

*Application of Solar Technology to Today's
Energy Needs—Vol. II*

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Volume II

**Application of
Solar Technology
to Today's Energy Needs**

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PREFACE

The previous volume of this report presented the results of an analysis of a large number of solar energy systems designed to meet the energy requirements of homes, apartment buildings, shopping centers, industries, and small communities. This volume provides detailed information about the assumptions made in these calculations and the techniques employed.

An attempt was made to present a broad sampling of the systems which may be available during the next 10 to 15 years. The richness and variety of opportunities is astonishing; chapter IV describes several hundred different systems designs on separate charts. It is difficult to thumb through these pages without admiring the ingenuity and inventiveness of the industry. The richness of this base of ideas and the encouraging rate at which new ideas are emerging, are one of the greatest assets of solar technology.

Apart from presenting a catalog of system concepts, this volume describes a methodology for evaluating the economic and technical merits of small-scale energy systems which can be owned by any of a variety of owners. We hope that the techniques described here will be widely applicable to analysis of small-scale energy systems. The first chapter presents a method for computing the effective cost of energy as a function of the financial expectations and tax status of several different kinds of owners. The second presents a method for computing the performance of different kinds of systems operated in an optimum way. A third chapter presents a technique for parametrizing uncertainties about future fuel and electricity prices. The final pages contain a list of corrections for errors discovered in volume 1.

If the bulk of the resulting work is intimidating, we can only say that we could find no way to abbreviate the presentation without sacrificing a sense of the richness of the alternatives **Or the** complexity of the problem of choosing between them.

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NOT E: This Volume discusses the analytical methods used and provides details on each system analyzed. Volume I summarizes the analysis of system performance and costs, discusses policy, major impacts and constraints on solar markets, and reviews direct solar technology,

Chapter I

ANALYTICAL METHODS

Chapter I.—ANALYTICAL METHODS

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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 equipment 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. '

¹OMB 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. In 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 meas-

ure 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.

²Paul 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 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:

$$\begin{aligned} &\text{average capital charges perceived} \\ &\text{by the final consumer of energy} \\ &= k_c X \text{ (initial cost of equipment)} \end{aligned}$$

The constant in this equation (k_c), 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-1 and I-2 for several assumptions about ownership. The assumptions used to prepare these curves are shown in table I-1 (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-1 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

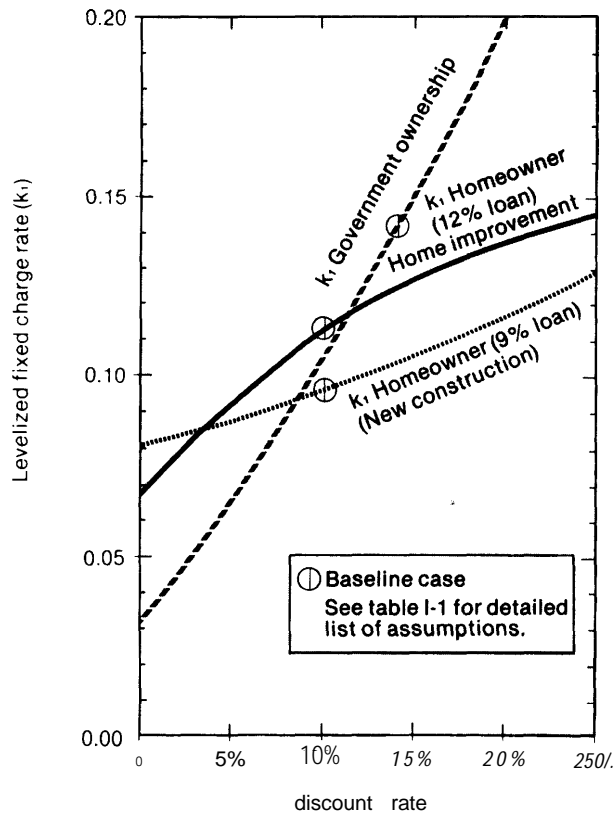


Figure 1-2.—Sensitivity of Capital Charges to Rate of Return for Corporate Owner

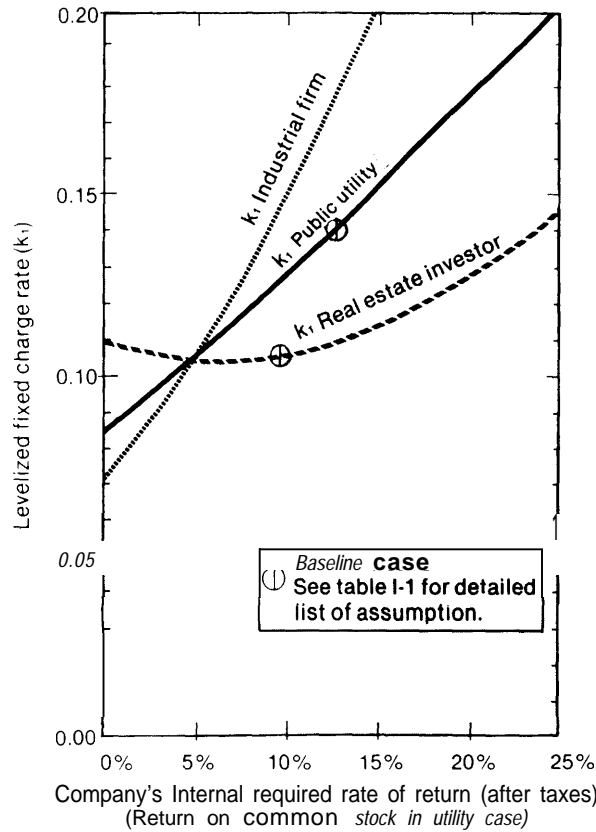


Table I-1.— Baseline Assumptions Used to Prepare Figures I.1 and I.2.

| | 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 | 0 | 0 | 0 | 0 | 0 | .122 | 0 |
| Earnings of common stock | — | — | — | — | — | .13 | 0 |
| Fraction of common stock | 0 | 0 | 0 | 0 | 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 | 0 |
| 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 depreciation . 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:

$$\begin{aligned} &\text{average O\&M costs perceived} \\ &\text{by energy consumer} \\ &= k_2 X (\text{O\&M cost in first year} \\ &\quad \text{of the system's operation}) \end{aligned}$$

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:

$$\begin{aligned} &\text{average energy costs} \\ &\text{perceived by consumer} \\ &= k_3 X (\text{energy costs in the first year} \\ &\quad \text{of the system's operation}) \end{aligned}$$

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:

$$\begin{aligned} \text{PRICE} = &k_1 \times (\text{initial price of equipment}) \\ &+ k_2 \times (\text{initial O\&M costs}) \\ &+ k_3 \times (\text{initial energy costs}) \\ &+ (\text{levelized replacement costs}) \end{aligned}$$

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:

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

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:

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

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

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

| | |
|---|---|
| <p>a = accelerated depreciation multiplier ($a = 1$ for straight line; $a = 2$ for double-declining balance)</p> <p>$B(r, LN, t)$ = interest paid during year t on \$1.00 of debt paying interest r over LN years (defined in equation 12)</p> <p>$CRF(d, L)$ = capital recovery factor for a loan with interest d payable over L years (defined in equation 3)</p> <p>d = consumer's discount rate</p> <p>d' = consumer's discount rate in constant dollars $(1 + d') = (1 + d)/(1 + i)$</p> <p>$D(a, DP, t)$ = 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)</p> <p>$DEP(a, DP, R)$ = net present value of depreciation with accelerated depreciation multiplier a, depreciation period DP, and discount rate R (defined in equation 29)</p> <p>DP = depreciation period</p> <p>$E(t)$ = payments for energy made during year t (evaluated in constant dollars valued at the first year of the system's operation)</p> <p>f = fraction of initial value of system financed with mortgage</p> <p>FIX = fixed charge made by a utility or other industry to cover levelized capital expenses and yield the desired rate of return</p> <p>f_b = fraction of utility plant financed with bonds</p> <p>f_c = fraction of utility plant financed with common stock</p> <p>f_p = fraction of utility plant financed with preferred stock</p> <p>i = annual rate of inflation</p> <p>IN = fraction of capital value of plant paid for insurance annually</p> <p>$INCOME(t)$ = gross receipts received by a system owner during year t of a system's operation</p> <p>ITC = investment tax credit (fraction of capital value of plant deducted from taxes in first year of operation)</p> <p>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</p> <p>$K(t)$ = capital expended during year t of a plant's construction (evaluated in dollars valued at the first year of the system's operation)</p> <p>k = multiplier for determining the capital-related component of the levelized PRICE paid by customers for energy from the initial installed cost .</p> | <p>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*</p> <p>k_s = 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"</p> <p>$k_4(t)$ = 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*</p> <p>L = period over which system costs are measured</p> <p>LN = period of loan</p> <p>M_o = routine operating costs in the first year of the system's operation</p> <p>$M(t)$ = 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</p> <p>N = the system's life in years</p> <p>N_c = number of years required to construct a large plant or system</p> <p>N_r = life of major replacements</p> <p>$PV(d)$ = present value of a cash flow given a discount rate d (defined in equation 1)</p> <p>PRICE = levelized annual price charged to the customer</p> <p>PT = fraction of initial capital value of the equipment paid annually for property tax</p> <p>r = interest rate paid on mortgages</p> <p>R = commercial and industrial required rate of return</p> <p>R_u = utility's permitted rate of return (defined in equation 32)</p> <p>r_b = interest rate paid by utilities on bonds</p> <p>= return paid by utilities on common stock</p> <p>= return paid by utilities on preferred stock</p> <p>$S(R, LN)$ = 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)</p> <p>t = the year of system operation under consideration</p> <p>T = net income tax rate (defined in equation 11)</p> <p>T_f = Federal income tax rate</p> <p>T_s = State income tax rate</p> <p>TAX(t) = income tax paid in year t</p> <p>$\delta(t)$ = a switch function used for convenience, $b(t) = 0$ unless $t = 0$ in which case $\delta(0) = 1$</p> |
|---|---|

*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_0 . 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:

$$\text{LEVELIZED CAPITAL COSTS} = k_1 K_0 \quad (4)$$

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

where $\text{CRF}(d, L)$ 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:

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

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

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 M_0 , the levelized annual O&M expenses are given by:

$$\text{LEVELIZED OPERATING COSTS} = k_3 M_0 \quad (6)$$

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

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

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:

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

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

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

PRICE

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

$$\text{PRICE} = k_1 K_0 + k_2 E(1) + k_3 M_0 + \sum_{t=1}^L k_4(t) M(t) \quad (9)$$

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 mortgage.—It is assumed that the homeowner will finance a solar unit on a new home with the same mortgage 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:

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

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:

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

$$B(r, LN, t) = [(1+r)^{-t} - (r - \text{CRF}(r, LN))^{-t}] \text{CRF}(r, LN)$$

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 0 and the total annual capital-related costs during year t

can be expressed as follows: (15)

$$\begin{aligned} \text{CAPITAL CHARGES (t)} = & k_o [(1-f) \text{CRF}(d, L) + \\ & f \text{CRF}(r, LN) - T(1+r)^{-t} (r - \text{CRF}(r, LN)) \\ & + \text{CRF}(r, LN) + (1-T)PT + IN] \end{aligned}$$

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

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

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

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

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(1). The equations are identical to the ones developed in the previous case:

LEVELIZED COST OF PURCHASED ENERGY = k'₂ E(1) (17)

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

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 k₃ 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.

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

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

PRICE

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

$$\text{PRICE} = k'_1 K_0 + k'_2 E(1) + k'_3 M_0 + \sum_{t=1}^L k'_4(t) M(t) \quad (21)$$

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 $D(a, DP, t)K_0$ 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 \times \$100/10 = \20 , the second year deduction is $2 \times (100 - 20)/10$, 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:

$$D(a, DP, t) = \begin{cases} (a/DP) (1-a/DP)^{t-1} & t < t_0 \\ (1-a/DP)^{t_0-1} / (DP-t_0+1) & t \geq t_0 \end{cases} \quad (22)$$

$t_0 =$ the first year for which t is greater than or equal to $1 + DP (I-I/a)$

A shift is made to straight-line depreciation when $t = t_0$. 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 $ITC \times K_0$ 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_0).

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:

$$OUTLAYS (t) = \begin{cases} (1-f)K_0 & \text{when } t=0 \\ K_0 [PT+IN+ fCRF (r, LN)] + \\ (1+i)^t [M_0 + M(t) + E(t)] \\ + TAX(t) & \text{when } t > 0 \end{cases} \quad (23)$$

where $f =$ fraction of project financed by debt
(24)

$$TAX(t) = T(INCOME (t) - (1+i)^t(M_0 + M(t) + E(t)) - K_0(fB(r, LN, t) + D(a, DP, t) + PT + IN) - (\text{deductions for major replacements}) - K_0 ITC \delta(t-1)$$

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

As shown, the tax is reduced by $K_0 ITC$ 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:

$$INCOME (t) = FIX + (1+i)^t (MO + E(t)) \quad (25)$$

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:

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

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

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

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:

$$DE P(a, DP, R) = \begin{cases} 0 & \text{if } d = 0 \\ \frac{1}{DP[CRF(R, DP)]} & \text{if } a = 1 \\ (a/DP) \frac{1 - \left[\frac{1-a/DP}{1+R} \right]^{t_0-1}}{R + a/DP} + \left[\frac{1-a/DP}{(DP-t_0+1)} \right] \left[\frac{(1+R)^{DP+1-t_0-1}}{R(1+R)^{DP}} \right] & \text{if } a > 1 \end{cases} \quad (29)$$

$t_0 =$ first integer greater than or equal to $1 + DP(1-1/a)$

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

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

$$PRICE = FIX + CRF(d, L) \sum_{t=1}^L \left| \frac{[M_0 + E(t)] (1+i)^t}{(1+d)^t} \right| \quad (32)$$

$$PRICE = k_1'' K_0 + k_2'' E(I) + k_3'' M_0 + \sum_{t=1}^L k_4''(t)M(t) \quad (33)$$

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-

³The 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).

