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Photovoltaics Program
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A Normative Price for Energy from an Electricity Generation System: An Owner-Dependent Methodology for Energy Generation (System) Assessment (OMEGA)

Volume I: Summary

Robert G. Chamberlain- Jet Propulsion Laboratory
Kirby M. McMaster- Loyola Marymount University, Los Angeles, California

October 15, 1981

Prepared for
U.S. Department of Energy
Through an Agreement with
National Aeronautics and Space Administration
by
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

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ABSTRACT

This report presents a generalization and updating of the Utility-Owned Solar Electric System (USES) methodology [Doane 1976], which is in widespread use throughout the energy generation systems analysis community. The major new contributions are these:

(1) Relaxation of the ownership assumption.

(2) Removal of the constraint that all systems compared must have the same system lifetime.

(3) Explicit treatment of residual system value at the end of system life. (Removal of the assumption that all components within a system have lifetimes commensurate with the system lifetime.)

(4) Explicit treatment of variations in system performance with time.

(5) Explicit treatment of tax incentives, including use of the investment as a tax shelter. Tax incentives incorporated include investment tax credits, solar tax credits, property tax rates, accelerated depreciation, and capital gains.

(6) Incorporation of financial benefits of usable thermal energy, utility buy-back (in parallel or simultaneous mode) of excess electricity generated, capacity displacement and fuel savings credits, and, where appropriate, roof credits.

The net present value of the system, viewed as an investment, is determined by consideration of all financial benefits and costs (including a specified return on investment). Along the way, life cycle costs, life cycle revenues, and residual system values are obtained. Break-even values of system parameters are estimated by setting the net present value to zero. While the model was designed for photovoltaic generators with a possible thermal energy byproduct, its applicability is not limited to such systems.

The resulting Owner-dependent Methodology for Energy Generation system Assessment (OMEGA) consists of a few equations that can be evaluated without the aid of a high-speed computer.

This report is published in two volumes. Volume I is a self-contained summary, and can be thought of as a user's guide to the application of OMEGA. Volume II gives the complete derivation.

ACKNOWLEDGEMENTS

The methodology presented in this report is a derivative of the Utility-owned Solar Electric Systems (USES) model [Doane 1976] created by **Dr. James W. Doane** of Science Applications Incorporated, Golden, CO, and **Dr. Richard P. O'Toole** of the Jet Propulsion Laboratory (JPL). It has also benefitted from the development of the Solar Array Manufacturing Industry Costing Standards (SAMICS) [Chamberlain 1979] methodology, which was based on the USES approach; discussions with **Robert W. Aster, Dr. James W. Doane, Chester S. Borden,** and **Dr. Richard B. Davis** were particularly relevant and helpful. **Mary Anne Fraresso** performed a yeoman's service in rewriting Volume I to express the OMEGA algorithm in its entirety.

Dr. Kirby M. McMaster (associate professor at Loyola Marymount University) reviewed the derivations and the pedagogical presentation from beginning to end. Although the first draft of this document was written before Dr. McMaster was at JPL, he contributed much to the content. The final draft, however, is the senior author's and responsibility for any obscurities or inaccuracies that may remain are his.

A preliminary draft was distributed to reviewers at JPL, at the Department of Energy (DOE), in industry, and at universities. Comments by **Tom W. Hamilton** were particularly helpful.

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ACRONYMS

APSEAM	Alternative Power Systems Economic Analysis Model
BBEC	Busbar Energy Cost
DOE	Department of Energy
FERC	Federal Energy Regulatory Commission
IPD	Implicit Price Deflator
LCP	Lifetime Cost and Performance (Model)
M&D	Marketing and Distribution (Model)
NASA	National Aeronautics and Space Administration
NPV	Net Present Value
OMEGA	Owner-dependent Methodology for Energy Generation (System) Assessment
PURPA	Public Utilities Regulatory Policies Act
PV	Photovoltaics (or Present Value, depending on context)
QIV	Fourth Quarter (of the Implicit Price Deflator published by the Department of Commerce)
SAMICS	Solar Array Manufacturing Industry Costing Standards
SYSGEN	Utility Generation System Production Costing Model
USES	Utility-owned Solar Electric Systems (Model)

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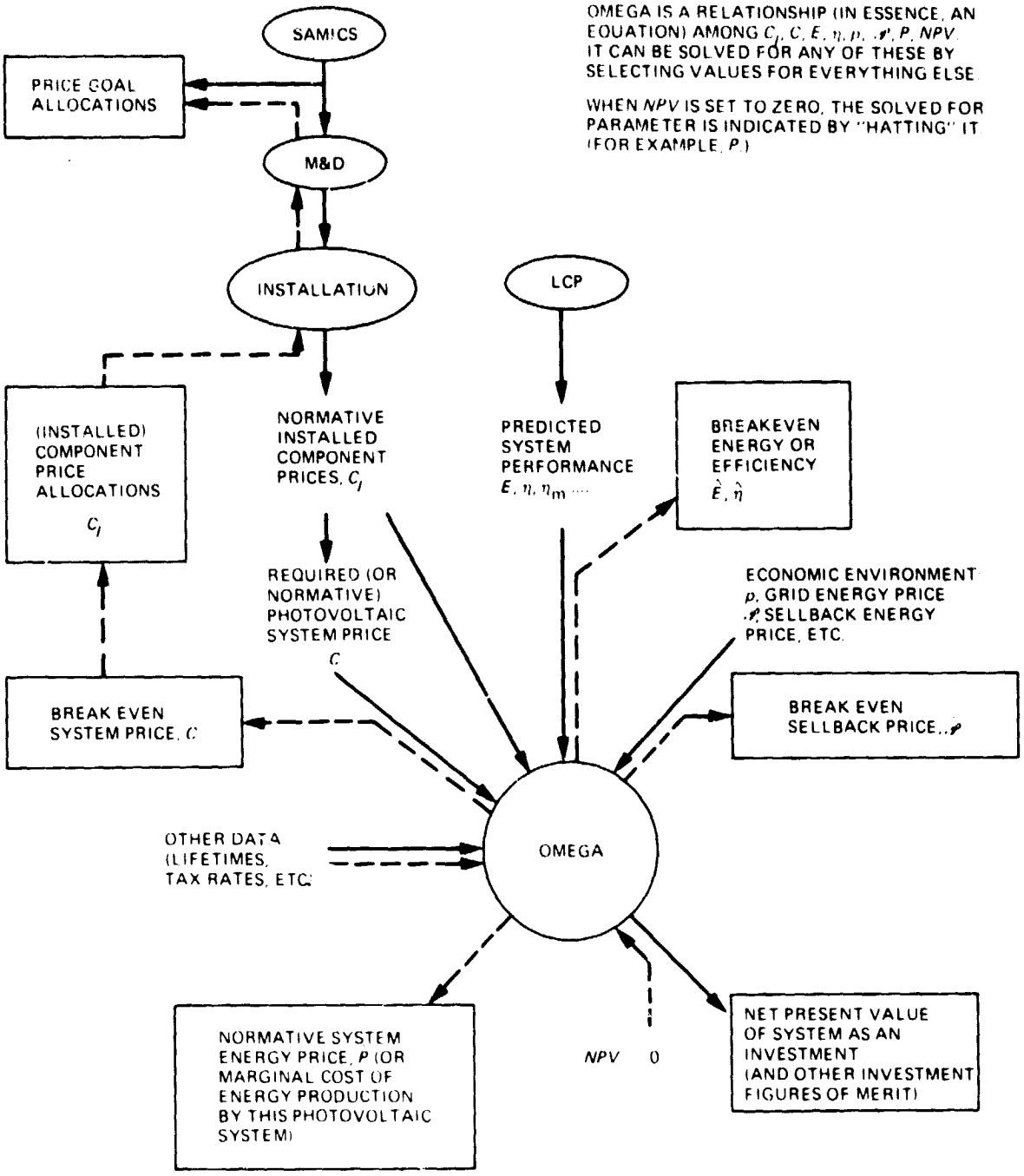

SOLID LINES PRODUCE A SUPPLY SIDE, NORMATIVE PRICE ANALYSIS
DASHED LINES PRODUCE A DEMAND SIDE, BREAK EVEN PARAMETER ANALYSIS
(MODELS ARE CIRCLED, POTENTIAL OUTPUTS ARE BOXED, INPUTS ARE BARE.)

MAJOR RELATIONSHIPS OF OMEGA

1. INTRODUCTION

The Utility Owned Solar Electric Systems (USES) methodology [Doane 1976][1] is widely accepted and used throughout the country as a standard for the evaluation of the economics of utility-owned electrical energy generation systems. (In contrast to the scope suggested by its name, there is nothing in the methodology that precludes its application to the evaluation of the economics of other electricity generation technologies than solar – "advanced", conventional, or an arbitrary combination.)

1.1 Contributions Of The Owner-dependent Methodology For Energy Generation System Assessment (OMEGA)

During the four years since USES was published, it has become apparent that there is a need for the capability to explore the impact of different ownership options, to incorporate a variety of potential system-related savings, to remove some of the analytical constraints, and to treat some of economic factors more explicitly, while still maintaining a simple methodology so that a high-speed computer is not essential. The major contributions of OMEGA are described below:

(1) Figure 1 (the frontispiece) describes pictorially how OMEGA can be used to find normative prices and break-even values of parameters.

(2) The assumption that the system under consideration is owned by a utility has been expanded: OMEGA is applicable to the evaluation of the economics of electrical and/or thermal[2] energy generation systems owned by a *utility* (privately owned or municipally owned), a *business*, or a *consumer*[3]. Systems can be *new construction* or *retrofit construction* – only homeowner-owned retrofit systems are considered here, but it should be noted that only the numerical values of parameters, and not their mathematical relationships in the model, are affected by this distinction. Also, systems can be *grid-connected* or *stand-alone*. Owners of grid-connected systems may *sell all* of the electricity generated by the system to the electric utility and buy all the electricity needed or they may use as much of the system-generated electricity as they need, *sell excess* electricity to the utility and buy back-up power when needed. Some owners may also have the option of purchasing the system as a *tax shelter*, in which case they will normally resell the system after a relatively small number of years.

(3) The constraint that all systems compared must have the same system lifetime has been removed by levelizing the system energy price in constant energy dollars, instead of constant nominal dollars. Of course, if systems with different lifetimes are compared, *system lifetime* becomes one of the relevant decision criteria, which is not the case if those lifetimes are the same.

