced on buildings in the range of $30 million, with smaller projects earning approximately 1 percent more.[12] In the analysis which follows it is assumed that apartment owners earn 1 O-percent returns after taxes.

It is quite possible, however, that the investors will expect higher rates of return on the incremental equity invested in solar equipment. Investing in conventional equipment to provide utility service to rental units is a necessary part of construction costs. Added funds for new energy equipment may well be perceived as a higher risk investment and be subjected to tests commonly applied in other economic sectors.

A series of interviews with organizations attempting to sell new energy equipment indicated a reasonably consistent pattern of expectations about the return from equipment such as new heat-recovery systems and heat pumps. It was felt that most investors would expect the new equipment to "pay for itself" in 4 to 5 years. This corresponds to an investment paying 15 to 20 percent returns for a period of 10 years. It is, of course crucial to understand the circumstances under which solar equipment would be considered a routine part of rental property, and the circumstances under which a large rate of return would be expected for the equipment. It is reasonable to suppose that in the early stages solar equipment would be required to provide substantial rates of return for investors.

An average debt-to-value ratio for apartment buildings has been substantially more difficult to determine. This is partly due to the fact that loan amounts are typically computed on the basis of an assumed "debt coverage ratio, " instead of on a fixed rule of-thumb for downpayments. The debt coverage ratio is defined as the ratio between the stabilized net income of the property owner and the cost of paying the mortgage. This ratio can be as low as 1.10 in cases where a long-term Government lease makes risk minimal, and it can be as high as 1.25 or more in instances where occupancy is uncertain. Conversations with several bankers and examination of recent loan packages indicate that assuming a debt-to-value ratio of 75 percent could be used as a "typical case" to represent today's market.

[12] McCloud Hodges, Real Estate Consultant, McLean, Va., private communication,

Tax Status

It is assumed that the owners of rental property have a sufficiently high enough taxable income to pay State and Federal taxes at a combined rate of 50 percent. As noted earlier, most apartments qualify for double-declining balance depreciation; it is assumed that equipment is depreciated with double-declining balances over a deprecia- tion interval of 15 years, regardless of the actual lifetime of the equipment. Apart- ments do not qualify for investment tax credits on energy equipment, and none are assumed in the analysis.

Insurance and Property Taxes

Property tax and insurance rates are assumed to be identical to the rates paid by homeowners.

INDUSTRIES

It is assumed that an industry finances 30 percent of its investments in new energy equipment with debt instruments paying 10-percent interest rates.

Expected Rate of Return

As in the previous case, the rates of return expected on novel industrial equipment will depend critically on the perception of the risks involved. In general, however, industries expect to recover capital on new equipment very quickly to ensure continued competitiveness in an economic climate which may be changing rapidly. The Thermo-Electron Corporation recently surveyed a number of chemical, paper, and refining industries and concluded that 50 percent would invest in equipment if a 22-percent return on investment after taxes could be expected. (See figure 1-3.) In the following analysis, it is assumed that industries use a required rate of return of 20 percent to determine the cost of energy generated by onsite equipment.

Taxes

It is assumed that industries pay Federal and State taxes at a combined rate of 50 percent. Most industries are able to use an investment tax credit granted during the first year of a system's operation; qualifying property must be tangible, depreciable, and must have a useful life of at least 3 years.[13] The amount of the credit has fluctuated since it was first instituted, but it is currently 10 percent. This amount is assumed as the "baseline" credit for computing industrial costs.

UTILITIES

Utilities finance equipment primarily from three sources: bonds, preferred stocks, and common stocks. Statistics showing the national average of utility fund sources are shown in table 1-3.

Bonds

Bond financing is relatively inexpensive compared with other sources of capital, but there is a limit to the amount of capital which can be raised from bonds. A bond is a contract to pay a fixed amount to the holder regardless of the utility's income. A failure to pay the required interest could, in principle, lead to bankruptcy of the utility. To protect themselves, lenders require that utilities have an income sufficient to make debt payments even in times of economic hardship. The most common measure of this margin of safety is called the debt "coverage ratio, " which is defined to be the ratio of income before taxes to annual debt payments. During 1974, the average privately owned utility had a coverage ratio of 2.4. In practice, lenders maintain these coverage ratios by linking interest rates to them. Debt financing becomes prohibitively expensive or unavailable if debt service requires too great a fraction of utility income. For the purposes of this analysis, however, it is assumed that utility debt remains at the current national average of 53 percent, although utilities attempt to achieve a situation where only

[13] IRS publication 572, 1976 edition, p. 1.