⁴E PRI Technical Assessment Group, Technical Assessment Guide, August 1977.

investments 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.

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

There is some dispute in the utility community about whether to reduce the cost of debt by the factor $1-T$ 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 $S(R, LN)K_0$ is set aside each year where:

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

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 $t = 0$. 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 construction” 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_0) 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_0) can be approximated as follows:

$$K_0 = \sum_{t=-N_c}^0 K(t) \left[\frac{1+i}{1+R_u} \right]^t \quad (36)$$

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:

$$\text{OUTLAYS } (t) = K_0 [PT + IN + f_b r_b + f_c r_c + f_p r_p + \quad (37)$$

$$SR_u(LN)] + TAX(t) + (1+i)^t (M_0 + M(t) + E(t)) \quad (38)$$

$$TAX(t) = T [INCOME(t) - (1+i)^t (M_0 + M(t) + E(t))$$

- $K_0 (f_b r_b + PT + IN + D(a, DP, t))$
- (deductions from major replacements)]
- $K_0 ITC \delta (t-1)$

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

$$FIX' = k_1''' K_0 + \sum_{t=1}^L k_4'''(t) M(t) \quad (39)$$

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

$$k_4'''(t) = \frac{CRF(R_u, L)}{1-T} \left(\frac{1+i}{1+R_u} \right)^{t_0} \left[1 - \frac{ITC}{1+R_u} - T \times DEP(a, DP, R_u) \right] \quad (41)$$

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

$$PRICE = k_1''' K_0 + k_2''' E(1) + k_3''' M_0 + \sum_{t=1}^L k_4'''(t) M(t) \quad (42)$$

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:

$$\text{INCOME}(t) = \text{FIX}' + (1+i)^t \text{IM}_0 + E(t) \quad (43)$$

A number of simplifications have been introduced into this accounting procedure. The same capital value, K_0 , 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

$$\begin{aligned} \text{INCOME}(t) = K_0 & \left[\text{PT} + \text{IN} \right. \\ & \left. + \frac{R_u + S(R_u, LN) - T \infty D(a, DP, t)}{(1-T)} \right] \\ & + (1+i)^t (M_0 + E(t) - K_0 \times \text{ITC} \alpha (t-1) \\ & - \text{expenses for major replacements} \end{aligned} \quad (44)$$

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:

$$\begin{aligned} \text{PRICE} = k_1'''' K_0 + k_2'''' E(1) + k_3'''' M_0 \\ + \sum_{t=1}^L k_4''''(t) M(t) \end{aligned} \quad (45)$$

where

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

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

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

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

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

(47)

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 credit-

worthiness 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:

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

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

⁵The Cost of Energy 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 equipment 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 non-solar buildings. In 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 mortgages 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).⁶ 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-

⁶Evaluation 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 2.8 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 govern-

ments 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 9.69 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

⁷NE WS, Mar 19, 1976, Federal Home Loan Bank Board, table I

⁸Statistical 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)

⁹State and Local Finances - Significant Features, AC I R 1973-74

¹⁰1972 Council of Governments Report

¹¹Statistics 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 10-percent returns after taxes.

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

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.

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 depreciation interval of 15 years, regardless of the actual lifetime of the equipment. Apartments 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

¹³IRS 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

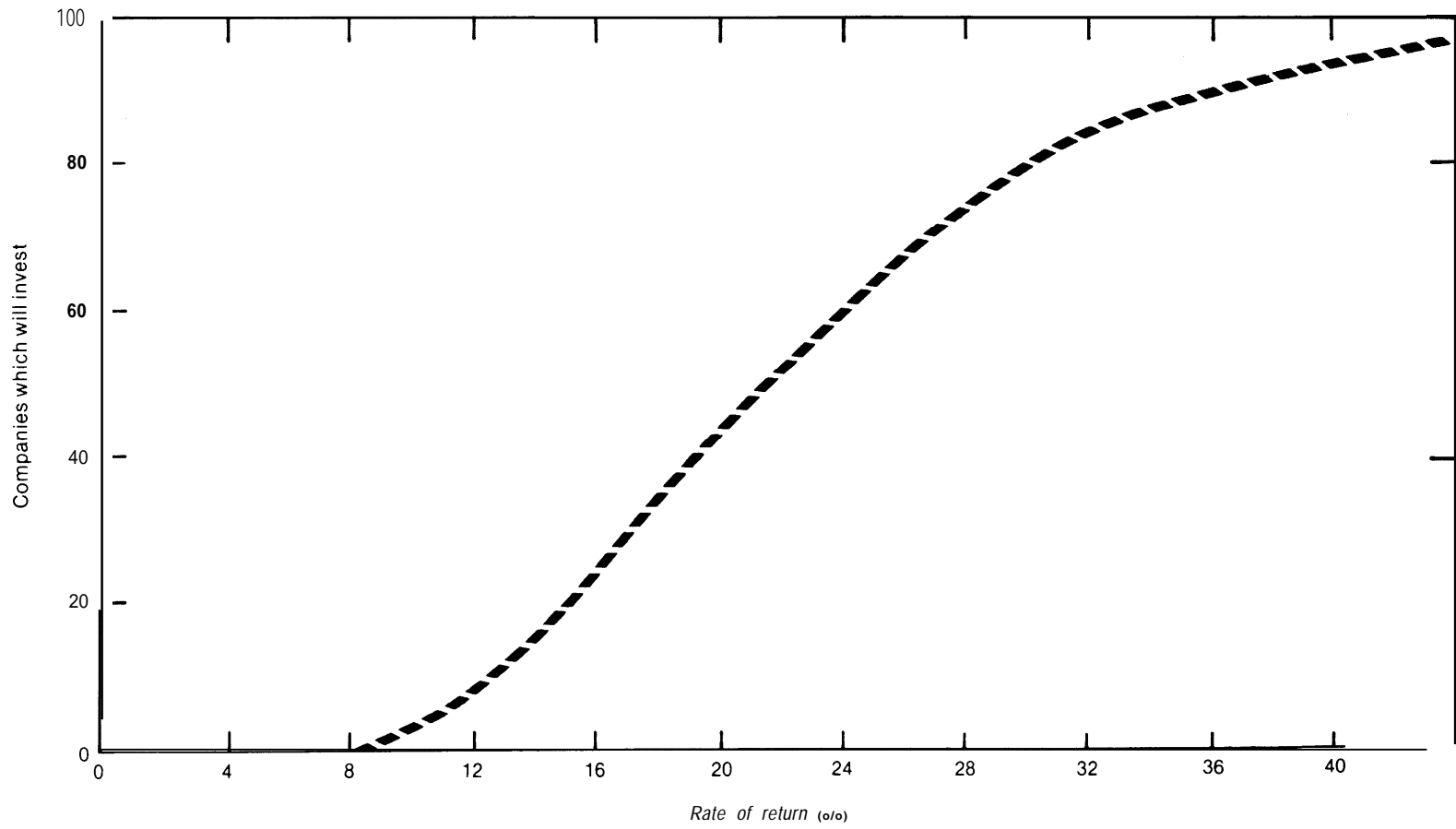


Table 1-3.—Summary of the Financing of Public-Owned Utilities in the United States 1973,74

| | 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) | 7.51 (January) |
| | 9.37 (December) | 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. "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.

¹Statistics 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 utilities: in 1973 (see table I-I), 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 10-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. 's

¹⁵Op. 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 |
| (Earnings)-(inflation). | | | | 0.4 | 5.9 | 8.4 | 7.2 | 6.3 | 7.4 |
| | | | | | | | | 8.3 | 9.6 |
| | | | | | | | | | 10.0 |

^aStatistics of private, Owned Electric Utilities in the United States 1974, FPC, P. XXIX.
^bStatistical Abstract of the United States 1975, U.S. Department of Commerce, P. 416.

Chapter II

**CURRENT AND PROJECTED
FUEL COSTS**

Chapter II-CURRENT AND PROJECTED FUEL COSTS

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Current and Projected Fuel Costs

Anticipating the future cost of energy in the United States is an extremely uncertain undertaking. The complex industry is in rapid flux, and the past is an unreliable guide to the future. Prices will depend on:

- the cost of developing and producing domestic fuel resources;
- the price of imported fuels;
- the cost of producing synthetic fuel substitutes;
- externalities such as environmental regulations; and
- regulatory impact, both explicit and implicit.

Confident estimates in these areas simply are not possible, although a large number of the estimates can be supported. The predicted future price of fuel can have a strong influence on both private and public decisions about solar energy. Investments in solar and other conservation equipment will appear more attractive if energy prices are expected to rise sharply instead of remaining constant or increasing gradually. Public perception of future energy prices may be guided, to a large degree, by the Government's behavior on this issue. As long as the Government insists that energy prices will not rise, the public almost certainly will make decisions on this basis.

CURRENT ENERGY PRICES

The prices charged during 1976 for residential and utility fuels in the four regions examined in this study are illustrated in table II-1. It should be noted that there is a significant difference between prices paid for residential natural gas in different parts of the country (\$3.18 per million Btu (MMBtu) in Boston and \$1.10 per MMBtu in Kansas City in 1975), and the prices charged for utility coal (\$5 per ton in Albuquerque, where access to mines is direct, and \$25 per ton in Boston, where transportation costs are significant). In general, energy prices demonstrate a greater geographic variation than the total amount of sunlight available for solar installations, and the two effects may cancel each other out. In New England, for example, insolation rates are relatively low, but fuel prices are high.

The prices charged for electricity are more difficult to summarize, since most utilities charge different rates in summer and winter and use "declining block rates" to

define costs in each season. The actual residential rate schedules used in each of the four cities in 1976 are plotted as a function of monthly consumption in figure I 1-1. As can be seen, electric prices vary greatly around the country.

The rates used in evaluating the cost of electricity consumed by different customers are simplified approximations of the actual prices charged. The assumed rate schedules are summarized in table 11-2, and residential rates are illustrated in figure 11-2. The schedules were prepared from the actual rates, using procedures outlined in table II-3. Different schedules were applied, as appropriate, to residences, apartments, shopping centers, and industries. Where different summer and winter rates applied, the rates were averaged by weighting each seasonal rate according to the number of months in the season. Complex rate schedules were simplified with linear approximations in some instances.

Table II-1.—1976 Fuel Prices

| Location | Residential consumer prices incl. applicable taxes ^a (mils/kWh) | | Average delivered contract price at utility electric plants, January 1976 ^b (mils/kWh) | | |
|-----------------------|--|--|---|------------------------------|------------------------|
| | Natural gas | No. 2 heating oil | Natural gas | Residual fuel oil (No. 6) | Coal |
| Albuquerque | 4.980 (Dallas) | 9.893 ^c (Mountain) | 2.696 (New Mexico) | 6.335 (New Mexico) | 0.8601 (New Mexico) |
| Boston | 10.87 (Boston) | 10.40 (Boston) | 5.669 (Vermont) | 6.171 (Massachusetts) | 4.239 |
| Fort Worth | 4.980 (Dallas) | Not Available (West South Central) | 2.966 (Texas) | 6.010 (Texas) | 0.9010 (Texas) |
| Omaha | 3.747 (Kansas City) | 9.573 ^c (West North Central) | 2.365 (Nebraska) | 5.474 (Nebraska) | 3.276 (Nebraska) |

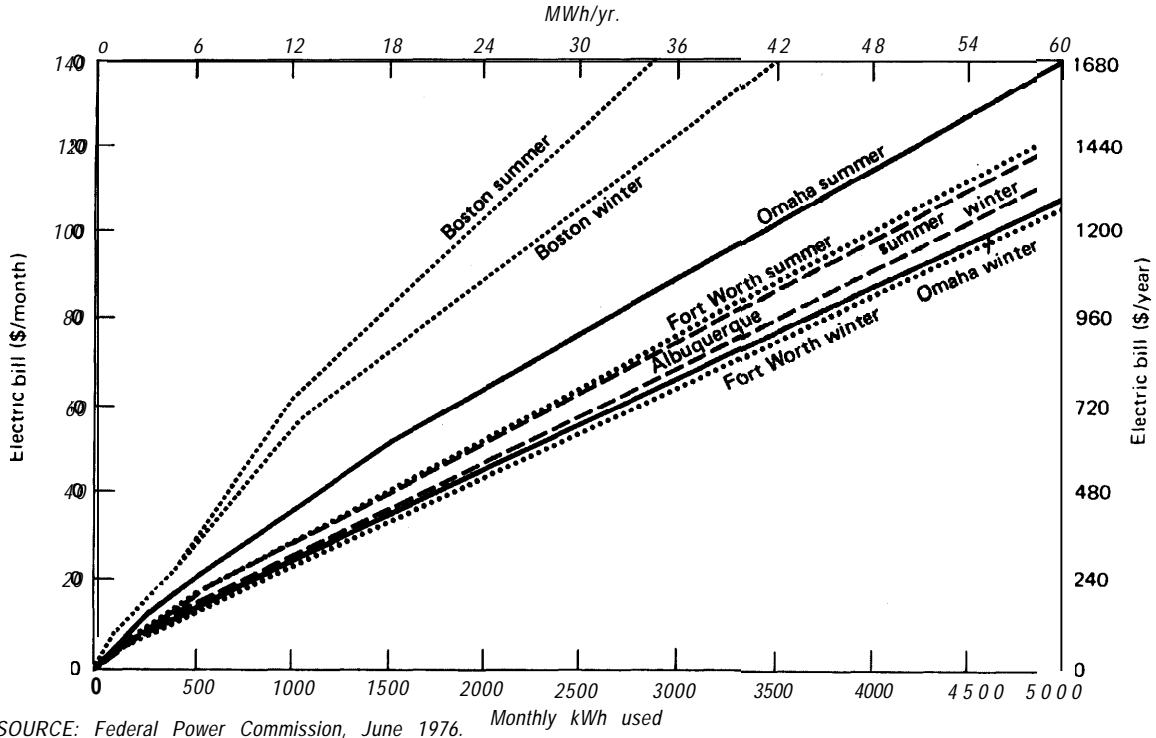
(Note The following conversion factors were used. 1 therm = 2930 kWh; 1 gallon No 2 oil = 40.64 kWh; 1 kWh = 3413 Btu)

^aRetail Prices and Indexes of Fuels and Utilities Residential Use, Bureau of Labor Statistics, US Dept of Labor, March 1976

^bFederal power Commission News Release No. 22363, May 19, 1976.