(4) The implicit assumption that the value of the system drops abruptly to zero at the planning horizon has been removed by explicit treatment of the residual system value. This is a particularly important extension to USES when the discount rate is small enough and/or the planning horizon close enough that revenues and/or costs anticipated after that time are not negligible. It is also important because the investment horizon need not be a common multiple of the lifetimes of system components.

---

[1] The USES methodology is referred to so often in this document that the bibliographic reference [Doane 1976] is not repeated after this point.

[2] Sale of thermal energy is not treated.

[3] The term *consumer* is used here in its conventional sense as meaning a private individual (or family), rather than in its precise sense of "one who or that which consumes." Since consumer ownership of an energy generation system almost implies that the consumer is a *homeowner*, that term is occasionally used when the context makes it appropriate.

(5) Variations in system performance over time (due to modular construction, predictable weather variations, degradation, maintenance, etc.) are treated explicitly.

(6) Tax incentives are treated simplistically in USES, by an "effective income tax rate," though an appendix does provide for explicit consideration of investment tax credits and depreciation. In OMEGA, investment tax credits, solar tax credits, component-specific accelerated depreciation, and possible capital gains (due to the interaction of inflation with accelerated depreciation) benefits of resale of the system are all treated explicitly.

(7) While OMEGA is normally applied separately to each system to be compared, it is also possible to compare each system against a baseline scenario. In this mode of application, *capacity credits* can be taken for capital expenditures (e.g., for generation capacity) that can be deferred (or avoided altogether) as a result of installing the system under consideration, and *fuel savings credits* can be taken for expenses (e.g., for fuel) that can be avoided. In addition, *roof credits* can be taken for capital savings that may result from physical attributes of the system (e.g., use of collectors as roofing material) not directly related to the system's function as an energy generator.

(8) The "bottom line" of USES was the *normative system energy price* (identified there as the *busbar energy cost*), with the system's *life cycle cost* and *annualized cost* as intermediate results. OMEGA also produces the *break-even sellback price* (which is the *normative system energy price* for grid-connected systems if all of the energy produced is sold to the utility), the system's *life cycle revenues*, *residual system value*, and *net present value*, and the procedure for finding the *break-even numerical values* of any of the exogenous[4] variables.

1.2 Limitations

While OMEGA has a considerably wider scope than USES, the objective of keeping the analysis simple enough to avoid the necessity of high-speed computers to perform the computations has ruled out treatment of the following issues:

(1) The value of a good depends upon the need for that good. Since the timing of needs for energy does not necessarily match the timing of energy available from the system under consideration, a single price per unit of energy (or a single break-even buy-back price in the case of grid-connected systems) may be too coarse a measure of value for some purposes. Time of day pricing and value determination is dealt with in detail in the Lifetime Cost and Performance (LCP) computer model [Borden 1980].

(2) Changes in economic conditions can have profound impacts on the viability of specific investments. While USES and OMEGA both assume that inflation, escalation, interest, and related rates are constant, the Alternative Power Systems Economic Analysis [computer] Model (APSEAM) provides the capability to deal with these variations [Davis 1980].

(3) The OMEGA model, while considering the system owner's tax environment in some detail, does contain some simplifying assumptions. For example, the owner's marginal tax rate does not depend on system benefits or costs. In addition, the complications resulting from the carry-forward, carry-back, and refundability of tax losses and credits (but not those losses and credits themselves) are ignored. The APSEAM computer model [Davis 1980] can be used to study the effects of these factors.

[4] The *exogenous variables* are those that the user of the methodology must supply as input.

(4) The capability is provided to explore the tax advantages resulting from resale of the system at a price higher than the depreciated value on the owner's ta. books. However, finding an optimal value of the timing of such a resale of the system – or of any exogenous (i.e., input) variable – must be performed by the user of OMEGA. Furthermore, only one resale is considered; if the user wishes to select between purchase of a new, a second-hand, a third-hand, etc., system as a tax shelter, the user must investigate each alternative as a separate system, each with its own input data.

(5) System performance is exogenous (i.e., input) to OMEGA, as are any capacity credits and fuel savings credits. In practice, these factors depend upon the resultant system economics. The LCP computer model [Borden 1980] treats the dynamic interaction between performance and economics explicitly. In a utility-owned system, the analysis must take into account the effect of the system under consideration on the dispatching of other energy generation systems already in the grid; a utility simulation model, such as SYSGEN [Finger 1979] is required to determine that interaction. A dynamic utility expansion model is needed to provide good estimates of capacity and fuel savings credits over a time span of years.

(6) OMEGA provides an estimate of the minimum value of the sellback price that would make the system under consideration economically viable as an investment. Federal Energy Regulatory Commission regulations [FERC 1980], however, require that that price reflect the utility's net avoided cost. This, in turn, depends upon factors that are not directly related to the system under consideration, such as the penetration of weather-dependent systems into the grid. Thus, it is difficult to know to what the OMEGA estimate of the break-even sellback price should be compared – unless, of course, there is a sellback price offered by the utility. An estimate of that sellback price could be obtained by application of OMEGA (or, better, APSEAM [Davis 1980]) to the full utility system with and without a suitable number of systems of the type under consideration included in the generation mix; again, a utility simulation and expansion model, along with LCP [Borden 1980], would be required.

(7) OMEGA allows for consideration of systems from which only *excess* electricity is sold to the utility. The amount which is excess is supplied exogenously, and depends not only on the system itself, but on the specification of an appropriate time base (instantaneously, hourly, monthly, or whatever). The time of day detail in LCP [Borden 1980] could be used to generate this information.

1.3 Approach

The OMEGA approach is a straight-forward modeling of all of the financial benefits and costs (including a specified return on investment) throughout the system life and beyond, assuming that system components are replaced when necessary and that system performances follows a predictable pattern. Capital expenditures on system components are assumed to recur, increased by inflation, at the end of component lifetimes. The system performance pattern is assumed to repeat with a known period. Most of the cost elements are derived from the capital expenditures, others are supplied exogenously. Financial benefits are assumed to grow at the rate of energy price escalation. The collection of submodels thus produces time sequences of benefits and costs, expressed in nominal dollars.

The *life cycle revenue* is defined as the sum of the present values of all of the financial benefits up to the end of the system lifetime. The *life cycle cost* is the sum of the present values of all of the costs over the same time period. The *residual system value* is defined as the net present value of all financial benefits and costs that occur after the end of the system lifetime, and depends upon the fate of the system at that time.

The *net present value* of the system is defined as the *life cycle revenue* minus the *life cycle cost* plus the *residual system value.*

The *normative system energy price* is that value of the *system energy price* or of the *sellback energy price* which would make the *net present value* of the system equal to zero. The equations given here for the *normative system energy price* are based on the assumption that the system will continue to be used (rather than salvaged) after the end of the system lifetime.

Break-even numerical values of other variables are those values – if they exist – that would make the *net present value* of the system equal to zero, given that all other exogenous variables are at their nominal values, that the *system energy price* (if relevant) is equal to the retail price of grid energy, and that the *sellback energy price* (if relevant) is exogenously specified.

The remainder of this volume presents the OMEGA algorithm in its full generality. Appendix A contains a workbook format that may be used to organize and present the results. (The workbook does not contain enough space to perform the actual calculations.) Curtailment of funding precluded the preparation of a BASIC computer program, which was intended to provide verification of the algorithmic details as well as computational convenience.

2. CALCULATE CAPITAL INVESTMENTS

Input

Φ_c = Escalation factor for the price of capital goods from the base year to the start of system operation (at $t = 0$).

$\Phi_{\$}$ = Inflation (of dollars) from the base year to the start of system operation.

Compute

ϕ_c = $\Phi_c/\Phi_{\$}$, the real escalation of capital prices from the base year, Y_b, to the start of systems operation.

Input

k = Discount rate, in percent per year. This rate expresses the way in which the timing of a cash flow affects the worth of that cash flow to the prospective owner. (All percentages, of course, must be divided by 100% before they are used in calculations).

g_c = Capital cost escalation rate, in percent per year.

Compute

R_c = $(1 + g_c)/(1 + k)$, the discounted escalation rate for capital goods.

Input

Y_b = Base year for constant dollars. Prices computed by application of this methodology are expressed in constant dollars corresponding to the beginning of this year.

Y_{co} = Year of first usable energy production. The first financial benefits are obtained at the end of this year. All times are expressed relative to the beginning of this year (that is, $t = 0$ on January 1 of Y_{co}). In addition, this is *the present* for present value computations.

j = Type of capital good. For example: j = "*W*" denotes working capital.

t_0 = Time at which the system starts full capacity operation.

t_j = Time, with respect to Y_{co}, at which funds for capital goods of type j must be expended, expressed in years.

t_f = Time of the first system-resultant cash flow, expressed in years after the start of system operation. (Thus, its numerical value will usually be negative.)

N = System lifetime, expressed in years. The system lifetime marks the dividing time between life cycle costs and residual system value.

C_j = Purchase cost of capital goods of type j, expressed in base year dollars ($\$_b$). This cost includes any allowance for construction contingencies that may be necessary.

δ_j = Additional cost of replacement of capital goods of type j, expressed as a fraction of the capital cost of initial installation.

L_j = Lifetime (i.e., replacement period) of capital goods of type j, expressed in years.

Note: Working capital (j = "W") may be included among the types of capital if desired. If an estimate of the parameters is available, use it. If it is desired to produce an estimate here, use the algorithm without working capital to obtain estimates of xpm_v, spm_v, tpm_v, and bpm_v, input the values of

l = Operating expense coverage period, the time (usually a fraction of a year) for which the system owner must be able to cover operating expenses out of working capital. The numerical value of this factor is determined by the "lumpiness" of revenue and cost cash flows and by the differences in their timing. If the owner has sufficient flexibility to defer payment of costs, without penalties, the numerical value could be zero.

and

s_j = Spares fraction for capital goods of type j, expressed as a fraction of purchase cost. The numerical value depends on the specific system design; a small system will often have no spares.