Figure I-3.—Cumulative Distribution of ChemicaL Petroleum Refining, and Paper and Pulp Companies Willing To Invest in Inplant Cogeneration Equipment Versus Internal Rate of Return on Investment

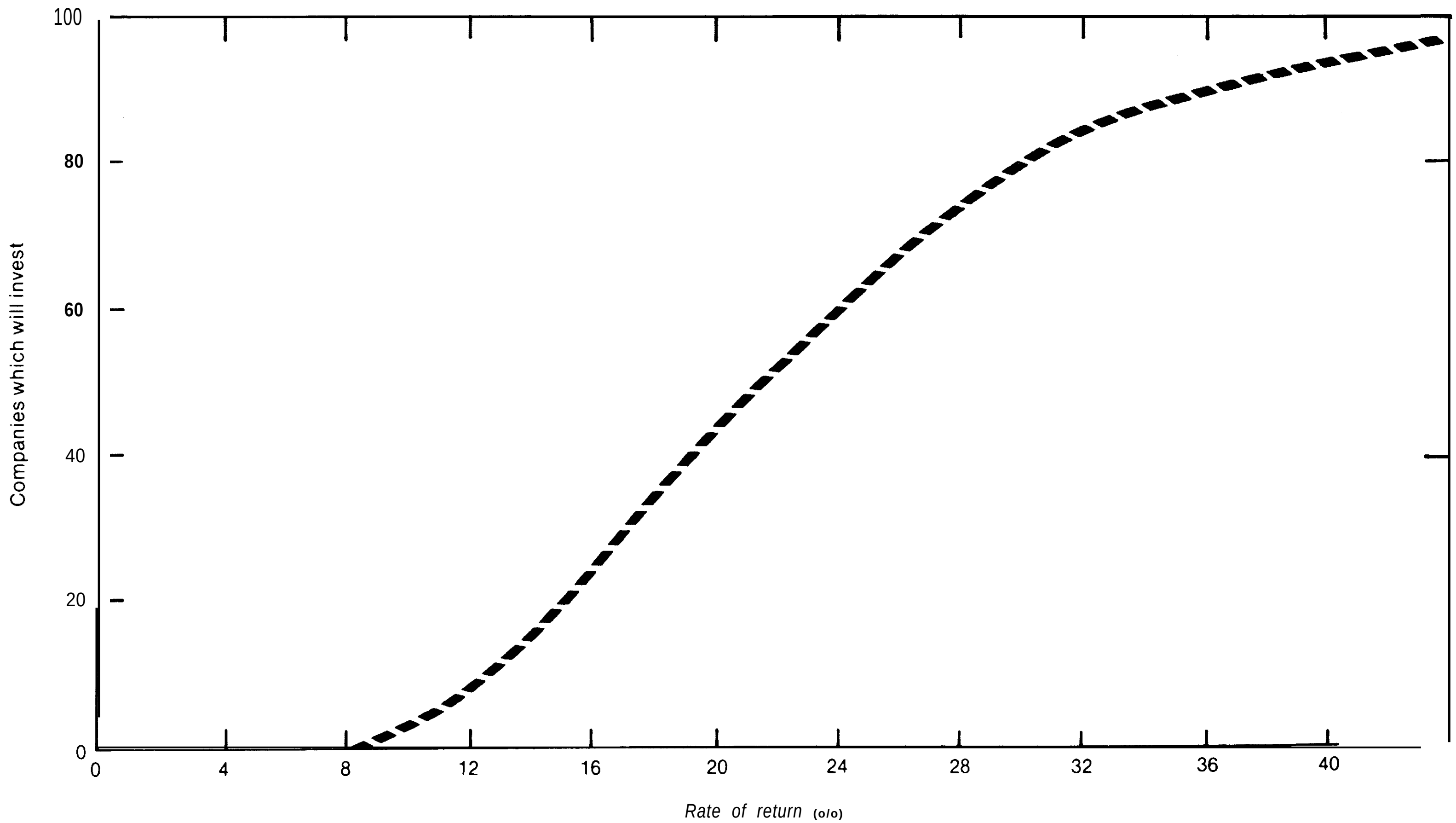

Table 1-3.—Summary of the Financing of Public-Owned Utilities in the United States 1973.74

	1974	1973
I Long-term *debt*		
A. Percentage of capitalization and retained earnings (1)	*53.0*	*52.3*
B. Average interest rate (2)	*6.3*	*5.9*
C. Average rate paid on new debt issues (4) & (5)	*8.15 (January)* 9.37 *(December)*	*7.51* (January) *8.17* (December)
D. *Times interest earned (3)*	*2.4*	*2.6*
II. Preferred stock		
A. Percentage of capitalization	12.0	12.1
B. Average dividend rate (2)	6.8	6.4
C. Average dividend rate paid on new issues (6)& (7)	7.68-11.50	7.15-8.6
III. Common stocks *and* retained *earnings*		
A. Percentage of capitalization and retained earnings (1)	*34.8*	*35.6*
B. Percentage return on common equity (3)	*10.7*	*11.5*
C. Common dividend payout ratio (3)	*70.4*	*67.9*