^cMonthly Energy Review FEA, May 1976, p. 60.

Figure II.1.—Actual 1976 Residential Declining Block-Rate Structure Including Fuel Adjustment



SOURCE: Federal Power Commission, June 1976.

Table II-2.—Model's Assumed 1976 Electric Rate Structures

| City | Loads (see previous table) |
|--------------------|--|
| Albuquerque | |
| SFH | Bill = $1.60 + .02928 X \text{ kWh}$ kWh<650 $\{ 6.41 + .021876 X \text{ kWh}$ kWh>650 |
| TNH, LR, HR, SC | Bill = $102.50 + .011043 X \text{ kWh}$ D<50 $\{ 10 + 3.85 X .011043 X \text{ kWh}$ D>50 |
| Boston | |
| SFH, TNH | Bill = $2.23 + .0558 X \text{ kWh}$ kWh<1000 $\{ 22.027 + .03603 X \text{ kWh}$ kWh>1000 |
| LR, HR | Bill = $1.60 \times \text{No. units} + .29 \times D + .0629 \times \text{kWh}$ kWh<200 x D, and kWh<12,000 $1.60 \times \text{No. units} + .41 \times D + .0623 \times \text{kWh}$ kWh>200 x D, and kWh<12,000 $1.60 \times \text{No. units} + .29 \times D + .0625 \times \text{kWh}$ kWh<120 x D, and kWh>12,000 $1.60 \times \text{No. units} + 1.838 \times D + .0472 \times \text{kWh}$ kWh>120 X D, and kWh>12,000 82 + 3.664 X D + .03707 X kWh D<800, and kWh<300 84.44 + 3.664 X D + .02893 X kWh D<800, and kWh>300 |
| SC | Bill = $3013.50 + 3.433 \times D + .03707 X$ D>800 and kWh<300 $3015.94 + 3.433 \times D + .02893 X$ D>800, and kWh>300 |
| Fort Worth | |
| SFH | Bill = $1.69 + .0368 X \text{ kWh}$ kWh<200 $\{ 3.95 + .02548 X \text{ kWh}$ kWh>200 |
| "D-500" | D Bill = 1.65 D<8 $1.85 + 1.85 X (D-8)$ D>8 0 D<500 0 D>500 |
| TNH, LR, HR, SC | Bill = D Bill + $92.40 + .01703 \times \text{kWh}$ kWh>50,000 + 100 X ("D-500") D Bill + $943.90 + 0.1313 \times \text{kWh} + 1.703 X$ ("D-500") kWh<100,000 + 200 X ("D-500") D Bill + $1600.44 + .01043 \times \text{kWh} + 3.016 X$ ("D-500") kWh>100,000 + 200 X ("D-500") |
| Omaha | |
| SFH | Bill = $3.91 + .0289 X \text{ kWh}$ kWh<800 $\{ 9.65 + .02174 X \text{ kWh}$ kWh>800 |
| TNH, LR, SC | Bill = $93.88 + .0218 X \text{ kWh}$ kWh<7,500 + 300 x D $\{ 147.21 + 2.13 X D + .0147 X$ kWh>7,500 + 300 X D |

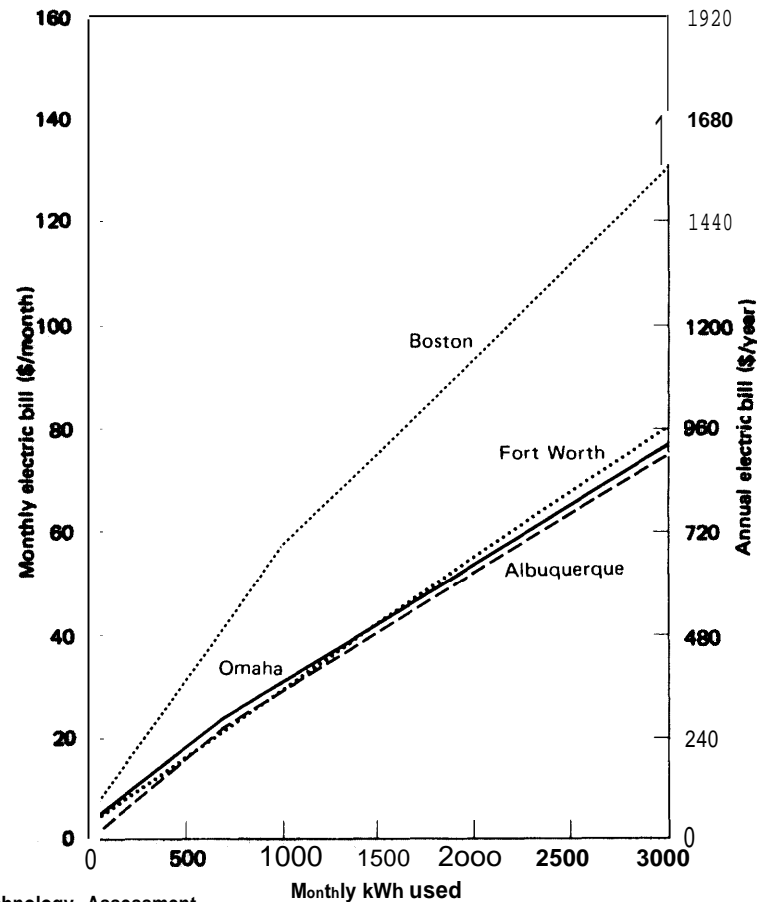
Source: Office of Technology Assessment

Table n-3.-Simplified Electric Rate Schedules

| City (electric utility) | Fuel adjustment (mils/kWh) | Actual electric rate schedules from which simplified schedules are developed for each case modeled (Effective date) | | | | |
|--|----------------------------|---|--|--|-------------------------|-------------------------------------|
| | | Single family house (SFH) | 8 Unit townhouse (TNH) | 36 Unit low rise (LR) | 196 Unit high rise (HR) | Shopping center (Se) |
| Albuquerque (Public Service Company of New Mexico) | 3.043 | Schedule #1 residential service (May 23, 1975) | Schedule #3 general power service (May 23, 1975) | No. 3 | No. 3 | No. 3 |
| Boston (Boston Edison Company) | 19.1 | Residence rate B (Oct. 17, 1975) | Rate B | Apartment house rate C (Oct. 17, 1975) | Rate C | General service rate (Oct. 17 1975) |
| Fort Worth (Texas Electric Service Co.) | 2.13 | Rate R residential service (Dec. 3, 1975) | Rate G general service | Rate G | Rate G | Rate G |
| Omaha (Omaha Public Power District) | 2.07 | Schedule #10 residential service (March 1, 1976) | Schedule #30 general service (March 1, 1976) | No. 30 | No. 30 | No. 30 |

RawDataSuPrint by FPC Bureau of Planning 1976

Figure II-2.—1976 Residential Electric Rate Structure Used in Model



SOURCE: Office of Technology Assessment.

ESTIMATES OF FUTURE ENERGY PRICES

As indicated, methods to project future energy prices are quite inexact. A variety of organizations have published estimates of the future prices of energy and, as may be expected, the results vary greatly. As a result, rather than relying on a simple projection to provide a set of energy prices for comparison, a range of estimates has been used. These include:

1. no increase in energy prices in constant dollars;
2. residential energy price projections generated by Brookhaven National Laboratory (BNL); and

3. a projection chosen arbitrarily higher than the BNL forecast.

The results of these estimates are illustrated in figures II-3 through II-10 for the four cities examined. This set is used to demonstrate the sensitivity of price in the analysis. It is intended not to represent most probable future energy prices, but a set of projections representing several plausible forecasts of future energy prices. The choice of these bounds is explained below, along with a description of how the curves were obtained.

The Brookhaven National Laboratory (BNL) is responsible for preparing the Department of Energy's (DOE) projections of future energy prices. However, because the Federal Energy Administration (FEA) had responsibility for setting "near-term" energy policy, the Brookhaven modelers were required to use FEA's energy price projections through the year 1985. The BNL projections used here were received in July 1976, and at the time were BNL's "baseline" (high nuclear power) residential energy price projections.¹ There is no single "standard" set of BNL energy price projections, as a number of scenarios with different assumptions about the future have been run and have yielded differing results. Furthermore, BNL is constantly updating its energy price projections as new data become available.³

Even DOE's energy price forecasters admit that all forecasts are necessarily speculative. However, the more sophisticated forecasters, such as BNL, take their initial guesses and run them in supply/demand models to see if the resulting mix of fuels looks "reasonable." If the initial guess results in an unlikely mix of fuels being burned (all natural gas and no oil or coal, for example), the future energy price guesses are revised and the model is run again. This process is repeated until they have a "reasonable-looking" set of future energy price guesses which result in a "reasonable-looking" future energy use mix.² The result of these analyses is a set of energy price ratios indicating the growth in energy prices as a function of the current price of energy.

BNL concurred that:

1. The exponential curve fit (described below) is an acceptable way of extrapolating their energy price ratios to beyond the year 2000.

¹Residential energy price projections from BNL supplied by Eric Hirst, Oak Ridge National Laboratory, July 1976

²D Behling (BNL), private communication, July 19, 1976

³Ibid

⁴M Beller (BNL), private communication, July 19, 1976

2. Applying these price ratios to actual 1976 prices of energy in various regions of the country is an acceptable way of projecting future energy prices in each location.
3. Applying the corresponding residential price ratio to 1976 prices of commercial and utility fuels is an acceptable way of projecting these energy prices.⁵

Figures II-3 through II-10 illustrate the BNL energy price projections through the year 2000 for residential natural gas, residential heating oil, and residential electricity in Albuquerque, N. Mex., Boston, Mass., Fort Worth, Tex., and Omaha, Nebr.

PROJECTIONS

High Projection.—The BNL projections indicate a relatively modest increase in energy prices over the next few decades. It is possible, however, that the price of energy may reach levels higher than those shown in the BNL projections as a result of shortages and the higher cost of producing new sources. Given the large number of uncertainties surrounding estimates, it is impossible to accurately quantify either of these effects. In addition, a tax on energy could also raise the price. A high price ceiling for energy, was chosen and it was assumed for this scenario that current prices rise gradually to stable prices at these high levels.

This price behavior is determined by assuming that energy prices rise to the stable level PRICE (∞) according to the following formula:

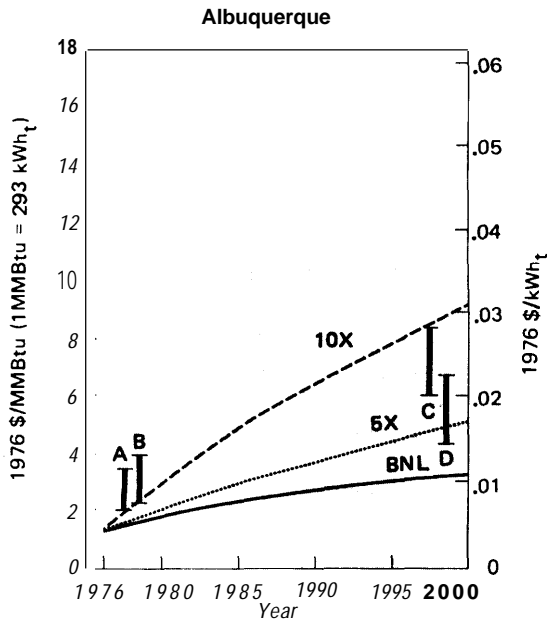
$$\text{PRICE}(t) = \text{PRICE}(\infty) \times \left(1 - \exp \left(-\frac{t_0 - t}{T_r} \right) \right) \quad (1)$$

where PRICE(t) is the energy price in year t, and T_r is a time constant* indicating the speed with which the price approaches the final threshold. The BNL data were fitted to

⁵D Behling (BNL), *op cit*

*The time constant (T_r) of 283 years for the three high projections, is a reasonable choice since it is close to the typical lifetime of generating plants, mines, oil-pumping rigs, etc

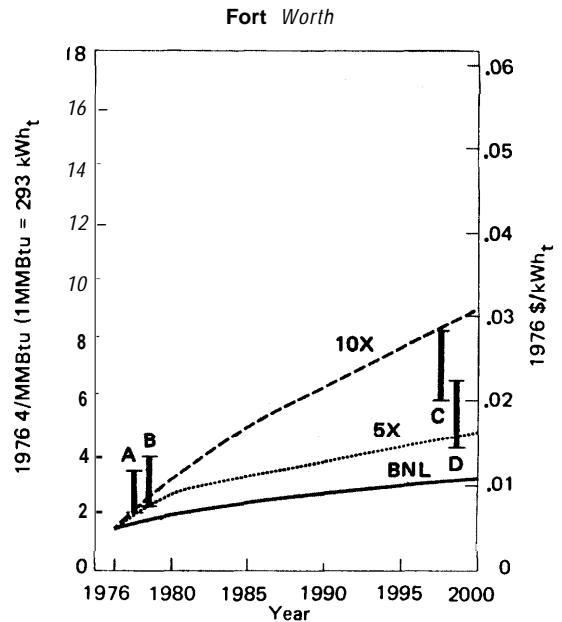
Figure II-3.—Assumed Future Residential Natural Gas Prices



- A. Unregulated natural gas in 1976
- B. LNG in 1976
- C. Synthetic gas from coal @ \$40/ton
- D. Synthetic gas from coal @ \$20/ton

SOURCE: Office of Technology Assessment.