Then, unless l is zero, estimate the net annual operating expense by

$$OPR = \begin{cases} \dfrac{X_b\, xpm_v}{(1-\sigma)\, spm_v} + \{[\tau\omega - (1-\tau)\alpha\, tpm_v]\, p - \sigma(1-\tau)\, \mathcal{P}\, bpm_v\} E & \text{if } \sigma \neq 1 \\ \dfrac{X_b\, xpm_v}{(1-\tau)\, bpm_v} - \dfrac{\alpha\, tpm_v}{bpm_v}\, p\, E & \text{if } \sigma = 1 \end{cases}$$

Then, the estimated working capital is given by

$$C_W = l\, OPR + \Sigma_j\, s_j\, C_j\,,$$

and its parameters are given by

$L_W = 0$, $L_W = \infty$, $\theta_W = 1$, $\delta_W = 0$, μ_{TW} and μ_{BW} = irrelevent, TI_W = irrelevant, and $f_W = 0$.

For each value of j, compute

CI_{jt} = Capital investment in capital goods of type j at time t expressed in $\$_t$.

by

$$CI_{jt} = \begin{cases} C_j \Phi_c (1 + g_c)^{t_j} & \text{for } t = t_j \\ C_j \Phi_c (1 + g_c)^{t} (1 + \delta_j) & \text{for } t = t_j + L_j, t_j + 2L_j, \ldots \end{cases} \quad (1)$$

Compute

CI_t = Capital investment at time t, expressed in $\$_t$.

by

$$CI_t = \sum_j CI_{jt} \quad (2)$$

Then, compute the following for each j:

(1) CI_{vj} = Sum of the present values of all capital investments of type j, expressed in $\$_b$.

by

$$CI_{vj} = \frac{1}{\Phi_{\$}} \sum_{t=t_f}^{\infty} \frac{CI_{jt}}{(1+k)^t}$$

$$= \phi_c R_c^{t_j} C_j \left[1 + (1 + \delta_j) \frac{R_c^{L_j}}{1 - R_c^{L_j}} \right] \quad (3)$$

(2) $CI_{RSC,j}$ = Sum of the present values of capital investments of type j, possibly made before, but not depreciated until after the end of the system lifetime, expressed in $\$_b$.

by

$$CI_{RSC,j} = \frac{1}{\Phi_{\$}} \sum_{t=N}^{\infty} \frac{CI_{jt}}{(1+k)^t} \quad (4)$$

(3) $CI_{LCC,j}$ = Sum of the present values of capital investments of type j, mode during the system lifetime and depreciated at least one time (hence the '$N - 1$'), expressed in $\$_b$.

by

$$CI_{LCC,j} = \frac{1}{\Phi_{\$}} \sum_{t=t_f}^{N-1} \frac{CI_{jt}}{(1+k)^t} \quad (5)$$

Then, by using:

$$\frac{1}{\Phi_s} \sum_t \frac{\omega + (1 - \omega)\,\sigma_t}{\omega + (1 - \omega)\,\sigma} \frac{CI_{jt}}{(1 + k)^t} \qquad (6)$$

Compute: Using the following summation on t:

CI'_{vj} t from t_f to ∞

$CI'_{RSC,j}$ t from N to ∞

$CI'_{LCC,j}$ t from t_f to $N - 1$

3. CALCULATE CAPITAL COST MULTIPLIERS

Input

ω = Owner-type indicator. If the prospective owner of the system under consideration is a consumer, $\omega = 0$; if it is a company (utility or non-utility), $\omega = 1$.

σ = Sellback fraction. This is the fraction of the system-produced electrical energy which is sold to the electric utility grid. Unless the value of σ is zero (no sellback) or unity (all sellback), it is desirable to obtain this fraction from a simulation of the operation of the system.

σ_t = Fraction of the electrical energy produced by the system during each year t which is sold to the electrical utility. If the system owner *is* the utility, this is the fraction sold to some other utility or the fraction put into storage.

τ = System owner's marginal income tax rate (combined federal and state) expressed as a fraction of net taxable income.

μ_j = Depreciation method to be used for capital goods of type j, which may be different for the accounting books than for the tax books.

θ_j = Salvage value of capital goods of type j at the end of their lifetime, expressed as a fraction of purchase cost.

3.1 Depreciation and Valuation Functions

A = Age of capital goods, expressed in years.

DL = Depreciation lifetime of the capital goods, expressed in years.

θ = Salvage value, expressed as a fraction of the purchase price.

μ = Depreciation method:

"*SL*" = Straight line

"*SYD*" = Sum of the years' digits

"*DDB*" = Double declining balance

M = Time at which switch is made to straight line = $\begin{cases} DL/2 & \text{if } DL \text{ is even} \\ (DL+1)/2 & \text{if } DL \text{ is odd} \end{cases}$

$dep\,(A, DL, \mu, \theta)$ = Depreciation function, the change in value of capital during the preceding year, where the capital good is of age t out of a depreciable life of DL, the depreciation method is μ, and the salvage value fraction is θ.

$$dep(A, DL, \mu, \theta) = \begin{cases} 0 & \text{if } A < 1 \\ 0 & \text{if } DL < A \end{cases}$$

$$dep(A, DL, \text{"SL"}, \theta) = \{(1-\theta)\, DL \quad \text{if } 1 \leq A < DL \tag{7}$$

$$dep(A, DL, \text{"SYD"}, \theta) = \left\{(1-\theta)\, \frac{2(DL+1-A)}{DL(DL+1)} \quad \text{if } 1 \leq A < DL \right. \tag{8}$$

$$dep(A, DL, \text{"DDB"}, \theta) = \begin{cases} (1-\theta)\left(\frac{2}{DL}\right)\left(1-\frac{2}{DL}\right)^{A-1} & \text{if} \quad 1 \leq A \leq M \\ (1-\theta)\left(1-\frac{2}{DL}\right)^{M}\left(\frac{1}{L-M}\right) & \text{if} \quad M < A \leq DL \end{cases} \tag{9}$$

3.1.1 Book Depreciation

For each value of j, compute:

$bdep_{vj}$ = Present value of book depreciation function

by

$$bdep_{vj} = \sum_{T=1}^{L_j} \frac{bdep(T, L_j, \mu_j, \theta_j)}{(1+k)^T},$$

Note that the *bdep* function in the summation is just the *dep* function of the previous subsection evaluated with $\mu = \mu_{Bj}$ and $DL = L_j$. Similarly, the *tdep* function used in the next subsection is just the *dep* function evaluated with $\mu = \mu_{Tj}$ and $DL = TL_j$.

3.1.2 Tax Depreciation

Compute for each value of j:

$tdep_{vj}$ = Present value of tax depreciation deductions.

by

$$tdep_{vj} = \sum_{T=1}^{L_j} \frac{\omega + (1-\omega)\sigma_T}{\omega + (1-\omega)\sigma} \frac{tdep(T, L_j, \mu_j, \theta_j)}{(1+k)^T} \tag{11}$$

Compute for each value of j:

$tdep_{RSC,j}$ = Present value, as of initial purchase, of the tax depreciation deductions on goods of type j after the end of the system lifetime.

by

$$tdep_{RSC,j} = \frac{1}{\Phi_S}\left(\sum_{t=t_f}^{N-1}\frac{CI_{jt}}{(1+k)^t}\sum_{T=N-t}^{L_j} + \sum_{t=N}^{\infty}\frac{CI_{jt}}{(1+k)^t}\sum_{T=1}^{L_j}\right) \times \frac{\omega+(1-\omega)\sigma_{t+T}}{\omega+(1-\omega)\sigma}\frac{tdep(T,L_j,\mu_j,\theta_j)}{(1+k)^T}/CI_{RSC,j} \quad (12)$$

Compute for each value of j:

$tdep_{LCC,j}$ = Present value, as of time of initial purchase, of the tax depreciation deductions on goods of type j up to the end of the system lifetime.

by

$$tdep_{LCC,j} = \frac{1}{\Phi_S}\sum_{t=t_f}^{N-1}\frac{CI_{jt}}{(1+k)^t}\sum_{T=1}^{N-t}\frac{\omega+(1-\omega)\sigma_{t+T}}{\omega+(1-\omega)\sigma}\frac{tdep(T,L_j,\mu_j,\theta_j)}{(1+k)^T}/CI_{LCC,j} \quad (13)$$

3.1.3 Book Valuation

$sch(A, DL, \mu, \theta,)$ = Schedule function for the depreciating value of capital of age A when the depreciable life is DL, the depreciation method is μ, and the salvage value fraction is θ, expressed as a fraction of the initial value.

$$sch(A, DL, \mu, \theta) = \begin{cases} 0 & \text{if } A < 0 \\ \theta & \text{if } DL \leq A \leq \text{actual life} \\ 0 & \text{if actual life} < A \end{cases}$$

$$sch(A, DL, \text{"}SL\text{"}, \theta) = \begin{cases} 1 - (1-\theta)\frac{A}{DL} & \text{if } 0 \leq A \leq DL \end{cases} \quad (14)$$

$$sch(A, DL, \text{"}SYD\text{"}, \theta) = \begin{cases} 1 - \frac{2(1-\theta)}{DL(DL+1)}[(2DL+1)A + A^2] & \text{if } 0 \leq A \leq DL \end{cases} \quad (15)$$

$$sch(A, DL, \text{"}DDB\text{"}, \theta) = \begin{cases} (1-\theta)\left(1-\frac{2}{DL}\right)^A + \theta & \text{if } 0 \leq A \leq M \\ (1-\theta)\left(1-\frac{2}{DL}\right)^M\left(\frac{DL-A}{DL-M}\right) + \theta & \text{if } M \leq A \leq DL \end{cases} \quad (16)$$

Compute

$bsch_{vj}$ = Present value of book value of capital goods of type j as a multiple of initial price.

by

$$bsch_{vj} = \sum_{T=0}^{L_j} \frac{bsch\,(T, L_j, \mu_j, \theta_j)}{(1+k)^T} \tag{17}$$

Compute

$bsch_{RSC,j}$ = Present value, as of initial purchase, of the book value of goods of type j after the end of the system lifetime, taking into account that a non-integral number of replacement cycles may have been completed at the end of the system life, expressed as a multiple of the value at initial purchase.

by

$$bsch_{RSC,j} = \frac{1}{\Phi_s}\left(\sum_{t=t_f}^{N-1} \frac{CI_{jt}}{(1+k)^t} \sum_{T=N-t}^{L_j} + \sum_{t=N}^{\infty} \frac{CI_{jt}}{(1+k)^t} \sum_{T=0}^{L_j}\right) \frac{bsch(T, L_j, \mu_j, \theta_j)}{(1+k)^T} / CI_{RSC,j} \tag{18}$$