NOTES All references are to Statistics *of Privately Owned Electric Utilities in the United States for* 1974 *and* 1973. Published by the Federal Power Commission
(1) 1974, p XXII, (2) 1974, p XIX, (3) 1974 p XIV< (4) 1974, p XIII; (5) 1973, p XXVI; (6) 1973, p XXVIII, (7) 1974, p XVI

about 50 percent of their financing comes from bonds. (See table 1-3.)

The average double-A bonds issued for utilities during January 1974 paid 8.15 percent interest, and those issued in December paid 9.37 percent. It is assumed that the interest paid on utility bonds will be 8.5 percent. A dramatic increase in the rates paid by utilities has, **however, created a situation** where the average interest rate paid by utilities on long-term debt is far less than the cost of new debt. In 1974, for example, the average cost of debt to public utilities was 6,3 percent. [14] The increase **in the cost of debt is due both to an overall increase in the cost of bonds, and that the credit ratings of many utilities have dropped in recent years due to financial difficulties in the industry. Bonds with lower ratings command higher interest rates to compensate the investors for the higher risks which they involve** In January 1975, triple-A bonds paid 8.99 percent interest, double-A bonds paid 9.45 percent, A-bonds paid 10.37 percent, and BAA-bonds paid 11.57 percent. A rate of 9 **percent is used in the analysis.**

[14] *Statistics of Privately Owned Electric Utilities in the United States,* 1975, *Federal Power* Commission, *p L, S-260*

Stocks

After raising as much of its capital requirement as it can from internally generated cash and bonds, a utility will turn to the stock market for the remainder. In general, the rate of return paid to preferred stockholders is less than that paid **for common stock, and it is therefore assumed that the utility will issue as much preferred stock as possible. Since the preferred stock is similar to a bond in that it imposes a contractual obligation on the company to pay a fixed fee at a specified time, there are limits on the amount of capital which can be raised from preferred stocks, In fact, many preferred stock issues explicitly limit** the percentage of net worth which can be raised **in this way in order to maintain an acceptable level of confidence in the reliability of preferred stock payments, Preferred stocks averaged about 12.2 percent of the total outstanding stock of publicly owned util-** *i tie: in 1973* **(see table l-l), and this fraction is assumed in the analysis. Rates paid for preferred stock have risen sharply in recent years for the same reasons, causing the rise in the price of new debt. The average return paid on preferred stock in 1974 was 6.8 percent, although new issues were sold for rates**

varying from 7.68 to 11.5 percent. A rate of 9 percent is assumed in the analysis.

Any remaining capital requirements must be met by issuing additional common stock in the company. The feasibility of doing this in a real market will depend strongly on the perceived strength of the utility at the time of issue, which will, in turn, depend on the price-earnings ratio at the time.

The average return paid on common utility stock in 1974 was 10.77 percent. This may not be an appropriate value to assume as a return, however, since 1974 was a very poor year for owners of utility stock. Table I-4 indicates the historic pattern of inflation and rates of return on utility equity.

Earnings have averaged 7 to 8 percent above inflation. Since it has been assumed that inflation will average 5.5 percent, a 13-percent return on equity is used to compute utility costs.

Taxes

It is assumed that utilities qualify for the lo-percent investment tax credit on all purchases, and that double-declining balance depreciation schedules are employed over a period of 30 years. Federal and State taxes are assumed to have a combined effective tax rate of 50 percent. Ad valorem, property taxes, and other taxes are assumed to be 2 percent per year. [15]

[15] Op. cit. (ERDA/J PL-101 2-76/3).

Table I-4.–Historic Pattern of Inflation and Rates of Return on Utility Equity

	1974	1973	1972	1971	1970	1969	1968	1967	1966
Earnings available for common stock[a]	10.7	11.5	11.8	11.7	11.8	12.2	12.3	12.8	12.8
GNP deflator[b]	10.3	5.6	3.4	4.5	5.5	4.8	4.0	3.2	2.8
(Earnings)-(inflation)	0.4	5.9	8.4	7.2	6.3	7.4	8.3	9.6	10.0

[a] *Statistics of* private/y *Owned* Electric Utilities in the United States 1974, FPC, P. XXIX.
[b] *Statistical Abstract* of *the* United States 1975, US. Department of Commerce, P. 416.