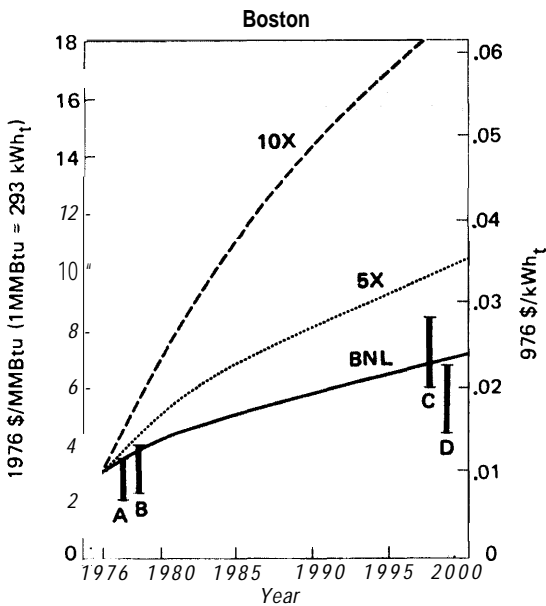
Figure II-5.—Assumed Future Residential Natural Gas Prices



- A. Unregulated natural gas in 1976
- B. LNG in 1976
- C. Synthetic gas from coal @ \$40/ton
- D. Synthetic gas from coal @ \$20/ton

SOURCE: Office of Technology Assessment.

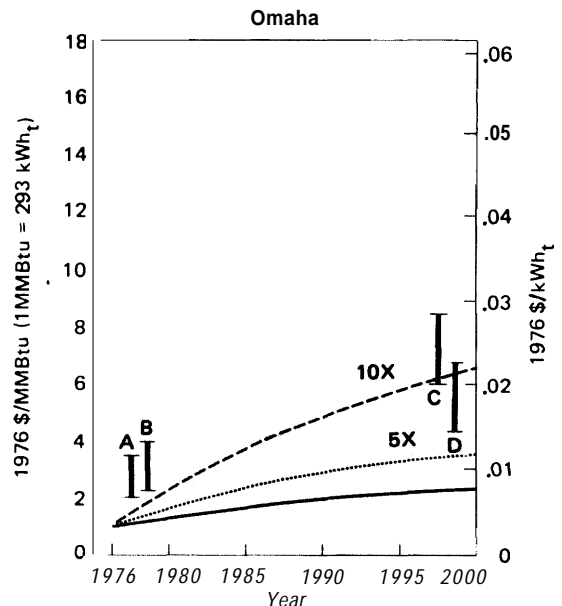
Figure n-4.-Assumed Future Residential Natural Gas Prices



- A. Unregulated natural gas in 1976
- B. LNG in 1976
- C. Synthetic gas from coal @ \$40/ton
- D. Synthetic gas from coal @ \$20/ton

SOURCE: Office of Technology Assessment.

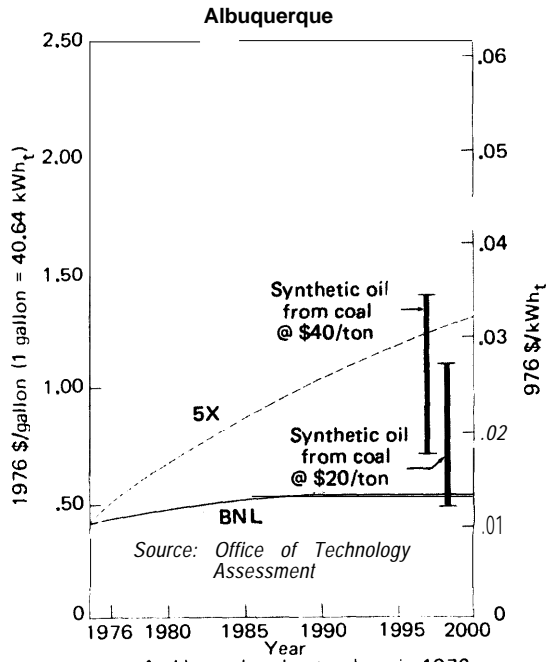
Figure II-6.—Assumed Future Residential Natural Gas Prices



- A. Unregulated natural gas in 1976
- B. LNG in 1976
- C. Synthetic gas from coal @ \$40/ton
- D. Synthetic gas from coal @ \$20/ton

SOURCE: Office of Technology Assessment.

Figure II-7.—Assumed Future Residential Heating Oil Prices



- A. Unregulated natural gas in 1976
- B. LNG in 1976
- C. Synthetic gas from coal @ \$40/ton
- D. Synthetic gas from coal @ \$20/ton

Figure II-9.—Assumed Future Residential Heating Oil Prices

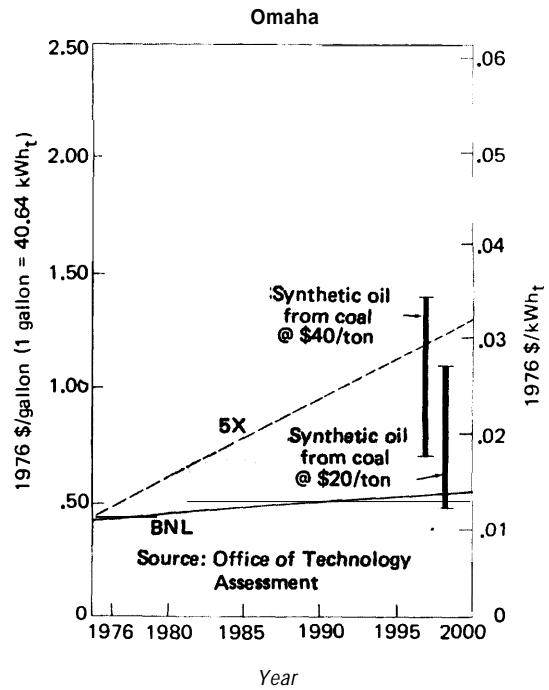


Figure II-8.—Assumed Future Residential Heating Oil Prices

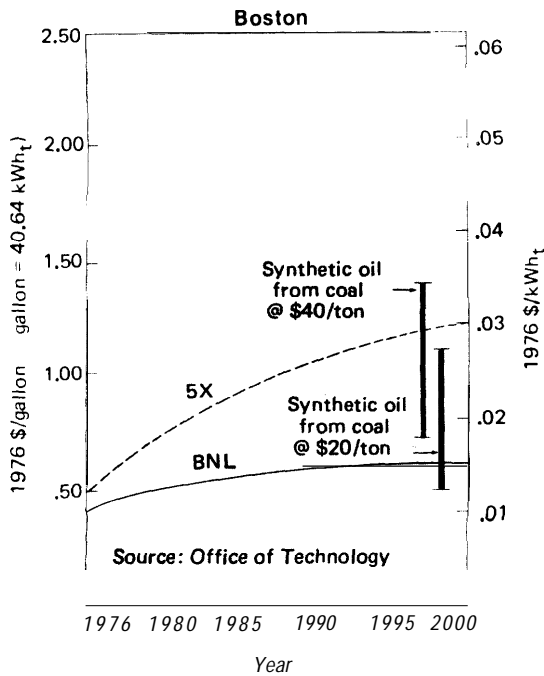
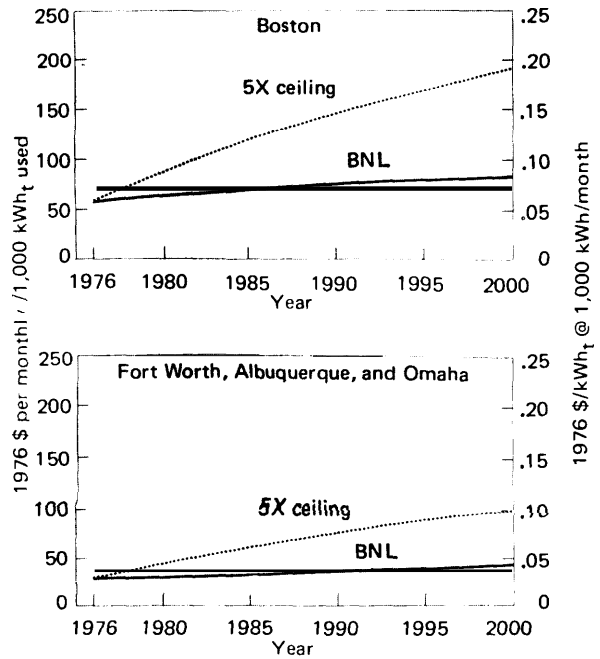


Figure II-10.—Assumed Residential Electricity Rate Increases



SOURCE: Office of Technology Assessment

this curve, and the results shown in table 11-4. The table also shows constants chosen to yield prices higher than the BNL projections.

Table n-4.-Constants for Brookhaven National Laboratory Price Increase Projections*

| | PRICE (m) PRICE (1976) | t_0 | T_1 |
|-------------------------------|---------------------------|--------|--------|
| BNL electricity | 1.62 | 1952.8 | 28.334 |
| BNL gas | 2.89 | 1965.7 | 24.334 |
| BNL oil | 1.71 | 1951.2 | 28.334 |
| 2x cost projection | 2.00 | 1956.4 | 28.334 |
| 5x cost projection | 5.00 | 1979.7 | 28.334 |
| 10x cost projection | 10.00 | 1973.0 | 28.334 |

*These constants are defined in equation (1) in the text. The price ratio shown in the first column is the constant dollar ratio between an assumed future 'stable' price of energy of the type shown and the price paid in 1976.

For the purposes of this study, the five-times-cost (5 x) projection was chosen. A discussion of the factors making up the cost of the principal energy sources follows this section to demonstrate the plausibility at the 5 x projection.

FOSSIL FUEL PRICES

Natural Gas

Current natural gas prices in most of the country are a result of Federal and State regulatory actions, which control the price from the wellhead to the ultimate user. The large cost variations between localities, as evidenced by comparing Boston and Omaha, result from the differences in transportation costs and the volume of supplemental gas resources (propane-air mixture, synthetic natural gas from petroleum products, and liquefied natural gas) that must be used to meet demand. These latter supplies are only partially price regulated, and their costs to the gas distributor more nearly reflect the real incremental costs of new supplies. However, these costs are averaged with that of flowing gas so the ultimate user does not see this incremental price. Current regulated gas prices range from about \$0.20 to \$1.49 per million Btu

(MMBtu) at the wellhead and from about \$1.85 to \$4.70 per MMBtu (1976 prices) delivered to residences, depending on when the gas was dedicated to the interstate market.⁶ In some parts of the country (the intrastate market), natural gas prices are not regulated and new contract gas sells for about \$1.00 to \$2.00 per MMBtu at the wellhead. The average price of natural gas to residences in the intrastate market area is about \$2.35 per MMBtu. ⁸Future gas prices will be determined by the costs of bringing in new reserves as existing fields are depleted, developing synthetic natural gas from coal and liquids, and providing imported liquefied natural gas. Although precise estimates for 1985 and 2000 are not possible at present, arguments can be made which show that the range chosen is reasonable.

Gas from new reserves in the interstate market was priced by the Federal Energy Regulatory Commission (formerly the Federal Power Commission) at \$1.45 per MCF at the wellhead in 1977. However, as previously stated, new gas at the wellhead is selling for up to \$2.00 per MMBtu where not regulated. Synthetic natural gas (SNG) from petroleum products (naphtha and propane) is currently priced at anywhere from \$3.00 to \$4.20 per MMBtu at the plant gate. Although no plants to produce synthetic gas from coal have been built, estimates are that gas from such plants will cost from \$4.00 to \$6.00 per MMBtu (\$4.50 to \$7.50 per MMBtu delivered to residences) if coal costs \$20.00 per ton. ^{9,10} If the cost of coal doubled to \$40.00 per ton, SNG prices would increase by approximately \$1.50 per MMBtu resulting in a delivered residential price of

⁶Quarterly Report of Gas Industry Operations, American Gas Association, Third Quarter, 1977.

⁷Federal Energy Regulatory Commission, News Release FE-69, Nov. 24, 1977.

⁸Quarterly Report of Gas Industry Operations, op cit

⁹Gas Supply Review, American Gas Association, vol. 5, January 1977, pp 9-10.

¹⁰Richard A. Tybout, *Public Utilities Fortnightly*, VOI 99, Mar. 31, 1977, p 17.

\$6.00 to \$9.00 per MMBtu. The current price of gas imported as a liquid in cryogenic tankers (liquefied natural gas or LNG) ranges from about \$1.75 to \$2.90 per MMBtu delivered to the pipeline.¹¹ Although the above prices, which are indicative of the marginal costs of new supplies, are presently rolled into the cost of flowing gas from existing wells, the total price will more nearly equal the marginal cost as the latter depletes.

When transportation and distribution costs (about \$0.50 to \$1.50 per MMBtu) are added to the above prices, the result is a range of marginal prices from \$2.25 to \$9.00 per MMBtu. Although these are current prices, the upper end of the range already reaches or exceeds the 5 x ceiling prices in the year 2000 for all cities except Boston (see figure II-4). As stated earlier, a considerable portion of Boston's gas is made up of supplemental supplies, and current prices there are much closer to marginal cost of new supplies. However, if synthetic natural gas (SNG) from coal is included, an upper price of \$9.00 per MMBtu (delivered) is obtainable, which approximates the 5 x ceiling price in Boston in the year 2000. It appears that the set of 5 x ceiling curves for natural gas is at least plausible.

Oil

A similar analysis can be developed for oil. The present average price of domestic oil is about \$1.50 per MMBtu (\$8.75 per barrel) at the well head.¹² Uncontrolled oil is about \$2.40 per MMBtu and imported oil costs about \$2.25 to \$2.60 per MMBtu.¹³ Residential heating oil currently costs about \$3.35 per MMBtu delivered (\$0.46 per gallon). This is about 30 percent above the price of crude oil, reflecting the costs of refining, transporting, and distributing the fuel oil.