Compute

$bsch_{LCC,j}$ = Present value, as of the time of initial purchase, of the book value of goods of type j up to one year before the end of the system lifetime, taking into account that a non-integral number of replacement cycles may have been completed at that time, expressed as a multiple of the value at initial purchase.

by

$$bsch_{LCC,j} = \frac{1}{\Phi_s} \sum_{t=t_f}^{N-1} \frac{CI_{jt}}{(1+k)^t} \sum_{T=0}^{N-1-t} \frac{bsch(T, L_j, \mu_j, \theta_j)}{(1+k)^T} / CI_{LCC,j} \tag{19}$$

3.1.4 Tax Valuation

Compute

$tsch_{vj}$ = Present value of tax valuation function.

by

$$tsch_{vj} = \sum_{T=0}^{L_j-1} \frac{1-\tau\,[\omega + (1-\omega)\sigma_T]}{1-\tau\,[\omega + (1-\omega)\sigma]} \frac{tsch(T, L_j, \mu_j, \theta_j)}{(1+k)^T} \tag{20}$$

Compute

$tsch_{RSC,j}$ = Present value, as of the time of initial purchase, of the tax value of goods of type j after the end of the system lifetime, taking into account that a non-integral number of replacement cycles may have been completed at that time, expressed as a multiple of the value at initial purchase.

by

$$tsch_{RSC,j} = \frac{1}{\Phi_s}\left(\sum_{t=t_f}^{N-1}\frac{CI_{jt}}{(1+k)^t}\sum_{T=N-t}^{L_j} + \sum_{t=N}^{\infty}\frac{CI_{jt}}{(1+k)^t}\sum_{T=0}^{L_j-1}\right) \times \frac{1-\tau\left[\omega+(1-\omega)\sigma_{t+T}\right]}{1-\tau\left[\omega+(1-\omega)\sigma\right]}\frac{tsch(T,L_j,\mu_j,\theta_j)}{(1+k)^T}/CI_{RSC,j} \quad (21)$$

Compute

$tsch_{LCC,j}$ = Present value, as of the time of initial purchase, of the tax value of goods of type j up to one year before the end of the system lifetime, taking into account that a non-integral number of replacement cycles may have been completed at that time, expressed as a multiple of the value at initial purchase.

by

$$tsch_{LCC,j} = \frac{1}{\Phi_s}\sum_{t=t_f}^{N-1}\frac{CI_{jt}}{(1+k)^t}\sum_{T=0}^{N-1-t}\frac{1-\tau[\omega+(1-\omega)\sigma_{t+T}]}{1-\tau[\omega+(1-\omega)\sigma]}\frac{tsch(T,L_j,\mu_j,\theta_j)}{(1+k)^T}/CI_{LCC,j} \quad (22)$$

3.2 Insurance Multipliers

By using:

$$ins = \sum_t \frac{1-\tau\left[\omega+(1-\omega)\sigma_t\right]}{1-\tau\left[\omega+(1-\omega)\sigma\right]}R_c^t \quad (23)$$

Compute:		Using the Following Summation on t:
ins_{vj}	= Insurance multiplier during and after system lifetime.	t from t_f to ∞.
$ins_{RSC,j}$	= Insurance multiplier after the end of the system lifetime.	t from $N+1$ to ∞.
$ins_{LCC,j}$	= Insurance multiplier before the end of the system lifetime.	t from t_f to N.

3.3 Mortgage Value Function

Input

MP = Mortgage period, expressed in years. Not necessarily assumed to be shorter than the component lifetime. (If the mortgage period differs for different kinds of capital goods, this must be MP_j, instead of MP.)

i = Bond or mortgage interest rate, expressed as a percent (of debt value) per year. The numerical value may depend upon whether the system is new or retrofit construction.

Compute (for each j if mortgage periods differ for different kinds of capital goods).

$sff_{i,MP}$ = Sinking fund factor; the uniform periodic payment, as a fraction of the ***final balance*** (cf the definition of the capital recovery factor) that will accumulate (including all interest) in MP periods to that final balance at a periodic interest rate of i, with interest on the balance compounded every period.

by

$$sff_{i,MP} = \begin{cases} i/[(1+i)^{MP} - 1] & \text{for } i \neq 0 \\ 1/MP & \text{for } i = 0 \end{cases} \tag{24}$$

Compute (for each j if necessary)

$crf_{i,MP}$ = Capital recovery factor; the uniform periodic payment, as a fraction of the original principal, that will fully repay a loan (including all interest) in MP periods at a periodic interest rate of i, with interest on the unpaid balance compounded every period.

by

$$crf_{i,MP} = \begin{cases} i/[1 - (1+i)^{-MP}] & \text{if } i \neq 0; \\ 1/MP & \text{if } i = 0 \end{cases} \tag{25}$$

or

$$crf_{i,MP} = sff_{i,MP} + i$$

For each kind of capital goods, j, compute

$mort_{vj}$ = Sum of the present values, as of the time of initial purchase, of the mortgage value function for goods of type j, expressed as a multiple of the value at initial purchase. (The value depends upon the type of capital goods only if the mortgage period also does.)

by

$$mort_{vj} = \sum_{T=0}^{L_j - 1} \frac{crf_{i,MP} - (1+i)^T \, sff_{i,MP}}{i(1+k)^T} \tag{26}$$

3.4 Capital Cost Multipliers

Input

r = Required (that is, normative) after-tax rate of return on equity investment, expressed as a percent (of book value of equity) per year.

ϵ = Down-payment fraction, the portion of a capital improvement that lending institutions will not cover.

β_1 = 'Other' (non-income) tax rate, expressed as a fraction (per year) of taxable value.

β_2 = Insurance rate, expressed in % per year.

β_3 = Investment tax credit rate, expressed as a fraction of capital investment.

β_4 = Solar (one-time only) tax credit rate, expressed as a fraction of capital investment. Limitations on the maximum tax credit are ignored, but the effects of such limitations can be approximated by modifying the value of this input.

F = Financing method indicator:

$F = 1$ If the system owner is a company ($\omega = 1$) and the project is to be financed out of the corporate general fund (that is, with the company's constant leverage, partly by debt and partly by equity).

$F = 0$ If the project is to be financed by a mortgage; that is, if either the system owner is a consumer or if the system owner is a company, but the project will not be financed out of the general fund.

The total capital cost multiplier is given by

$$ccm_{vj} = [\,Fk + (1-F)r\,]\; bsch_{vj} + bdep_{vj} + (1-F)(1-\epsilon)[(1-\tau)i - r]\; mort_{vj}$$
$$+ (1 - \tau[\omega + (1-\omega)\sigma])\,\beta_1\; tsch_{vj} - [\omega + (1-\omega)\sigma]\left[\tau\, tdep_{vj} + \beta_3\,\frac{Cl'_{vj}}{Cl_{vj}}\right] \qquad (27)$$
$$+ (1 - \tau[\omega + (1-\omega)\sigma])\,\beta_2\,\phi_c\,\frac{C_j(1+\delta_j)\,ins_{vj}}{Cl_{vj}} - \frac{\beta_4}{\Phi_s(1+k)^{t_j}}\,\frac{Cl_{it_j}}{Cl_{vj}}$$

The residual capital cost multiplier is given by

$$ccm_{rj} = [\,Fk + (1-F)r\,]\; bsch_{RSC,j} + bdep_{vj} + (1-F)(1-\epsilon)[(1-\tau)i - r]\; mort_{vj}$$
$$+ (1 - \tau[\omega + (1-\omega)\sigma])\beta_1\; tsch_{RSC,j} - [\omega + (1-\omega)\sigma]\left[\tau\, tdep_{RSC,j} + \beta_3\,\frac{Cl'_{RSC,j}}{Cl_{RSC,j}}\right],$$
$$+ (1 - \tau[\omega + (1-\omega)\sigma])\beta_2\,\phi_c\,\frac{C_j(1+\delta_j)ins_{RSC,j}}{Cl_{RSC,j}}$$
$$\frac{\beta_4}{\Phi_s(1+k)^{t_j}}\,\frac{Cl_{it_j}}{Cl_{RSC,j}}\begin{cases}1 & \text{if } t_j \geq N\\ 0 & \text{if } t_j < N\end{cases} \qquad (28)$$

The (life cycle) capital cost multiplier is given by

$$ccm_j = [\,Fk + (1-F)\,r\,]\; bsch_{LCC,j} + bdep_{vj} + (1-F)(1-\epsilon)\,[(1-\tau)\,i - r\,]\; mort_{vj}$$

$$+ (1 - \tau\,[\omega + (1-\omega)\,\sigma\,])\,\beta_1\; tsch_{LCC,j} - [\omega + (1-\omega)\,\sigma\,]\left[\tau\; tdep_{LCC,j} + \beta_3\;\frac{CI'_{LCC,j}}{CI_{LCC,j}}\right] \qquad (29)$$

$$+ (1 - \tau\,[\omega + (1-\omega)\,\sigma\,])\,\beta_2\;\phi_c\;\frac{C_j\,(1+\delta_j)\,ins_{LCC,j}}{CI_{LCC,j}} - \frac{\beta_4}{\Phi_s\,(1+k)^{t_j}}\;\frac{CI_{jt_j}}{CI_{LCC,j}}\;\begin{cases}1 \text{ if } t_j < N\\ 0 \text{ if } t_j \geq N\end{cases}$$

4. CALCULATE ELECTRICAL ENERGY PRODUCED

4.1 Initial Full Capacity System Performance

Input

Z = Nameplate size of the system at capacity, expressed in kWp.

η = Average system efficiency during year t_o, the first year of full capacity operation (i.e., for t in the range $t_o < t \leq t_o + 1$)

S = Total solar energy incident on the system during year t_o, expressed in kWh/kWp.

Compute

E = Net electrical energy produced by the system during the first year of capacity operation, expressed in kWh.

by

$$E = S Z \eta \tag{30}$$

4.2 System Performance During Construction

Input

Z_t = Average nameplate size of the system in each year t, expressed in kWp (for $t \geq t_o$, $Z_t = Z$)

η'_t = Average system efficiency, due to the combined effect of all factors, in each year t.

S_t = Total solar energy incident on the system during each year t, expressed in kWh/kWp.