Future oil and gas prices will depend on the cost of producing and transporting hy-

¹¹Gas Supply Review, American Gas Association, VOI 5, February 1977, pp 10-11

¹²Monthly Energy Review, DOE, November 1977, p 72

¹³Ibid, pp 72, 76

drocarbons from new sources and decisions made by petroleum exporting nations. The present price charged for oil from domestic sources can be approximated by the price of uncontrolled oil, \$2.35 per million Btu, [it has been estimated that oil produced from advanced recovery techniques at existing sites may cost as much as \$4.30 per million Btu (\$25 per barrel) before the supply of oil from these resources begins to fall rapidly.¹⁴ The cost of imported oil will probably be the largest factor in determining oil price over the next 10 to 15 years. Although there is no way to be certain that these prices will continue to increase from their present levels of \$2.25 per MMBtu, the continuing growth of world demand and the likely peak in production around 1990 make it improbable that prices will fall. Prices for oil produced from coal and oil shale can only be approximated, as no operating plants exist. As with SNG, these prices are subject to considerable uncertainty. In an analysis performed by ERDA (now DOE) in March 1976, shale oil prices of \$2.50 per MMBtu were obtained. However, this study indicated that estimates of \$3.25 per MMBtu had been made by others. The report also noted that their calculation could range as high as \$4.00 per MMBtu, depending on financing assumptions.¹⁵ Oil from coal was not estimated in the study, but the similarity between these processes and production of SNG from coal allows the same price range (\$4.00 to \$6.00 per MMBtu) to apply.

The price of delivered residential heating oil is presently about 30 percent higher than crude oil. The range of costs quoted above, \$2.25 to \$6.00 per MMBtu, is therefore equivalent to \$3.15 to \$8.00 per MM Btu, or \$0.45 to \$1.10 per gallon for delivered residential heating oil. These prices bracket the 5 x ceiling price in the year 2000 for all of the cities (see figures I I-7 through 11-9) in

¹⁴Enhanced Oil Recovery in the United States, Office of Technology Assessment, U S Congress, Washington, D C., January 1978.

¹⁵Proposed Synthetic Fuels Commercial Demonstration Program: Fact Book, ERDA, Washington, D C , March 1976

question, even before any real increase between now and 2000 is taken into account. The plausibility of this 5 x ceiling again appears justified.

Coal

The price of coal varies enormously around the country depending on the distance over which the coal must be shipped, heat content, and sulfur content (which determines the amount of pollution which will be released by burning), and a variety of other factors which determine its burning properties. Contract prices paid for coal by utilities vary from about \$4.00 per ton in North Dakota to nearly \$40.00 per ton in New Jersey. ”

Future prices will depend both on the extent to which the price of coal rises to meet the increasing price of competing fuels, and the extent to which environmental restrictions are imposed. If utilities are allowed to use western coal without flue gas desulfurization (FGD) technologies to meet air quality standards, the average price of coal would be lower than if they used eastern coal and FGD devices. Estimates are that sulfur cleanup will add as much as \$0.60 per MMBtu to the price of coal. ¹⁷

Based on this and on current coal prices, a range of \$1.00 to \$2.50 per MMBtu is not unreasonable. It should be noted that no coal prices as such are included in the price projections in figures II-3 through II-10. Coal will show up in the price of electricity as it has already appeared with respect to synthetic gas and oil. The sensitivity of electricity prices to coal prices will be discussed in more detail below.

ELECTRICITY PRICES

The two major components of electricity prices are the cost of fuel and the capital cost of the powerplant. The relative signifi-

¹⁶Annual Summary of Cost and Quality of Steam-Electric Plant Fuels, 1976, Staff Report by the Bureau of Power, Federal Power Commission, May 1977

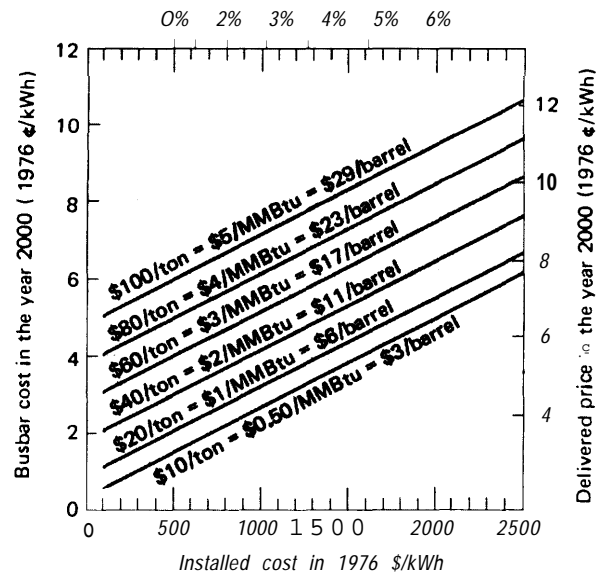
¹⁷National Energy Outlook, Federal Energy Administration, February 1976, p F-6

cance of either depends on the fuel used. Fuel costs are much more significant for oil-fired plants than that for coal or nuclear, since oil is two to five times more expensive on a Btu basis. The interaction between these two factors is shown in figures II-11 and II-12 which show the cost of electricity sold at the generating plant (busbar cost) and the average electricity sales price, delivered to the customer, as a function of the following variables:

- the installed cost of the generating facility in dollars per kw;
- the cost of fuel burned in the facility (coal, oil, or gas); and
- the “capacity factor, ” defined as the average percentage use of the facility’s capacity.

Figure II.11 .—Potential Marginal Costs of Baseload Electricity in the Year 2000 (75 Percent Load Factor)

Annual escalation in installed cost (above inflation)

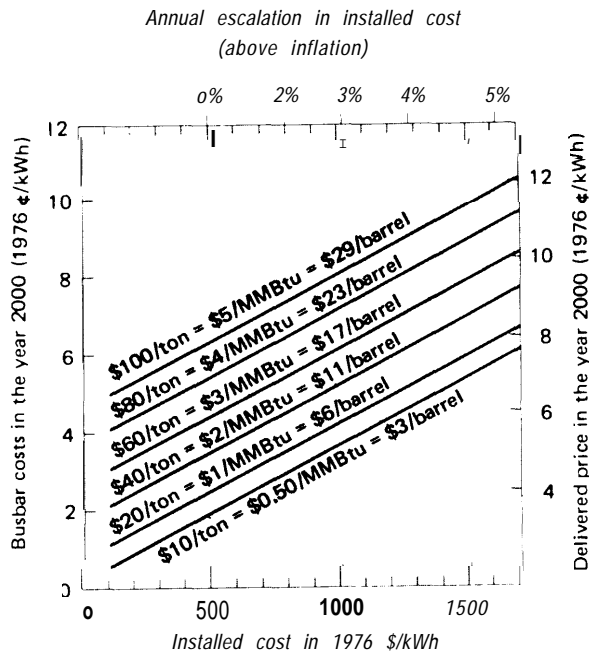


Assumptions

- 75% load factor
- 1976 Installed cost \$500/kWh
- 35% efficiency in generation and transmission
- Transmission and distribution cost \$300 to \$400/kWh
- Operating costs (exclusive of fuel) = \$0.01/kWh
- Capital cost 0.15

SOURCE: Office of Technology Assessment,

Figure II-12.— Potential Marginal Costs of Baseload Electricity in the Year 2000 (50 Percent Load Factor)



Assumptions

- 50% load factor
- 35% efficiency in generation and transmission
- Transmission and distribution cost \$300 to \$400/kWh
- Operation
- Operating costs (exclusive of fuel) \$0.01/kWh
- Capital cost 0.15

SOURCE: Office of Technology Assessment.

In all cases it has been assumed that the plant is 35 percent efficient (including all losses in transmission and distribution). The delivered electricity costs includes, among other factors, the cost of building and operating a network of transmission and distribution lines

Coal Powerplants

Coal-fired plants presently on order cost about \$500 per kW, including flue gas desulfurization devices.¹⁸ Using present utility coal prices of about \$1.00 per MMBtu (\$20.00 per ton) and a capacity factor of 75 percent, a delivered electricity price of

¹⁸The Economic and Social Costs of Coal and Nuclear Electric Generation, National Science Foundation, Washington, D C , March 1976, p 12

about \$0.035 per kWh results from figure 11-11. It must be noted that this is the cost of baseload electric power, i.e., that produced by a large plant operating at a capacity factor of about 75 percent.

Utility loads fluctuate, however, and about 30 percent of the total electricity generated will need to come from facilities which can adjust their output rapidly (on the order of minutes to hours) to meet these fluctuations. These are typically smaller steam turbines (less than 100kW), combustion turbines, diesel engines, or hydroelectric storage systems, and are relatively expensive to operate. The cost of this intermediate and peak load electricity is about 1.35 to 3 times that of baseload electricity. The total cost of electricity is the weighted average of the base, intermediate, and peak-load electricity, and is about 40 percent higher than the baseload price. Therefore, \$0.035 per kWh for baseload must be adjusted for a total cost to the customer of about \$0.049 per kWh. A further adjustment is needed, since the rates to different classes of customers are not the same. In 1975, residential customers paid about 15 percent more per kWh than the average to all customers.²⁰

The future price of electricity will depend on the escalation rate of powerplant capital costs and fuel. For example, it can be seen from figure 11-11 that a 3-percent-per-year escalation rate, above inflation, will cause a \$500 per kW plant to cost \$1,000 per kW by the year 2000. If this is coupled with a real price rise in coal from \$1.00 to \$2.00 per MMBtu, the delivered cost of baseload electricity becomes \$0.057 per kWh.

Applying these adjustments produces a total marginal cost in the year 2000 of \$0.092 per kWh delivered to a residential customer. Previous discussion has already shown this coal price to be plausible (it is

¹⁹1977 National Energy Outlook, (Draft), Federal Energy Administration, Washington, D C , January 1977, Appendix C, p. 19.

²⁰Statistical Yearbook of the Electric Utility Industry, Edison Electric Institute, New York, N Y., October 1976, p. 54.

being paid by some utilities today). There are no generally accepted estimates at this time for the projected capital cost increase. The actual rate will have a substantial effect on electricity prices from coal-fired plants and is, therefore, one of the major uncertainties in assessing the relative economics of alternative energy systems.

Nuclear Powerplants

Another major uncertainty is associated with the cost of nuclear-generated electricity. The possible changes in plant capital costs are even more crucial in this instance because fuel costs do not contribute as significantly as in the case of coal. The many studies on the relative marginal costs of new nuclear and coal-fired electricity have reached no definitive conclusion. It is likely that percentage changes in capital costs will be similar for both coal-fired and nuclear plants, since the largest component is the construction cost, which is relatively independent of the type of plant built. As a result, nuclear costs will be more affected by capital cost escalations because nuclear power is more capital-intensive.

Another controlling item in the relative costs is the relative fuel costs and the associated environmental and safety features peculiar to each fuel cycle. This means that if nuclear electricity prices are to be significantly lower than the \$0.092 per kWh previously calculated, assuming a 3-percent real increase in capital costs, the price of nuclear fuel must not increase significantly. However, present knowledge about moderately priced U_3O_8 resources and serious problems in developing a breeder reactor make it likely that nuclear fuel prices will continue to climb.

With regard to electricity, the 5 x ceiling curve loses plausibility only if electricity prices remain near their present marginal costs. This means either no significant real increase in capital costs (below 3 percent) or the continuation or decrease (to compensate for any rise in capital costs above 3 percent) of present fuel costs. Again, it is not known what will occur in this context, but

the fact that there are major uncertainties means that the 5 x ceiling cannot be precluded.

OTHER PROJECTIONS

InterTechnology Corporation.—Several other price projections have appeared recently, in addition to those quoted above. To complete this discussion, a review of these are given for comparison. In a report on the economic potential of solar thermal energy to provide industrial process heat, InterTechnology Corporation assumed a series of real escalation rates to obtain price estimates for the year 2000 of \$2.14 per MMBtu for coal, \$9.20 per MMBtu for oil (approximately \$1.25 per gallon for delivered fuel oil), and \$8.02 per MMBtu for natural gas, all in 1976 dollars.²¹ The latter two are equal to or greater than the 5 x ceiling price used in this study. The coal costs correspond to coal at \$43 per ton which, if coupled with plant capital costs of \$1,000 per kW, produce residential electricity of about \$0.093 per kWh.

Battelle Columbus Laboratories.—In a similar study, Battelle Columbus Laboratories came up with estimates for the year 2000 of \$4.00 to \$6.00 per MMBtu for natural gas, \$5.00 to \$6.50 per MMBtu (\$0.70 to \$0.90 per gallon) for residential home heating oil, and \$1.50 to \$2.50 per MMBtu (\$30 to \$50 per ton) for coal delivered to utilities.²² Except for natural gas in Boston, these prices also bracket the estimated oil and natural gas prices in the year 2000 from the 5 x ceiling.

Federal Power Commission (FPC).—In a report by the Bureau of Natural Gas of the FPC (now the Federal Energy Regulatory Commission (FERC)), energy prices delivered to residences of \$4.16 per MMBtu for natural gas, \$3.58 per MMBtu for fuel oil

²¹ *Analysis of the Economic Potential of Solar Thermal Energy to Provide Industrial Process Heat*, InterTechnology Corporation, Warrenton, Va., February 1977

²² *Survey of the Applications of Solar Thermal Energy Systems to Industrial Process Heat*, Battelle Columbus Laboratories, Columbus, Ohio, January 1977

(\$0.050 per gallon) and \$0.035 per kWh for electricity (all in 1976 dollars) were projected for the year 2000.²³ **These are national averages, and no means to allocate them by region was given. It is not likely however, that regional adjustments would bring the prices near the 5 x ceiling in any of the four cities under consideration. These projections assume that all crude oil prices will remain at the present level of imported crude, \$2.32 per MM Btu. Any increase in this price will cause a corresponding increase in the other prices.**

²³*The Future of Natural Gas* Economic Myths, Regulatory Realities, Federal Power Commission, Bureau of Natural Gas, November 1976

Federal Energy Administration (FEA).—A final set of price projections is that developed by FEA (now DOE) in the draft of the 1977 National Energy Outlook.²⁴ Although only estimated to 1985, they can still be used for comparison to that date. Their results (in 1976 dollars) are \$3.72 per MM Btu for fuel oil (\$0.52 per gallon), \$2.78 per MMBtu for natural gas, and \$0.049 per kWh for electricity. These prices are based on imported crude oil prices of \$2.25 per MMBtu, and are those delivered to residential customers. In nearly all cases these are close to the 5 x ceiling curve.

²⁴1977 *National Energy Outlook*, (Draft), Federal Energy Administration, Washington, D C , January 1977, Appendix C, p 19,

Chapter III

**CALCULATION OF
BACKUP REQUIREMENTS**

Chapter III.- CALCULATION OF BACKUP REQUIREMENTS

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Calculation of Backup Requirements

The calculations presented in the previous chapter required an analysis of conventional and solar energy equipment operating in real environments. The techniques used to perform such an analysis were discussed generically in previous chapters. The following discussion reviews the analytical method in some detail. The Fortran programs used to perform the calculations reported elsewhere in this study are based on the methods described in this chapter and are reproduced in full in appendix III-B.

The analysis of system performance requires three basic steps:

1. Determine the onsite energy demand of the building (In the case of residences, this includes heating, cooling, hot water, and miscellaneous electrical demands.)
2. Determine the out put of solar collectors.
3. Determine the fraction of the on site energy demand that can be met from solar energy directly or from storage and the fraction that must be supplied from external energy sources (utility electricity, gas, or oil).

These three steps were performed for each hour of the year using measurements of the air temperature and available sunlight recorded during 1962 (1963 in the case of Boston). The calculation of the heating and cooling requirements of buildings was based on: the external temperature; an assumed pattern of occupancy and appliance use; and, assumed thermodynamic characteristics of the buildings. A program (E-cube) developed by the American Gas Association was used to convert the weather data and building descriptions into an hourly estimate of the demand for heating and cooling. Chapter V discusses the assumptions made about the buildings, and the assumptions made about patterns of occupancy, appliance usage, hot water demands, etc.

The performance of collectors was discussed generically in chapter VIII of the first volume and the methods actually used in the analysis are discussed in the final section of this chapter.

A critical question in the operation of a solar energy system is the amount of backup energy required and the pattern of this backup demand. Assessing the performance of an integrated system is a complex problem, however, and techniques have not yet been developed for optimizing the performance of such systems. The next few pages discuss techniques for approximating the optimum performance of several tytes of solar cogeneration systems including the optimum operation of Possible combinations Of storage equipment.

CONTROL STRATEGIES FOR COGENERATION SYSTEMS

Minimizing the energy required to operate both solar and fossil-fired cogeneration or total energy systems requires a careful control strategy. For example, it is necessary to: 1) optimally allocate the space-conditioning load between electrically powered

heating or cooling equipment and heat-driven equipment (e.g., electric versus absorption chilling for heat pumps versus direct heating); 2) determine the optimum ratio between thermal energy and electric energy produced by the cogeneration

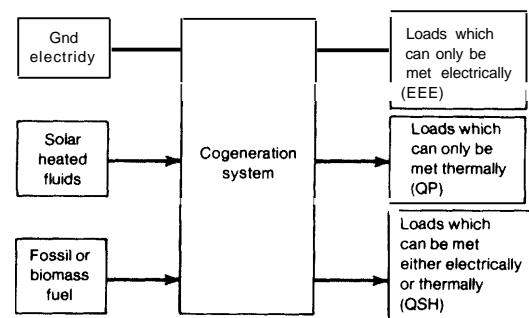
engines; 3) determine the best strategy for charging and discharging storage; and 4) determine the best strategy for buying energy from or selling energy to an electric utility or other backup power source. (Optimizing this last choice requires considering how the cogeneration strategy affects costs everywhere in the utility, which is a much more complex problem than the one addressed here.) In general, the more flexible the system, the less backup the system will require since complex controls can ensure that the system is operated as close as possible to the thermodynamic optimum for providing the necessary work. Greater flexibility and sophistication of controls often mean an increase in system costs, and the economic merits of these control systems will need to be determined on a case-by-case basis. The problem of optimizing system designs and control strategies taking full account of all of the real choices and constraints has not been fully solved. All that is offered here is a reasonable technique for approaching an optimum allocation. More work needs to be done in this area.

The following discussion presents algorithms for minimizing fuel use for a variety of different types of equipment. In most cases, controls for providing the kind of switching called for in the calculations are not now available; however, there is no reason to believe that such controls could not be developed if a demand for the systems emerged. Control systems can probably be manufactured quite inexpensively using modern electronics. Unfortunately, the control systems used on contemporary cogeneration systems have been relatively primitive, and there are few standardized designs.

Figure III-1 illustrates the general problem. Energy enters from three sources: 1) high-temperature heat from a solar collector, 2) high-temperature heat from fossil fuel available as backup, and 3) electricity used as a backup. Three kinds of energy demands must be met: 1) demands that can only be met electrically (e. g., artificial lighting),

which is called EEE; 2) demands that can be met either with electrical equipment or with thermal energy (e.g., refrigeration can be achieved with an electrically driven compressor or with thermally driven absorption equipment, and space heating can be achieved using thermal energy directly or with electric heating), which is called QSH; and, 3) loads that can be best met with direct thermal energy when it is available (e.g., domestic hot water or process heat), which is called QP.

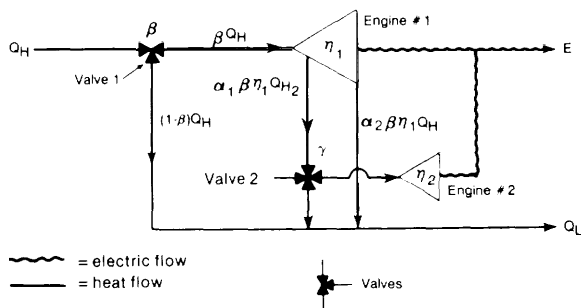
Figure III-1.—The Problem



The problem can best be understood by following the flow of energy from the initial source of high-temperature energy (Q_h) to the demands, examining the decisions that must be made at each point. The first choice needed is whether the high-temperature energy should be sent to the engines or be used directly. Figure III-2 shows valve #1 which splits the high-temperature heat sending βQ_h to the engines and $(1 - \beta)Q_h$ to the thermal loads where β represents the valve setting. The high-temperature heat enters the first engine and is converted into an electrical output of $\beta Q_h \eta_1$, where η_1 is the efficiency of the first engine. Some of the energy not converted to electricity is available as heated fluids. In a completely general case, two waste heat streams may be available: a "low-quality" waste heat stream at a temperature too low for use in a bottoming cycle; and, a "high-quality" stream, which can be used in a second engine. In the calculations that follow, the ratio between

the energy available as “high-quality” heat and the electrical output of the first engine is called α_1 , and the ratio of the energy available as “low-quality” heat to the electrical output of the first engine is called α_2 .

Figure III-2.—Simplified System Diagram



If a second, or bottoming cycle, engine is available, a choice must be made about the optimum use of the high-quality waste heat stream. The second valve can be used to send part of this energy to the second engine and part directly to thermal loads. The setting of this valve is indicated through the variable γ . When γ is 1, all of the high-quality waste heat is sent to the second engine.

With this notation, the net thermal (Q_T) and electrical (E) output of the system can be written as follows:

$$[E/Q_H] = \beta \eta_1 (1 + \gamma \alpha_1 \eta_2) \tag{1}$$

$$[Q_T/Q_H] = (1 - \beta) + \beta \eta_1 ((1 - \gamma) \alpha_1 + \alpha_2) \tag{2}$$

Here η_2 is the efficiency of the second engine. The problem becomes one of minimizing Q_H for fixed energy demands E and Q_T . If there is no thermal demand, clearly the optimum valve settings are $\beta = 1$ and $\gamma = 1$. It can be shown that as thermal demands increase, the best strategy will use the following procedure: 1) leave $\beta = 1$ and $\gamma = 1$ until the waste heat generated in this way cannot meet the thermal demands, 2) reduce the energy entering the second engine (i. e., $\gamma < 1$) while leaving $\beta = 1$ until the thermal demand cannot be met with $\beta = 1$, 3) meet additional thermal demands by leaving $\gamma = 0$ and reducing β . (See appendix III-A.)

The method for determining Q_H , β , and γ for a given E and Q_L is as follows:

If $Q_L \leq \alpha_2 E / (1 + \alpha_1 \eta_2)$, then

$$\beta = 1$$

$$Q_H = E / (\eta_1 (1 + \alpha_1 \eta_2)) \tag{3}$$

If $\alpha_2 E / (1 + \alpha_1 \eta_2) < Q_L < (\alpha_1 + \alpha_2) E$, then

$$\beta = 1$$

$$\gamma = [E(\alpha_1 + \alpha_2) - Q_L] / [\alpha_1 (Q_L \eta_2 + E)] \tag{4}$$

If $(\alpha_1 + \alpha_2) E < Q_L$, then

$$\beta = E / [E(1 - \eta_1 (\alpha_1 + \alpha_2)) + \eta_1 Q_L]$$

$$\gamma = 0$$

$$Q_H = E / \beta \eta_1 \tag{5}$$

Another layer of complexity now has to be added to describe optimum use of E and Q_L to meet the demands EEE , QSH , and QP . The QSH load can be met electrically or thermally. The performance of the electric units is described by the electric coefficient of performance $COPE$. Similarly, the coefficient of performance for the thermal unit is called $COPA$.

If $COPA > \eta_1 (COPE + (\gamma \eta_1 + \alpha_2) COPA)$, it is more efficient to use high-temperature thermal energy directly than to run it through the heat engine and use the waste heat and electricity. If this condition is not true, it is more efficient to meet some of the space-conditioning load (QSH) electrically. If two engines are available, the best use of the high-quality waste heat must be determined (e. g., is it more efficient to run it through the second heat engine or to use it directly?). If $\eta_2 COPE > COPA$, it is more efficient to run the high-quality waste heat through engine #2 and then use the electricity generated to meet the space-conditioning load instead of using the high-quality waste heat directly (through $COPA$) to meet the space-conditioning load.

The availability of storage equipment adds another dimension of complexity. Three types of storage are possible in cogeneration systems: 1) high-temperature storage; 2) low-temperature storage; and 3) electric storage. It is assumed that storage is never charged with backup power except in the cases where backup fossil heat is used to meet electric needs and excess waste heat produced in the process is available to

charge the low-temperature storage.

Low-temperature storage should not be charged directly from collector output; it is only charged when there is excess waste heat or when there is overflow from high-temperature storage. The use of high-temperature energy is minimized if all available energy in low-temperature storage is used before any high-temperature energy is used. High-temperature energy is kept in reserve since storing energy in this high-quality form maximizes the flexibility of using the available energy. A special problem arises when both batteries and high-temperature storage are available. It is assumed that batteries will be more expensive than high-temperature storage and therefore batteries should be kept charged whenever possible to maximize their use. This in turn assumes that the batteries were sized in an optimum way. When the high-temperature storage is filled, the overflow is sent to be stored in low-temperature storage. When low-temperature storage is filled, the overflow is discarded in a cooling tower or in some other way. If it is possible to sell excess electricity to an electric utility grid, however, this analysis assumes that an attempt is made to use the amount of high-temperature energy that exceeds the capacity of high-temperature storage to generate electricity for sale. The amount of electricity that can be sold is limited by the maximum generating capacity specified for the engines. In no case is electricity sold when high-temperature storage (when available) is not filled to capacity.

It should be noticed that in the analysis displayed here, it has been necessary to specify the hierarchy with which the storage units are charged and discharged. The priorities for using energy are: 1) meet onsite energy demands; 2) charge batteries; 3) charge high-temperature storage; 4) sell electricity to the grid; and, 5) charge low-temperature storage. In some cases meeting the electrical requirements results in a situation where low-temperature storage is charged because excess waste heat is available. The priorities for discharging storage are: 1) discharge low-temperature storage; 2) dis-

charge high-temperature storage; and, 3) discharge battery storage. Given this set of priorities, it is possible to optimize the use of available energy. While a reasonable case can be made for the priorities specified, it is entirely possible that system performance could be improved with a more sophisticated strategy. Solving this problem, and thereby allowing an optimum choice of storage types and capacities, would require that economic factors be considered along with the analysis of energy use. Such an optimization has not been attempted in this study.