Compute

e_t = Net electrical energy produced by the system in year t during the period of building up to capacity operation, expressed as a fraction of initial full-capacity output, E.

by

$$e_t = S_t Z_t \eta'_t / E \qquad \text{for } t \leq t_o \tag{31}$$

4.3 Relative System Performance After Installation

Input

L = System "revitalization" period, the length of the repetitive energy production cycle, expressed in years.

Compute

η_m = Relative performance, the net electrical energy produced by the system during the mth year into a repetition of the full-capacity system energy production cycle, expressed as a fraction (or multiple) of the initial full-capacity output, E. System performance is assumed to repeat in this pattern every L years.

by

$$\eta_m = (\eta_t' S_t)/(\eta S); \qquad m = t - t_o \qquad \text{for} \qquad t_o + 1 \leq t \leq t_o + L \tag{32}$$

5. CALCULATE PRICE MULTIFLIERS

5.1 Expense Multipliers

Input

g_s = Sellback energy price escalation rate, expressed in % (per year).

ϕ_s = Relative inflation (real escalation) of sellback prices from the base year to the start of system operation.

Compute

R_s = Discounted sellback price escalation rate.

by

$$R_s = (1 + g_s)/(1 + k)$$

Input

g_e = Energy price escalation rate.

ϕ_e = Relative inflation (real escalation) of energy prices from the base year to the start of system operation.

Compute

R_c = Discounted energy price escalation rate.

by

$$R_c = (1 + g_e)/(1 + k)$$

Input

g_x = Growth rate of annual expenses, in percent per year. This factor includes growth due to both increases in prices and any growth in the amounts of goods and services required.

Compute

R_x = $(1 + g_x)/(1 + k)$, the discounted escalation rate for expenses.

Input

X_t = One-time expense (if any) in each year t, expressed in $\$_b$. (Replacement costs could be expensed, rather than capitalized, by explicitly including them in this cost stream and eliminating them from capital costs by setting δ_j equal to the negative of C_j for all types of capital for which that treatment is desired.)

5.1.1 Repetitive Expenses

By using:

$$\sum_t R_x^t \frac{1-\tau[\omega+(1-\omega)\sigma_t]}{1-\tau[\omega+(1-\omega)\sigma]} \begin{cases} Z_t/Z & \text{if } t < t_o \\ 1 & \text{if } t \geq t_o \end{cases} \tag{33}$$

Compute:		Using the following summation on t:
(1) Z_v	Present value of total repetitive expenses as a multiplier of the first year repetitive expenses;	t from t_f to ∞.
(2) Z_{RSC}	Present value of total repetitive expenses made after the end of the system life time;	t from $N+1$ to ∞.
(3) Z_{LCC}	Present value of total repetitive expenses made during the system life time.	t from t_f to N.

5.1.2 Non-Repetitive Expenses

By using:

$$\sum_t R_x^t \frac{1-\tau[\omega+(1-\omega)\sigma_t]}{1-\tau[\omega+(1-\omega)\sigma]} X_t \tag{34}$$

Compute:		Using the following summation on t:
(1) x_v	Present value of total non-repetitive expenses;	t from t_f to ∞.
(2) x_{RSC}	Present value of total non-repetitive expenses after the end of the system lifetime;	t from $N+1$ to ∞.
(3) x_{LCC}	Present value of total non-repetitive expenses made during the system lifetime.	t from t_f to N.

5.1.3 Total-Expenses

Input

X_b = Annual expenses when the system is at full capacity, expressed in $\$_b$.

ϕ_x = Relative growth (real escalation) in annual expenses from Y_b to Y_{co}.

(1) Compute

xpm_v = Total expense multiplier, the present value of all expenses, expressed as a multiple of annual expenses when the system is at full capacity.

by

$$xpm_v = (1 - \tau[\omega + (1 - \omega)\sigma])\,\phi_x \left(Z_v + \frac{x_v}{X_b} \right) \tag{35}$$

(2) Compute

$rxpm$ = Residual expense multiplier, the present value of all expenses after the end of the system lifetime, expressed as a fraction of annual expenses when the system is at full capacity.

by

$$rxpm = (1 - \tau[\omega + (1 - \omega)\sigma])\,\phi_x \left(Z_{RSC} + \frac{x_{RSC}}{X_b} \right) \tag{36}$$

(3) Compute

xpm = Expense multiplier, the present value of all expenses during the system lifetime, expressed as a multiple of annual expenses when the system is at full capacity (X_b).

by

$$xpm = (1 - \tau[\omega + (1 - \omega)\sigma])\,\phi_x \left(Z_{LCC} + \frac{x_{LCC}}{X_b} \right) \tag{37}$$

5.2. Sellback Energy Price Multipliers

(1) Compute

bpm_v = Total sellback energy price multiplier.

By: If $\sigma = 0$, $bpm_v = 0$

By: If $\sigma \neq 0$, $bpm_v = \phi_s (1 + g_s)^{-1/2} \left\{ \sum_{t=t_f}^{t_o} \frac{\sigma_t}{\sigma} R_s^t e_t + \frac{R_s^{t_o}}{1 - R_s^L} \sum_{m=1} \frac{\sigma_{t_o+m}}{\sigma} R_s^m \eta_m \right\}$ (38)

(2) Compute

bpm = Sellback price multiplier during the system lifetime.

By: If $\sigma = 0$, $bpm = 0$.

If $\sigma \neq 0$, and $N \leq t_o$,

$$bpm = \phi_s (1 + g_s)^{-1/2} \sum_{t=t_f}^{N} \frac{\sigma_t}{\sigma} R_s^t e_t$$

If $\sigma \neq 0$ and $N > t_o$,

with $n = int\,[(N - t_o)/L)] - 1$, where $int(A)$ = the integer part of A

$$bpm = \phi_s (1 + g_s)^{-1/2} \left\{ \sum_{t=t_f}^{t_o} \frac{\sigma_t}{\sigma} R_s^t e_t + \frac{R_s^{t_o} (1 - R_s^{nL})}{1 - R_s^L} \sum_{m=1}^{L} \frac{\sigma_{t_o+m}}{\sigma} R_s^m \eta_m + R_s^{t_o+nL} \sum_{m=1}^{N-(t_o+nL)} \frac{\sigma_{t_o+m}}{\sigma} R_s^m \eta_m \right\} \quad (39)$$

(3) Compute

$rbpm$ = The sellback price multiplier after the system lifetime.

By: If $\sigma = 0$, $rbpm = 0$.

If $\sigma \neq 0$ and $N \leq t_o$,

$$rbpm = \phi_s (1 + g_s)^{-1/2} \left\{ \sum_{t=N+1}^{t_o} \frac{\sigma_t}{\sigma} R_s^t e_t + \frac{R_s^{t_o+L}}{1 - R_s^L} \sum_{m=1}^{L} \frac{\sigma_{t_o+m}}{\sigma} R_s^m \eta_m \right\} \quad (40)$$

If $\sigma \neq 0$ and $N > t_o$,

$$rbpm = \phi_s (1 + g_s)^{-1/2} R_s^{t_o+nL} \left\{ \sum_{m=N-(t_o+nL)+1}^{L} \frac{\sigma_{t_o+m}}{\sigma} R_s^m \eta_m + \frac{R_s^L}{1 - R_s^L} \sum_{m=1}^{L} \frac{\sigma_{t_o+m}}{\sigma} R_s^m \eta_m \right\}$$

5.3 Thermal Energy Price Multipliers

Input

α = Value of system-produced thermal energy in the first year of full capacity operation ($t_o \leq t \leq t_o + 1$).

α_t = System-produced thermal energy value in year t, expressed as a fraction of the value the system-produced electrical energy would have at the grid price of electricity, p.

(1) Compute

tpm_v = Total thermal energy price multiplier. This factor is the sum of *tpm* and *rtpm*.

By: If $\alpha = 0$, $tpm_v = 0$

If $\alpha \neq 0$,

$$tpm_v = \phi_e (1 + g_e)^{-1/2} \left\{ \sum_{t=t_f}^{t_o} \frac{\alpha_t}{\alpha} R_e^t e_t + \frac{R_e^{t_o}}{1 - R_e^L} \sum_{m=1}^{L} \frac{\alpha_{t_o+m}}{\alpha} R_e^m \eta_m \right\} \tag{41}$$

(2) Compute

tpm = Thermal energy price multiplier during the system lifetime.

By: If $\alpha = 0$, $tpm = 0$

If $\alpha \neq 0$ and $N \leq t_o$,

$$tpm = \phi_e (1 + g_e)^{-1/2} \sum_{t=t_f}^{N} \frac{\alpha_t}{\alpha} R_e^t e_t$$

If $\alpha \neq 0$ and $N > t_o$,

$$tpm = \phi_e (1 + g_e)^{-1/2} \left\{ \sum_{t=t_f}^{t_o} \frac{\alpha_t}{\alpha} R_e^t e_t + \frac{R_e^{t_o}(1 - R_e^{nL})}{1 - R_e^L} \sum_{m=1}^{L} \frac{\alpha_{t_o+m}}{\alpha} R_e^m \eta_m \right.$$

$$\left. + R_e^{t_o+nL} \sum_{m=1}^{N-(t_o+nL)} \frac{\alpha_t}{\alpha} R_e^m \eta_m \right\} \tag{42}$$

(3) Compute

rtpm = Thermal energy price multiplier after the system lifetime.

By: If $\alpha = 0$, $rtpm = 0$.

If $\alpha \neq 0$ and $N \leq t_o$,

$$rtpm = \phi_e (1 + g_e)^{-1/2} \left\{ \sum_{t=N+1}^{t_o} \frac{\alpha_t}{\alpha} R_e^t c_t + \frac{R_e^{t_o+L}}{1 - R_e^L} \sum_{m=1}^{L} \frac{\alpha_{t_o+m}}{\alpha} R_e^m \eta_m \right\} \tag{43}$$

If $\alpha \neq 0$ and $N > t_o$,

$$rtpm = \phi_e (1 + g_e)^{-1/2} R_e^{t_o+nL} \left\{ \sum_{m=N-(t_o+nL)+1}^{L} \frac{\alpha_{t_o+m}}{\alpha} R_e^m \eta_m + \frac{R_e^L}{1 - R_e^L} \sum_{m=1}^{L} \frac{\alpha_{t_o+m}}{\alpha} R_e^m \eta_m \right\}$$

5.4 Electrical Energy Price Multipliers

(1) Compute

spm_v = System energy price multiplier, a factor which accounts for the effects of changes in system capacity and performance and the discounting of escalating financial benefits during and after the system lifetime. This factor is the sum of *spm* and *rspm*.