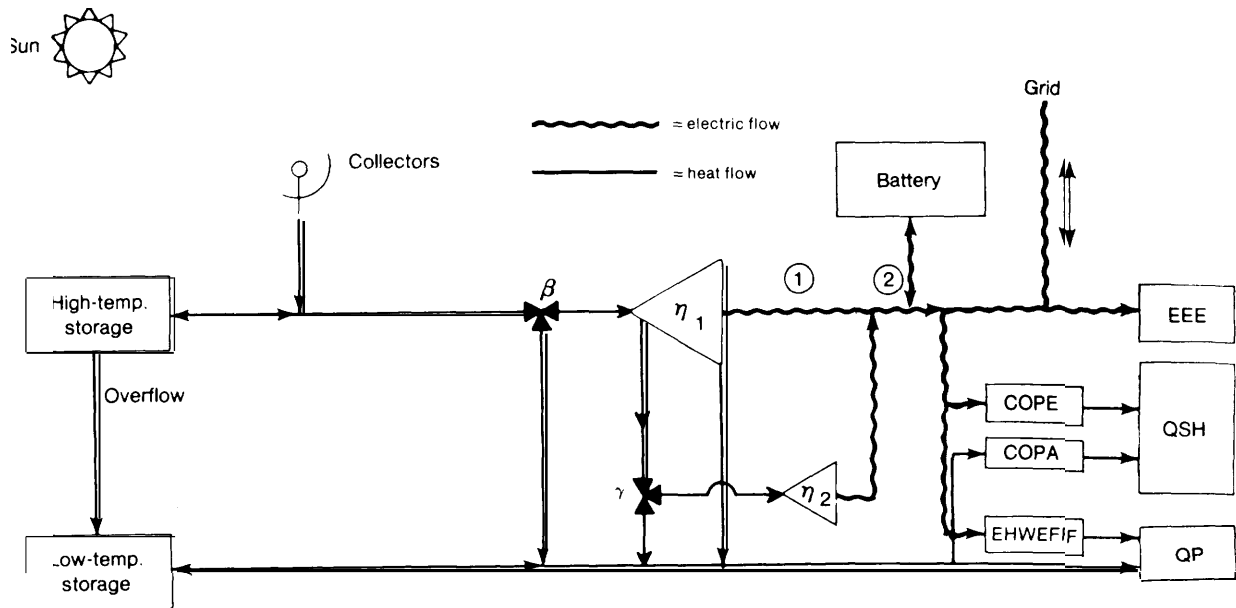
It can be seen that optimizing a generalized cogeneration system can be complex. The following sections present a detailed description of the logic used in a computer program designed to simulate the performance of optimized systems (a listing of this program is in appendix III-B). The logic depends on the type of backup energy available.

COGENERATION SYSTEM WITH ELECTRIC BACKUP

Figure III-3 shows the most general form for a cogeneration system which relies entirely on an electric utility for backup. As the loads must be met either from the output of the solar collectors, storage devices, or by backup electricity purchased from the grid, COPE and EHWEFF (the efficiency of the electric hot water heater) must always be non-zero. In a system with electric backup, energy from the collectors or storage is used to meet onsite energy demands with the following priorities: QP loads, QSH loads, EEE loads.

In the calculations, the system is optimized for each hour of the year. At the beginning of each hour the problem is as follows: Loads EEE, QSH, and QP must be met; the amount of energy in storage is known, and, the amount of high-temperature energy from direct solar energy is known. The problem is one of efficiently using the stored energy and the direct solar energy, and mini-

Figure III-3.—Cogeneration System With Grid Backup



mizing the energy that must be purchased.

The first step is to meet as much of the process load QP (and the space-conditioning load if COPA is non-zero) as possible with the energy available in low-temperature storage. If only part of these loads can be met from low-temperature storage, the process load QP is met first and any remaining energy is used for the QSH load.

The second step is to determine whether enough high-temperature energy is available to meet any QP load remaining after step one. Available high-temperature energy is the sum of the energy in high-temperature storage and the energy available directly from the collector. If the QP loads cannot be met by high-temperature energy (the remaining QP is called QP'), high-temperature storage is set to zero, and electricity is purchased from the grid in order to meet the remaining loads. The backup electricity which must be purchased in this case (EBU) is given by:

$$EBU = EEE + QSH + QP' / \epsilon HWEFF \quad (6)$$

where EHWEFF is the efficiency of the electric heater used to provide energy for the remaining QP loads [e. g., an electric hot water

heater). If the amount of high-temperature energy exceeds QP one of three paths must be taken depending on the relative values of COPA, COPE, η_1 , η_2 , α_1 , and α_2 .

A Case Where Thermal Energy Cannot Be Used To Meet the Space. Conditioning Load

If the available high-temperature energy exceeds the process load, it may be possible to meet some of the electrical demands using the available high-temperature energy. A check must first be made to determine whether it is possible to meet the QSH loads with thermal energy (i.e., whether COPA is non-zero). It is assumed that for heating purposes, COPA is always 1.0; therefore COPA can only be zero for a cooling load. If the QSH load cannot be met thermally; a check is then made to determine whether the optimum approach is to use all available high-temperature thermal energy to generate electricity and set β and γ to minimize the output of thermal energy (subject to the constraint that the remaining QP load is met). The available high-temperature thermal energy consists of all energy in high-

temperature storage and the energy available directly from the collectors.

A check must then be made to determine whether this results in the output of the first engine exceeding the maximum generating capacity specified. If the maximum is exceeded, it is necessary to recompute β, γ , and the amount of high-temperature energy used with the constraint that the electricity reaching point 1 in figure II-3 is equal to the maximum capacity of the first engine.

The next check that must be made is to determine whether the electricity generated now exceeds onsite demands for electricity. These onsite demands consist of: 1) the remaining QP loads; 2) QSH loads; 3) EEE loads; and, 4) charging the batteries at the maximum rate allowed by the power conditioner capacity specified. If the electricity that could be generated during the hour in question exceeds these onsite demands, it might be possible to sell electricity to the utility. A check must first be made, however, to determine whether selling electricity would result in a situation where the high-temperature storage unit was not filled to capacity at the end of the hour. If high-temperature storage would not be full, the amount of energy entering the engines and the valve settings are adjusted to reduce the amount of electricity and leave the high-temperature storage completely filled.

With this check the sequence is completed and the problem can be solved again for the next hour.

A Case Where Thermal Energy Is Used To Meet the Space-Conditioning Load

The previous discussion was limited to cases where QSH could not be met with thermal energy. If the following inequality holds:

$$\text{COPA} > \eta_1 (\text{COPE} + \text{COPA} (\alpha_1 + a)) \quad (7)$$

it is more efficient to meet the QSH loads with direct thermal energy than it is to meet these loads with a cogeneration approach where both thermal (COPA) and electrical

(COPE) equipment are used to meet thermal demands. This case can be treated using a method that is completely analogous to the case explained previously. All that is necessary is to define an "effective process load" QP' and an "effective QSH load" QSH' as follows:

$$\begin{aligned} \text{QP}' &= \text{QP} + \text{QSH}/\text{COPA} \\ \text{QSH}' &= 0 \end{aligned} \quad (8)$$

All other steps follow as described above.

A Case Where Using Thermal Energy To Meet the Space-Conditioning Load Is More Efficient Than Using Electricity Generated by the Second Heat Engine

If the following conditions hold:

$$\begin{aligned} \eta_1 (\text{COPE} + \text{COPA} (\alpha_1 + \alpha_2)) &< \text{COPA} \\ \text{COPA} &\geq \eta_2 \text{COPE} \end{aligned} \quad (9)$$

it is more efficient to meet QSH loads with direct thermal energy from the high-quality waste heat stream than it is to generate electricity with the second engine and use the electrical conversion unit characterized by COPE. Generating electricity with the first engine and using this electricity in the electrical conversion unit and all available waste heat to meet QSH demands thermally is more efficient than using the available high-temperature energy directly to meet the QSH demands.

The first step is to use all energy available in low-temperature storage to meet the QP and QSH demands. The second step is to determine whether the high-temperature energy available (i.e., the solar energy received directly during the hour plus any energy available from high-temperature storage; this sum is called SOLE in the remainder of this discussion) is sufficient to meet the remaining QP load. If the remaining QP cannot be met in this way, QP is reduced by the available energy and backup electricity must be purchased. The amount purchased can be computed using equation (6).

If the available high-temperature energy is greater than the remaining QP, a somewhat complex procedure must be used to determine the optimum valve settings. The

steps follow the sequence as outlined in equations (3) through (5), where an attempt is made to use all available high-temperature energy.

It is first determined whether sending all of SOLE through the first engine and all high-quality waste heat through the second engine (i. e., $\gamma = 1$ and $\beta = 1$) produces enough waste heat to meet the thermal loads. If the condition:

$$(\text{SOLE}) \eta_1 \alpha_2 \geq \text{QP} + \text{QSH}/\text{COPA} \quad (10)$$

holds, all QP and QSH loads can be met with low-quality waste heat. $\gamma = 1$ and $\beta = 1$ are the best valve settings, and the calculations can proceed to test whether engine maxima are exceeded.

If the inequality in (10) does not hold, it is necessary to send some of the high-quality waste heat directly to the thermal loads or, equivalently, the value of γ must be less than 1. (The theorem proved in appendix I I I-A shows that it is better to adjust γ than to adjust β). If the condition:

$$\text{SOLE } \eta_1 (\alpha_1 + \alpha_2) \geq \text{QP} + \text{QSH}/\text{COPA} \quad (11)$$

holds, then the QP and QSH demands can be met entirely with thermal energy without the need to divert any high-temperature energy from the input of the first engine, although some high-quality waste heat must be diverted from the second engine. The valve settings are then given by:

$$\beta = 1 \quad (12)$$

$$\gamma = \frac{\text{SOLE } \eta_1 (\alpha_1 + \alpha_2) - \text{QP} - \text{QSH}/\text{COPA}}{\text{SOLE } \eta_1 \alpha_1}$$

If the condition shown in equation (11) is not met, it is necessary to meet some of the QSH loads with electricity. The condition specified in equation (9) implies that it is more efficient to use high-temperature energy in the first engine and run the electricity through an electrical converter with COPE than to use it directly through the thermal conversion equipment characterized by COPA. The next step, therefore, is to determine whether it is possible to meet the QP load with valves set so that $\beta = 1$ and $\gamma = 0$.

This is possible if the following inequality holds:

$$\text{SOLE } \eta_1 (\alpha_1 + \alpha_2) \geq \text{QP} \quad (13)$$

Some QSH loads may be met thermally, with the remainder met electrically from the output of the first engine or (if necessary) from backup electricity.

The amount of QSH that can be met thermally (QCT) is given as follows:

$$\text{QCT} = [\text{SOLE } \eta_1 (\alpha_1 + \alpha_2) - \text{QP}] \text{COPA} \quad (14)$$

If the inequality in equation (13) does not hold, it is not possible to meet the QP loads without diverting some high-temperature energy from the input of the first engine. In this case all of the QSH loads must be met electrically from the output of the first heat engine (or, if necessary, from backup electricity) and the optimum valve settings are as follows:

$$\gamma = 0 \quad (15)$$

$$\beta = \frac{\text{SOLE} - \text{QP}}{\text{SOLE} (1 - \eta_1 (\alpha_1 + \alpha_2))}$$

(The quantity β will never be zero since it was necessary to determine that SOLE was greater than QP in order to reach the sequence of tests just described.)

Having determined the optimum valve settings it is again necessary to determine whether the use of SOLE with the optimum valve settings results in a situation where the first engine is required to produce electricity at a rate which exceeds the specified maximum capacity (ENGMAX). If the following inequality holds,

$$\beta \eta_1 \text{SOLE} > \text{ENGMAX} \quad (16)$$

the engine maximum is exceeded and it is necessary to readjust the valves.

The new valve settings are computed

following a sequence of tests similar to those indicated in equations (10) through (16):

A)

$$\begin{aligned} \text{If } QP + QSH/COPA \leq \alpha_2 \text{ ENGMAX, then} \\ \beta = 1 \\ \gamma = 1 \end{aligned} \quad (17)$$

B)

$$\begin{aligned} \text{If } QP + QSH/COPA \leq (\alpha_1 + \alpha_2) \text{ ENGMAX} \\ \beta = 1 \\ \gamma = \frac{\text{ENGMAX}(\alpha_1 + \alpha_2) - QP - QSH/COPA}{\alpha_1 \text{ ENGMAX}} \end{aligned} \quad (18)$$

C)

$$\begin{aligned} \text{If } QP + QSH/COPA > (\alpha_1 + \alpha_2) \text{ ENGMAX} \\ QP \leq (\alpha_1 + \alpha_2) \text{ ENGMAX} \\ QSH \leq (\text{ENGMAX} - \text{EEE})\text{COPE} + \\ (\text{ENGMAX}(\alpha_1 + \alpha_2) - QP)\text{COPA} \\ \text{Then } \beta = 1 \\ \gamma = 0 \end{aligned} \quad (19)$$

The third test involving the miscellaneous electrical load (E E E) is necessary to ensure that there is enough electrical output to meet the QSH loads, which are not met thermally.

D)

$$\begin{aligned} \text{If } QP + QSH/COPA > \alpha_2 \text{ ENGMAX} \\ QP \leq (\alpha_1 + \alpha_2) \text{ ENGMAX} \\ QSH > (\text{ENGMAX} - \text{EEE})\text{COPE} + \\ \text{ENGMAX}(\alpha_1 + \alpha_2) - QP(\text{COPA}) \end{aligned} \quad (20)$$

Then

$$\begin{aligned} \beta = \frac{[\text{COPA}(\text{ENGMAX})] / \\ [\eta_1 QSH + \eta_2 \text{COPE}[\text{EEE} - \text{ENGMAX}] + \\ \text{COPA} [QP\eta_1 + \text{ENGMAX}(1 - (\alpha_1 + \alpha_2)\eta_1)]]}{\gamma = 0} \end{aligned}$$

E)

$$\begin{aligned} \text{If } QP > (\alpha_1 + \alpha_2) \text{ ENGMAX, then} \\ \beta = \frac{\text{ENGMAX}}{\text{ENGMAX}(1 - \eta_1(\alpha_1 + \alpha_2)) + \eta_1 QP} \\ \gamma = 0 \end{aligned} \quad (21)$$

In each case a check must be made to determine the amount of electricity available for charging the battery.