By: If $\alpha = 1$, $spm_v = 0$.

If $\alpha \neq 1$,

$$spm_v = \phi_e (1 + g_e)^{-1/2} \left\{ \sum_{t=t_f}^{t_o} \left(\frac{1 - \alpha_t}{1 - \alpha} \right) R_e^t c_t + \frac{R_e^{t_o}}{1 - R_e^L} \sum_{m=1}^{L} \left(\frac{1 - \alpha_{t_o+m}}{1 - \alpha} \right) R_e^m \eta_m \right\} \tag{44}$$

(2) Compute

spm = System energy price multiplier during the system lifetime.

By: If $\alpha = 1$, $spm = 0$.

If $\alpha \neq 1$ and $N \leq t_o$,

$$spm = \phi_e (1+g_e)^{-1/2} \sum_{t=t_f}^{N} \left(\frac{1-\sigma_t}{1-\sigma}\right) R_e^t e_t \tag{45}$$

If $\sigma \neq 1$ and $N > t_o$,

$$spm = \phi_e (1+g_e)^{-1/2} \left\{ \sum_{t=t_f}^{t_o} \left(\frac{1-\sigma_t}{1-\sigma}\right) R_e^t e_t \right.$$

$$+ \frac{R_e^{t_o}(1-R_e^{nL})}{1-R_e^L} \sum_{m=1}^{L} \left(\frac{1-\sigma_{t_o+m}}{1-\sigma}\right) R_e^m \eta_m$$

$$\left. + R_e^{t_o+nL} \sum_{m=1}^{N-(t_o+nL)} \left(\frac{1-\sigma_{t_o+m}}{1-\sigma}\right) R_e^m \eta_m \right\}$$

(3) Compute

rspm = The system energy price multiplier after the system lifetime.

By: If $\sigma = 1$, $rspm = 0$.

If $\sigma \neq 1$ and $N \leq t_o$,

$$rspm = \phi_e (1+g_e)^{-1/2} \left\{ \sum_{t=N+1}^{t_o} \left(\frac{1-\sigma_t}{1-\sigma}\right) R_e^t e_t \right.$$

$$\left. + \frac{R_e^{t_o+L}}{1-R_e^L} \sum_{m=1}^{L} \left(\frac{1-\sigma_{t_o+m}}{1-\sigma}\right) R_e^m \eta_m \right\} \tag{46}$$

If $\sigma \neq 1$ and $N > t_o$,

$$rspm = \phi_e (1+g_e)^{-1/2} R_e^{t_o+nL} \left\{ \sum_{m=N-(t_o+nL)+1}^{L} \left(\frac{1-\sigma_{t_o+m}}{1-\sigma}\right) R_e^m \eta_m \right.$$

$$\left. + \frac{R_e^L}{1-R_e^L} \sum_{m=1}^{L} \left(\frac{1-\sigma_{t_o+m}}{1-\sigma}\right) R_e^m \eta_m \right\}$$

6. CALCULATE NET RESALE GAIN

(1) Input

RSL'_N = The price at which the system could be resold at time t, expressed in $\$_t$.

Compute

RSL_t = Revenue from resale of the system at time t expressed in $\$_t$.

By:

$$RSL_t = \begin{cases} RSL'_N & \text{if} \quad t = N \\ 0 & \text{if} \quad t \neq N \end{cases} \tag{47}$$

(2) For each value of j, compute

$TVAL_{jt}$ = Tax book value based on accelerated depreciation of capital goods of type j, at time t.

$STVAL_{jt}$ = Tax book value based on straight line depreciation of capital goods of type j, at time t.

by

$$TVAL_{jt} = CI_{jt}\, sch(t - t_j, TL_j, \mu_{Tj}, \theta_j) \qquad \text{for all} \qquad t \geq t_j$$

and

$$STVAL_{jt} = CI_{jt}\, sch(t - t_j, TL_j, \text{"SL"}, \theta_j) \qquad \text{for all} \qquad t \geq t_j,$$

where the *sch* functions are as defined by Equations (14) to (16) in Section 3.1.3.

Then compute

$TVAL_t$ = Depreciated value (on the tax books) of the system at time t, expressed in $\$_t$.

By

$$TVAL_t = \sum_j TVAL_{jt} \tag{48}$$

Compute

$STVAL_t$ = Depreciated value (on the straight line tax books) of the system at time t, expressed in $\$_t$.

By

$$STVAL_t = \sum_j STVAL_{jt} \tag{49}$$

(3) Input

$$\rho = \begin{cases} 0 \text{ if only accelerated depreciation in excess of decrease of market value is to be recovered.} \\ 1 \text{ if all depreciation in excess of decrease in market value is to be recovered.} \end{cases}$$

$$PUR = \sum_j CI_{j,t_j} \quad \text{- Purchase price of the system, expressed in nominal dollars of mixed vintage.} \tag{50}$$

RF = Fraction of depreciation which is to be 'recovered' $\leqslant 1.0$.

Compute

OI_N = The portion of revenues obtained from resale of the system which is designated as ordinary income.

By

$$OI_N = RF \{min [RSL_t, \rho PUR + (1 - \rho) STVAL_N] - TVAL_N\} \tag{51}$$

(4) Compute

CG_N = The portion of revenues obtained from resale of the system which is designated as capital gain.

By

$$CG_N = RSL_N - TVAL_N - OI_N \tag{52}$$

(5) Input

γ = Sellback price ratio. This is the average price obtained from the utility for electricity sold back to the grid expressed as a fraction (or multiplier) of the retail grid electricity price p.

Compute

NRG = Net resale gain, the present value of the after-tax gain from resale at the end of the system lifetime.

By

$$NRG = RSL_N - \tau[\gamma\, CG_N + OI_N] \tag{53}$$

7. CALCULATE THE BOTTOM LINE

Input

P = System energy price, the marginal cost of electrical energy produced by the system or the price of system-supplied electrical energy used by the system owner at the start of system operations ($t = 0$), expressed in $\$_b$/kWh.

p = Price of electrical energy obtained from the utility grid at the start of system operations ($t = 0$), expressed in $\$_b$/kWh.

$\mathcal{P}$ = Sellback price for electrical energy produced by the system and sold to the utility at the start of system operations ($t = 0$), expressed in $\$_b$/kWh.

7.1 Present Value of Electricity Not Sold Back

(1) VE = Total present value of non-sellback electricity.

$$VE = (1 - \sigma)(P - \tau\omega p)\, E\, spm_v \tag{54}$$

(2) VE_{RSV} = Residual value of non-sellback electricity generated after the end of the system lifetime.

$$VE_{RSV} = (1 - \sigma)(P - \tau\omega p)\, E\, rspm \tag{55}$$

(3) VE_{LCC} = Present value of non-sellback electricity generated during the system lifetime.

$$VE_{LCC} = (1 - \sigma)(P - \tau\omega p)\, E\, spm \tag{56}$$

7.2 Present Value of Thermal Energy

(1) TH = Total present value of all system-produced thermal energy.

$$TH = \alpha(1 - \tau\omega)p\, E\, tpm_v \tag{57}$$

(2) TH_{RSV} = Residual value of thermal energy after the end of the system lifetime.

$$TH_{RSV} = \alpha(1 - \tau\omega)p\, E\, rtpm \tag{58}$$

(3) TH_{LCC} = Present value of system-produced thermal energy generated during the system lifetime.

$$TH_{LCC} = \alpha(1 - \tau\omega)p\, E\, tpm \tag{59}$$

7.3 Present Value of Electricity Sold to the Grid

(1) SB = Total present value of system-produced electrical energy sold back to the grid.

$$SB = \sigma(1 - \tau)\mathcal{P}\, E\, bpm_v \tag{60}$$

(2) SB_{RSV} = Residual value of electrical energy sold back to the grid after the end of the system lifetime.

$$SB_{RSV} = \sigma(1-\tau)\mathcal{P}E\, rbpm \tag{61}$$

(3) SB_{LCC} = Present value (cost) of electrical energy sold back to the grid during the system lifetime.

$$SB_{LCC} = \sigma(1-\tau)\mathcal{P}E\, bpm \tag{62}$$

7.4 Present Value of Expenses

(1) OM = Total present value of recurrent and one-time expenses for operations, maintenance, fuel, etc.

$$OM = X_b\, xpm_v \tag{63}$$

(2) OM_{RSV} = Total residual value of recurrent and one-time expenses after the end of the system lifetime.

$$OM_{RSV} = X_b\, rxpm \tag{64}$$

(3) OM_{LCC} = Total present value (cost) of recurrent and one-time expenses during the system lifetime.

$$OM_{LCC} = X_b\, xpm \tag{65}$$

7.5 Present Value of Capital-Related Costs

(1) CI = Total present value of capital investments and related costs.

$$CI = \sum_j CI_{vj}\, ccm_{vj} \tag{66}$$

(2) CI_{RSV} = Present value of capital investments and related costs after the end of the system lifetime.

$$CI_{RSV} = \sum_j CI_{RSC_j}\, ccm_{rj} \tag{67}$$

(3) CI_{LCC} = Present value of capital investments and related costs during the system lifetime.

$$CI_{LCC} = \sum_j CI_{LCC_j}\, ccm_j \tag{68}$$

7.6 Net Present Value, Life Cycle Cost and Residual System Value

Net Present Value:

Without resale of the system ($\Delta = 0$)

$$NPV \text{ (with } \Delta = 0) = VE + TH + SB - CI - OM \tag{69}$$

Line Cycle Cost:

With resale of the system ($\Delta = 1$).

$$NPV \text{ (with } \Delta = 1) = VE_{LCC} + TH_{LCC} + SB_{LCC} - CI_{LCC} - OM_{LCC} + NRG \tag{70}$$

Residual System Value:

After the end of the 'system lifetime'

$$RSV = VE_{RSV} + TH_{RSV} + SB_{RSV} - CI_{RSV} - OM_{RSV} \tag{71}$$

8. BEYOND THE BOTTOM LINE – BREAK-EVEN ANALYSES

Break-Even System Efficiency:

$$\hat{\eta} = \frac{CI + OM}{VE + TH + SB}\,\eta \tag{72}$$

Break-Even Grid Energy Price:

$$\hat{p} = \frac{CI + OM - SB}{VE + TH}\,p \tag{73}$$

Break-Even Energy Production in the First Year of Capacity Operation:

$$\hat{E} = \frac{CI + OM}{VE + TH + SB}\,E \tag{74}$$

Break-Even Sellback Price for a Permanently-Owned System ($\Delta = 0$):

$$\hat{\mathscr{P}} = \frac{CI + OM - VE - TH}{SB}\,\mathscr{P} \tag{75}$$

Break-Even Sellback Price for a Temporarily-Owned System ($\Delta = 1$):

$$\hat{\mathscr{P}} = \frac{CI_{LCC} + OM_{LCC} - VE_{LCC} - TH_{LCC} - NRG}{SB_{LCC}}\,\mathscr{P} \tag{75}$$

Break-Even Initial System Capital:

where f_j = Price of capital goods of type j, expressed as a fraction of the initial system capital.

$$\hat{C} = (VE + TH + SB - OM)/\sum_j f_j\, ccm_{vj} \tag{76}$$

$$\hat{C}_j = f_j \hat{C} = \text{component prices for each } j \tag{77}$$

Break-Even Price of Component J:

$$\hat{C}_J = \frac{\hat{CI}_{vJ}}{\phi_C R_c^{I_J}\left[1 + (1 + \delta_J) R_c^{L_J}/(1 - R_c^{L_J})\right]} \tag{78}$$

Other Break-Even Values

The break-even values of any of the input parameters can be found by repeating the analysis, varying the value of the parameter of interest until the net present value, *NPV*, equals zero. A warning, however, is in order: Some parameters do not have enough influence on the net present value to cause break-even conditions, even with unrealizable values. Other parameters can solve the break-even equation ($NPV = 0$) only by taking on such unrealizable values. The user of this methodology is responsible for recognizing such results – the algorithm itself contains no tests to detect them.

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APPENDIX A
OMEGA WORKBOOK

APPENDIX A. OMEGA WORKBOOK

The complete OMEGA algorithm is described in Sections 2 through 8 of this volume. The derivation of the algorithm, along with discussion of many peripheral issues, is contained in Volume II.

This appendix is intended to provide a convenient format for manually applying the OMEGA algorithm.

The narrative descriptions of variables given here is abbreviated; more complete descriptions may be found in the body of the document.

The procedure to follow in using this workbook is as follows:

- Start at the beginning and proceed to fill in the blanks sequentially. The instructions may tell you to skip some calculations, depending on the values of certain variables.

- Boxes enclose those variables for which you must supply input values.

- Variables that are not boxed must be calculated; the numbers in parentheses refer to the appropriate equations in the body of the text. (The simplest equations are repeated here, so that reference back to the body is not necessary.)

  WARNING: All numbers expressed as percentages or as percent per year must be divided by 100% before they are used in calculations.

The Owner-Dependent Methodology for Energy Generation System Assessment

_____ Y_b = Base year for current dollars

_____ Y_{co} = First year of system operation. (Defines $t = 0$)

_____ Φ_c = Capital cost escalation factor from Y_b to Y_{co}.

_____ $\Phi_\$$ = General inflation factor from Y_b to Y_{co}.

_____ $\phi_c = \Phi_c/\Phi_\$$ = Real escalation of capital costs from Y_b to Y_{co}.

_____ k = Discount rate, in %/yr.

_____ g_c = Capital cost escalation rate, in %/yr.

_____ $R_c = (1 + g_c)/(1 + k)$ = Discounted escalation rate factor for capital goods.

$\{j\}$ = The set of types of capital goods. (If it is desirable to include working capital, see the discussion on page I-6.)

j = _____ means _____

j = _____ means _____

j = _____ means _____

j = _____ means _____

C_j = Initial cost for capital of type j, in $\$_b$.

t_j = Funding leadtime, with respect to Y_{co}, in yrs.

L_j = Expected useful lifetime in yrs.

θ_j = Salvage value, as fraction of C_j.

δ_j = Additional cost of replacement, as fraction of C_j.

μ_{Tj} = Tax depreciation method (*SL*, *SYD*, or *DDB*; usually *DDB*).

μ_{Bj} = Book depreciation method (*SL*, *SYD*, or *DDB*; usually *SL*).

TL_j = Tax life (usually a constant fraction, tf = _____, $\times L_j$), in yrs.

j	C_j	t_j	L_j	TL_j	θ_j	δ_j	μ_{Tj}	μ_{Bj}

_____ t_0 = Time, with respect to Y_{co}, of full capacity operation, in yrs.

_____ t_f = Time of first cash flow in yrs. Probably the most negative of the t_j.

_____ N = System lifetime, the arbitrary boundary between life-cycle costs and residual system value, in yrs.

(1) CI_{jt} = Capital investment in j at time t.

For j = _____ :

t							
CI_{jt}							

For j = _____ :

t							
CI_{jt}							

For j = _____ :

t							
CI_{jt}							

For j = _____ :

t							
CI_{jt}							

(2) CI_t = $\Sigma_j CI_{jt}$ = total capital investment at time t.

t							
CI_t							
t							
CI_t							

_____ σ = Fraction of electrical energy sold to the utility during the first year of full scale operation, $t_0 \leq t < t_0 + 1$.

σ_t = Fraction of electrical energy sold to the utility during each year t.

t								
σ_t								
t								
σ_t								

_____ ω = Owner type indicator: 0 for consumer, 1 for company

_____ r = After-tax rate of return on equity, in %/yr.

_____ ϵ = Down payment fraction.

_____ β_1 = Other (non-income) tax rate, in % of taxable value of capital.

_____ β_2 = Insurance rate; in % of book value of capital.

_____ β_3 = Investment tax credit rate, in % of investment.

_____ β_4 = One-time-only solar tax credit rate, in % of eligible investment.

_____ F = Financing method indicator.
(= 1 if $\omega = 1$ and the project is financed out of a corporate general fund)
(= 0 if the project is financed by a mortgage.)

PV (present value) of Capital Investments in j:

	Total (3)	After the End of the System Lifetime (4)	During the System Lifetime (5)
For j = _____	CI_{vj} _____	$CI_{RSC,j}$ _____	$CI_{LCC,j}$ _____
For j = _____	CI_{vj} _____	$CI_{RSC,j}$ _____	$CI_{LCC,j}$ _____
For j = _____	CI_{vj} _____	$CI_{RSC,j}$ _____	$CI_{LCC,j}$ _____
For j = _____	CI_{vj} _____	$CI_{RSC,j}$ _____	$CI_{LCC,j}$ _____

(b) PV of Capital investments in j weighted by the sellback fraction

NOTE: If $\beta_3 = 0$, CI'_{vj}, $CI'_{RSC,j}$ and $CI'_{LCC,j}$ need not be calculated.

If ($\omega = 1$) or if ($\omega \neq 1$ and $\sigma_t = \sigma$ for all t)

then $CI'_{vj} = CI_{vj}$, $CI'_{RSC,j} = CI_{RSC,j}$, $CI'_{LCC,j} = CI_{LCC,j}$

	Total	After the End of the System Lifetime	During the System Lifetime
For j = _____	, CI'_{vj} _____	, $CI'_{RSC,j}$ _____	, $CI'_{LCC,j}$ _____
For j = _____	, CI'_{vj} _____	, $CI'_{RSC,j}$ _____	, $CI'_{LCC,j}$ _____
For j = _____	, CI'_{vj} _____	, $CI'_{RSC,j}$ _____	, $CI'_{LCC,j}$ _____
For j = _____	, CI'_{vj} _____	, $CI'_{RSC,j}$ _____	, $CI'_{LCC,j}$ _____

(10) $bdep_{vj}$ = PV of book depreciation function. Note that $bdep\ (T, L_j, \mu_j, \theta_j)$ used in Equation (10) is the function $dep\ (A, DL, \mu, \theta)$ defined by Equation (7), (8), or (9), evaluated with $DL = L_j$ and $\mu = \mu_{Bj}$.

For j = _____ , $bdep_{vj}$ = _____

For j = _____ , $bdep_{vj}$ = _____

For j = _____ , $bdep_{vj}$ = _____

For j = _____ , $bdep_{vj}$ = _____

_____ τ = Owner's marginal (federal and state) income tax rate, in % of taxable income.

PV of tax depreciation functions:

If $\tau = 0$, skip the calculation of $tdep_{vj}$, $tdep_{RSC,j}$, and $tdep_{LCC,j}$.

Note that $tdep\ (T, L_j, \mu_j, \theta_j)$ used in Equations (11), (12), and (13) is the function $dep\ (A, DL, \mu, \theta)$ defined by Equations (7), (8), or (9), evaluated with $DL = TL$; and $\mu = \mu_{Tj}$.

	Total (11)	After the End of the System Lifetime (12)	During the System Lifetime (13)
For j = _____	, $tdep_{vj}$ = _____	, $tdep_{RSC,j}$ = _____	, $tdep_{LCC,j}$ = _____
For j = _____	, $tdep_{vj}$ = _____	, $tdep_{RSC,j}$ = _____	, $tdep_{LCC,j}$ = _____
For j = _____	, $tdep_{vj}$ = _____	, $tdep_{RSC,j}$ = _____	, $tdep_{LCC,j}$ = _____
For j = _____	, $tdep_{vj}$ = _____	, $tdep_{RSC,j}$ = _____	, $tdep_{LCC,j}$ = _____

(17) $bsch_{vj}$ = PV of schedule function. Note that $bsch\ (A, L_j, \mu_j, \theta_j)$ used in Equations (17), (18) or (19) is the function $sch\ (A, DL, \mu, \theta)$ defined by Equation (14), (15) or (16) evaluated with $DL = L_j$ and $\mu = \mu_{Bj}$.

	Total (17)	After the End of the System Lifetime (18)	During the System Lifetime (19)
For j = _____	$bsch_{vj}$ = _____	$bsch_{RSC,j}$ = _____	$bsch_{LCC,j}$ = _____
For j = _____	$bsch_{vj}$ = _____	$bsch_{RSC,j}$ = _____	$bsch_{LCC,j}$ = _____
For j = _____	$bsch_{vj}$ = _____	$bsch_{RSC,j}$ = _____	$bsch_{LCC,j}$ = _____
For j = _____	$bsch_{vj}$ = _____	$bsch_{RSC,j}$ = _____	$bsch_{LCC,j}$ = _____

Note that $tsch\ (T, L_j, \mu_j, \theta_j)$ used in Equations (20), (21) or (22) is the function $sch\ (A, DL, \mu, \theta)$ defined by Equations (14), (15) or (16) evaluated with $DL = TL_j$ and $\mu = \mu_{Tj}$.

If $\beta_1 = 0$, the *tsch*'s need not be calculated.

	Total (20)	After the End of the System Lifetime (21)	During the System Lifetime (22)
For j = _____	$tsch_{vj}$ = _____	$tsch_{RSC,j}$ _____	$tsch_{LCC,j}$ _____
For j = _____	$tsch_{vj}$ = _____	$tsch_{RSC,j}$ _____	$tsch_{LCC,j}$ _____
For j = _____	$tsch_{vj}$ = _____	$tsch_{RSC,j}$ _____	$tsch_{LCC,j}$ _____
For j = _____	$tsch_{vj}$ = _____	$tsch_{RSC,j}$ _____	$tsch_{LCC,j}$ _____

(23) Insurance Multiplier:

If $\beta_2 = 0$, do not calculate ins_{vj}, $ins_{RSC,j}$ or $ins_{LCC,j}$.

	Total	After the End of the System Lifetime	During the System Lifetime
For j = _____	ins_{vj} _____	$ins_{RSC,j}$ _____	$ins_{LCC,j}$ _____
For j = _____	ins_{vj} _____	$ins_{RSC,j}$ _____	$ins_{LCC,j}$ _____

For j = _____ , ins_{vj} _____ , $ins_{RSC,j}$ _____ , $ins_{LCC,j}$ _____

For j = _____ , ins_{vj} _____ , $ins_{RSC,j}$ _____ , $ins_{LCC,j}$ _____

_____ F = Financing method indicator: 0 if mortgage; 1 if not.

_____ i = Mortgage interest rate.

If $F = 1$ or if $\epsilon = 1$, skip the calculation of $sff_{i,M}$, $crf_{i,MP}$ and $mort_{vj}$.

_____ MP = Mortgage period, expressed in years.

_____ $sff_{i,MP}$ = sinking fund factor. (24)

_____ $crf_{i,MP}$ = $sff_{i,MP} + i$ = Capital recovery factor. (25)

$mort_{vj}$ = Mortgage value function. (26)

For j = _____ , $mort_{vj}$ = _____

For j = _____ , $mort_{vj}$ = _____

For j = _____ , $mort_{vj}$ = _____

For j = _____ , $mort_{vj}$ = _____

Capital Cost Multipliers

	Total (27)	Residual (28)	Life-Cycle Cost (29)
For j = _____	ccm_{vj} _____	ccm_{rj} _____	ccm_j _____
For j = _____	ccm_{vj} _____	ccm_{rj} _____	ccm_j _____
For j = _____	ccm_{vj} _____	ccm_{rj} _____	ccm_j _____
For j = _____	ccm_{vj} _____	ccm_{rj} _____	ccm_j _____

_____ Z = Nameplate size of the system at capacity, in kWp

_____ η = Average system efficiency during year t_0

_____ S = Total solar energy during year t_0, in kWh/kWp.

_____ $E = S Z \eta$ = Net electrical energy produced by the system during the first year of system operation. (30).

In each year t:

Z_t = Average nameplate size of the system, in kWp.

η'_t = Average system efficiency.

S_t = Total solar energy, in kWh/kWp.

t							
Z_t							
η'_t							
S_t							
t							
Z_t							
η'_t							
S_t							

(31) $e_t = S_t Z_t \eta'_t / E$ = Net electrical energy produced by the system in year t, for $t \leq t_0$.

t							
e_t							
t							
e_t							

_____ L = System 'revitalization' period, in yrs.

(32) $\eta_m = \eta'_t S_t/\eta S$ = Relative performance during mth year.

where $m = t - t_0$ for $t_0 + 1 \leq t \leq t_0 + L$

t	_____	_____	_____	_____	_____	_____	_____	_____
m	1	2	3	4	5	6	7	8
η_m	_____	_____	_____	_____	_____	_____	_____	_____
t	_____	_____	_____	_____	_____	_____	_____	_____
m	9	10	11	12	13	14	15	16
η_m	_____	_____	_____	_____	_____	_____	_____	_____
t	_____	_____	_____	_____	_____	_____	_____	_____
m	17	18	19	20	21	22	23	24
η_m	_____	_____	_____	_____	_____	_____	_____	_____

_____ g_x = Growth rate of expenses, in %/yr.

_____ R_x = $(1 + g_x)/(1 + k)$ = Discounted escalation rate.

x_t = One-time expense in each year t.

t	_____	_____	_____	_____	_____	_____	_____
x_t	_____	_____	_____	_____	_____	_____	_____
t	_____	_____	_____	_____	_____	_____	_____
x_t	_____	_____	_____	_____	_____	_____	_____

PV of Expenses:		Total		Residual		During the System Lifetime
(33) Repetitive	Z_v	_____	Z_{RSC}	_____	Z_{LCC}	_____
(34) Non-Repetitive	x_v	_____	x_{RSC}	_____	x_{LCC}	_____

_____ x_b = Annual expenses when the system is at full capacity, in $\$_b$/yr.

_____ ϕ_x = Relative growth in annual expenses from Y_b to Y_{co}.

Total Expense Multiplier:

_____ xpm_v = Total (35)

_____ $rxpm$ = Residual (36)

_____ xpm = During the system lifetime (37)

_____ g_s = Sellback energy price escalation rate, in %/yr.

_____ R_s = $(1 + g_s)/(1 + k)$ = Discounted sellback price escalation rate.

_____ ϕ_s = Relative inflation of sellback prices.

Sellback Energy Price Multiplier

_____ bpm_v = Total (38)

_____ bpm = During the system lifetime (39)

_____ $rbpm$ = Residual (40)

_____ g_e = Energy price escalation rate, in %/yr.

_____ R_e = $(1 + g_e)/(1 + k)$ = Discounted energy price escalation rate.

_____ ϕ_e = Relative inflation of energy prices.

_____ α = Value of thermal energy produced in first year of operation, relative to the value of electrical energy produced that year (priced at p, the grid price).

_____ α_t = Relative value of thermal energy produced in year t.

t							
α_t							
t							
α_t							

Price Multiplier:	Total	During the System Lifetime	Residual
Thermal Energy	(41) tpm_v _____	(42) tpm _____	(43) $rtpm$ _____
Electrical Energy	(44) spm_v _____	(45) spm _____	(46) $rspm$ _____

_____ Δ = System resale indicator: 0 if the system is not sold at $t = N$, the end of the system lifetime; 1 if the system is resold.

If $\Delta = 0$ (system is not resold), skip the energy price inputs immediately following the reference to Equation (53) on page 12 of this workbook.

(47) RSL_t = Revenue from resale of the system

= _____ at $t = N =$ _____; 0 otherwise

(48) $TVAL_t = \sum_j TVAL_{jt}$ = Tax book value based on accelerated depreciation at time t.

For j _____:

t						
$TVAL_{jt}$						

For j _____:

t						
$TVAL_{jt}$						

For j _____:

t						
$TVAL_{jt}$						

For j _____ :

t						
$TVAL_{jt}$						

_____ $TVAL_t$

(49) $STVAL_t = \sum_j STVAL_{jt}$ = Tax book value based on straight line depreciation at time t.

For j = _____ :

t						
$STVAL_{jt}$						

For j = _____ :

t						
$STVAL_{jt}$						

For j = _____ :

t						
$STVAL_{jt}$						

For j = _____ :

t						
$STVAL_{jt}$						

_____ $STVAL_t$

(50) _____ $PUR = \sum_j CI_{j,t_j}$ = Purchase price of the system. (Note that the values of CI_{j,t_j} are the first values for each j in the CI_{jt} calculations, which follow the reference to Equation (1) on page 2 of this workbook.)

_____	RF	= Fraction of depreciation 'recovered.'
_____	ρ	= Depreciation recovered indicator.
_____	γ	= Sellback price ratio. (This is not really an independent input; it must equal $\mathscr{P}/p$ – see the next input box.)

(51) _____ OI_N = Ordinary income obtained from resale of the system.

(52) _____ CG_N = Capital gain obtained from resale of the system.

(53) _____ NRG = Net resale gain

_____	P	= Marginal cost of electrical energy produced by the system at $t = 0$ expressed in $\$_b$/kWh.
_____	p	= Price of electrical energy obtained from the grid at $t = 0$ expressed in $\$_b$/kWh.
_____	$\mathscr{P}$	= Sellback price for electrical energy sold by the utility at $t = 0$ expressed in $\$_b$/kWh.

	Total		Residual		During the System Lifetime	
PV of Non-Sellback Electricity :	(54) VE	_____	(55) VE_{RSV}	_____	(56) VE_{LCC}	_____
PV of Thermal Energy :	(57) TH	_____	(58) TH_{RSV}	_____	(59) TH_{LCC}	_____
PV of Electricity Sold Back :	(60) SB	_____	(61) SB_{RSV}	_____	(62) SB_{LCC}	_____
PV of Expenses :	(63) OM	_____	(64) OM_{RSV}	_____	(65) OM_{LCC}	_____
PV of Capital Invesments :	(66) CI	_____	(67) CI_{RSV}	_____	(68) CI_{LCC}	_____
Net Resale Gain (calculated above)					NRG	_____
Total						

(69) NPV (If $\Delta = 0$, without resale): _____

(70) (If $\Delta = 1$, with resale): _____

(71) RSV Residual system value: _____

Break-Even Analyses:

(72) _____ $\hat{\eta}$ = System efficiency.

(73) _____ $\hat{p}$ = Grid energy price.

(74) _____ $\hat{E}$ = Energy production in the first year of operation.

(75) _____ $\hat{\mathscr{P}}$ = Sellback price.

f_j = Relative price of capital goods of type j.

j				
f_j				

(76) _____ $\hat{C}$ = Break-even initial system capital.

(77) $\hat{C}_j = f_j \hat{C}$ = Allocated break-even component price.

j				
$\hat{C}_j$				

(78) _____ $\hat{C}_J$ = Break-even price of component J = _____

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