With this, the correct valve settings have been determined. As before, however, a check must be made to determine whether using the specified settings will leave the high-temperature storage filled. If the high-temperature storage is not filled at the end of the hour, and if the use of the optimum valve settings results in a situation where electricity would be sold to the utility, the

system should be adjusted to use less high-temperature energy. (A similar recalculation is required if excess electricity cannot be sold to an electric utility grid.) The first step in such a recalculation is to determine the valve settings that would be used if the system met only the minimum electrical demands. This will be called EOUT where

$$\text{EOUT} = \text{EEE} + (\text{the maximum amount of electricity which can be placed in the batteries}) \quad (22)$$

The maximum amount of electricity that can be put in the batteries is the smaller of the following two quantities: 1) the specified capacity of the power conditioner; and, 2) the difference between the maximum specified battery capacity and the amount of electrical energy stored in the battery at the beginning of the hour.

The valve settings, which optimize production in the case where the system only produces electricity for EOUT, can be computed in the following sequence of steps:

A)

$$\begin{aligned} \text{If } QP + QSH/COPA \leq \alpha_2 \text{ EOUT}/(1 + \alpha_1 \eta_2) \\ \text{Then } \beta = 1 \\ \gamma = 1 \end{aligned} \quad (23)$$

B)

$$\begin{aligned} \text{If } QP + QSH/COPA > \text{EOUT}(\alpha_1 + \alpha_2) \\ \text{Then } \beta = 1 \\ \gamma = \frac{(\alpha_1 + \alpha_2) \text{EOUT} - QP - QSH/COPA}{\alpha_1 [\text{EOUT} + \eta_2 (QP + QSH/COPA)]} \end{aligned} \quad (24)$$

C)

$$\begin{aligned} \text{If } QP + QSH/COPA \leq \text{EOUT}(\alpha_1 + \alpha_2) \\ QP \leq \text{EOUT}(\alpha_1 + \alpha_2) \\ QSH \leq (\text{EOUT} - \text{EEE})\text{COPE} + \\ (\text{EOUT}(\alpha_1 + \alpha_2) - QP)\text{COPA} \\ \text{Then } \beta = 1 \\ \gamma = 0 \end{aligned} \quad (25)$$

D)

$$\begin{aligned} \text{If } QP + QSH/COPA > \text{EOUT}(\alpha_1 + \alpha_2) \\ QP \leq \text{EOUT}(\alpha_1 + \alpha_2) \\ QSH > (\text{EOUT} - \text{EEE})\text{COPE} + \\ (\text{EOUT}(\alpha_1 + \alpha_2) - QP)\text{COPA} \end{aligned} \quad (26)$$

Then β and γ are given by equation (20) using EOUT instead of ENGMAX,

E)

$$\begin{aligned} \text{If } QP > (\alpha_1 + \alpha_2) \text{EOUT} \\ \text{Then } \beta = \frac{\text{EOUT}}{\text{EOUT}(1 - \eta_1(\alpha_1 + \alpha_2)) + \eta_1 QP} \\ \gamma = 0 \end{aligned} \quad (27)$$

With the valve settings calculated in equations (23) through (27), it is possible to calculate the minimum amount of high-temperature energy that must enter the system to meet the loads. If the difference between the amount of solar energy produced during the hour and this minimum amount can be placed in high-temperature storage, the computation is complete for the hour. If high-temperature storage would be exceeded, another step must be taken. The amount of high-temperature energy available after the high-temperature storage is filled can be calculated and the optimum technique for using this energy computed by using equations (10) through (21) (assuming that electricity can be sold). If no electricity can be sold, the excess high-temperature energy is transferred to the low-temperature storage. The low-temperature storage is filled to capacity and the remaining energy discarded.

A Case Where Using Electricity To Meet the Space-Conditioning Load Is Always More Efficient Than Using Thermal Energy

If the inequality:

$$\text{COPA} < \eta_2 \text{COPE} \quad (28)$$

holds, it will be more efficient to meet the QSH loads using electricity from the second engine than it will be to use thermal energy to meet QSH loads directly. The thermal units characterized by COPA will, therefore, only be used if α_2 is sufficiently large to justify the installation of thermal conversion equipment. The basic procedure followed in this case is identical to the one described previously with small differences resulting from the relative values of COPA and $\eta_2 \text{COPE}$. The steps which are equivalent to equations (10) through (15) are as follows:

A)
If $\text{SOLE } \eta_1 \alpha_2 \geq \text{QP}$ (29)
Then $\beta = 1$
 $\gamma = 1$

(It should be noted that if COPA is not zero and $\text{SOLE } \eta_1 \alpha_2 > \text{QP}$, any "excess" low-quality waste heat is used to meet the space-

conditioning load.)

B)
If $\text{SOLE } \eta_1 (\alpha_1 + \alpha_2) \geq \text{QP} > \text{SOLE } \eta_1 \alpha_2$ (30)
Then $\beta = 1$

$$\gamma = \frac{\text{SOLE } \eta_1 (\alpha_1 + \alpha_2) - \text{QP}}{\text{SOLE } \eta_1 \alpha_1}$$

C)
If $\text{QP} > \text{SOLE } \eta_1 (\alpha_1 + \alpha_2)$ (31)
Then $\beta = \frac{\text{SOLE } \eta_1 (\alpha_1 + \alpha_2) - \text{QP}}{\text{SOLE } [\eta_1 (\alpha_1 + \alpha_2) - 1]}$

$$\gamma = 0$$

The remainder of the calculation can be readily derived following this pattern.

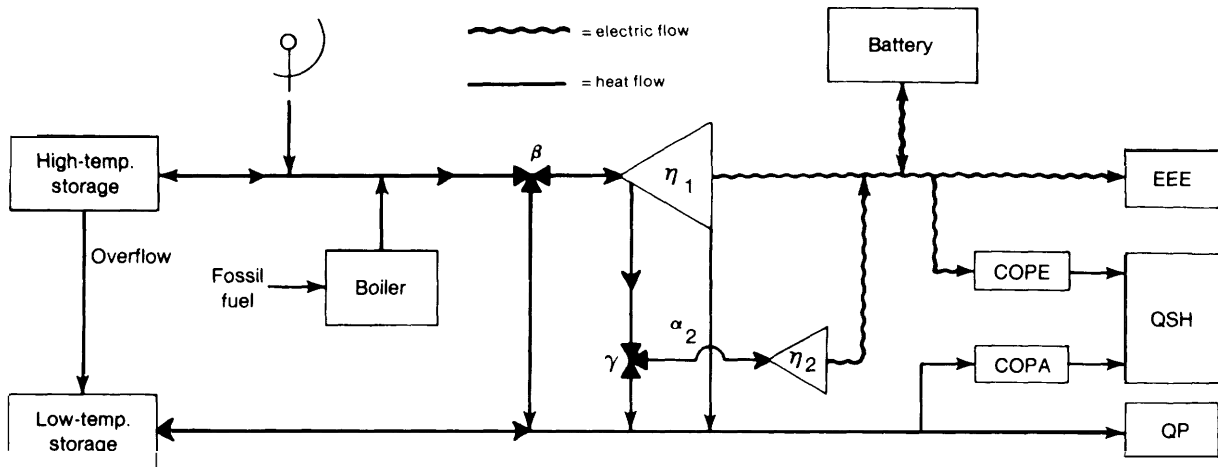
At the end of each hour, the net amount of electricity and low-temperature thermal energy produced from the high-temperature inputs and valve settings can be determined. These are used to meet the EEE, QSH, and QP loads. Any remaining low-temperature energy is placed in low-temperature storage. Any remaining electricity is placed in the batteries or sold to the utility if the batteries are filled. Onsite demands that cannot be met with the onsite power are met by purchasing electricity.

COGENERATION WITH FOSSIL FUEL OR BIOMASS BACKUP

Figure II I-4 illustrates a completely general cogeneration system, which is not tied to a utility grid but is backed up with a fossil or biomass fuel source. Notice (although not shown in figure 3) that in the general case there are three different kinds of boilers: 1) a boiler used in the system providing backup to the heat engine (this could be a coal-fired steam boiler to back up a solar-powered steam engine, the burner efficiency in the backup unit used in a Stirling engine, etc); 2) a boiler efficiency for the QSH loads (this could be the burner efficiency in an adsorption chiller), and 3) the boiler used to produce QP.

The logic of the fossil backup case is very similar to the logic employed in the electrically backed up system and details are not shown here. The program which per-

Figure III-4.—Cogeneration System With Fossil Fuel Backup



forms the necessary calculations is reproduced in appendix III-B. The major differences between the fossil and the electrical case are:

- Either COPA or COPE (but not both) can be zero in the case of fossil backup.
- It is assumed that the loads will be met at all times. If an engine size is specified which does not permit meeting the loads, the calculation performed in this analysis will correct the initial estimate as necessary.
- In some cases high-temperature energy from several different sources must be used to meet the onsite loads. It is assumed that the highest temperatures available to the system are obtained from burning fossil fuels or biomass, fluids emerge from collectors at a lower temperature, and fluids emerging from high-temperature storage are at a still lower temperature. (In most cases examined, it is assumed, however, that all three provide identical temperatures but an option for using different temperature is kept open. The efficiency of the first engine must be adjusted to reflect the different fluid temperatures.) The highest temperature fluids are used in the engine whenever possible.

A COMPUTER ANALYSIS OF COGENERATION

A Fortran computer program was prepared for this analysis which performs the optimization procedure just described. A sample of the data, which the program requires to perform an evaluation of a cogeneration system, is illustrated in table 111-1 and a sample of the formatted output of the program is illustrated in table II 1-2. A listing of the package of programs is shown in appendix 1 I I-B. An operating manual explaining the use and operation of these programs in greater detail is available as a separate Volume.

CALCULATION OF COLLECTOR PERFORMANCE

The techniques used to compute the thermal output of different kinds of collectors were explained in the appendix to chapter VIII of volume I and the equations used to compute the thermal and electrical output of photovoltaic devices were discussed in chapter X of volume 1. The following section describes how the formulas developed in volume I were used to evaluate the systems analyzed.

Collector output is computed in three

Table III-1.—Sample Input

TOT IO . JB

```

TITLE : PHOTOVOLTAIC COGENERATION--HIGH RISE, ALB (TEST SYSTEM)
SAVE HOURLY ELECTRICAL OUTPUT: NO
PRINT MONTHLY TOTALS OF SOLAR/DEMAND VARIABLES: YES
PRINT AVERAGE AND END OF MONTH VALUES OF STORAGE: YES
PRINT INPUT SUMMARY: YES
USE SEASONAL PARAMETERS: NO
FILE NUMBER FOR SYSTEM COEFFICIENTS: 90
LIST/CHANGE VARIABLES AND VALUES: NON
MAXIMUM PUMP/FAN LOAD--HEATING, COOLING (KW FAN/TOTAL OUTPUT): 59.24 59.24
HEAT LOSS FOR LT TANK OF LOW TEMP STORAGE (KWH/DEG CENT/HR): 0.001
AMBIENT TEMP. FOR LT STORAGE (DEG CENT): 25
FILE NUMBER FOR COLLECTOR COEFFICIENTS: 91
LIST/CHANGE VARIABLES AND VALUES: NON
FILES FOR ELECTRIC H/C COP'S: 43 44
INITIAL. VALUES OF LOW TEMP> HIGH TEMP, AND ELEC STORAGE (KWH): 5131/

```

subroutines:

COLL1, which is used for flat-plate collectors and two-axis tracking collectors (except heliostats]

COLL2, which is used for one-axis tracking collectors; and

COLL3, which is used for heliostats.

The three programs are very similar in basic structure. As a result, only the **COLL1 program is discussed in detail the discussion of the other two subroutines concentrates primarily on features that differ from COLL1.**

Each subroutine can be entered in **four different ways. These entry points are illustrated in figure III-5. The collector subroutine is called initially to read information from external files and to convert this data into a form that can be used in the computation. The subroutines obtain information in two steps. First two files are read; one containing the solar declination for each day of the year and one containing information about the performance of the collector. A sample file of collector performance characteristics required to operate the program was shown in table III-2. After these files are read, the performance characteristics can be changed as necessary. The revised set of performance characteristics can be saved in a new file for later use if this is desired.**

The program is then entered for each hour of the year to compute the electrical and thermal output of collectors **given information about ambient air temperature, the temperature of fluids entering the collector, and (if a fixed output temperature is specified) the output temperature of the collector.**

At the end of the yearly computation the program is entered two more times to print a description of the collector and to summarize the assumptions made about collector performance.

The COLL1 Collector Subroutine

The COLL1 subroutine computes the output of either flat-plate collectors or two-axis tracking collectors. It can be **used to compute the output of collectors that provide only thermal energy, of photovoltaic collectors that provide only electrical output, or of photovoltaic cogeneration systems that provide both thermal and electric output.** A listing of the program is given in appendix III-B.

Figure III-6 shows a flow diagram for the section of the program which reads and converts the initial data (entry point 1 on figure III-5).

The first input read is a table of declina-

Table III-2.—Sample Output

| PHOTOVOLTAIC COGENERATION--HIGH RISE, ALB (TFST SYSTEM) | | DATE : | 8/17/78 |
|--|--------------|--------------------------------|--|
| | | TIME : | 1b: 9:14 |
| <p>PHOTOVOLTAIC SYSTEM ELECTRIC BACKUP TWO-AXIS TRACKING SYSTEM COMBINED THERMAL AND ELECTRIC COLLECTOR CONSTANT OUTPUT TEMPERATURE LOADS SET UP FOR HIGH RISE APARTMENT BUILDING THE MISCELLANEOUS ELECTRIC LOADS AND THE HOT WATER LOADS ARE NOT SMOOTHED</p> | | | |
| SYSTEM COEFFICIENTS: | | COLLECTOR_ COEFFICIENTS: | |
| # | REAL NUMBERS | # | REAL NUMBERS |
| 1 | 0. | 1 | 5.000E+02 :CONCENTRATION RATIO (DIM) |
| 2 | 8.000E-01 | 2 | 7.600E-01 :OPTICAL EFFICIENCY OR TRANSMISS. (.LE. 1.00) |
| 3 | 1.000E+00 | 3 | 2.500E+03 :COLLECTOR AREA (M**2) |
| 4 | 1.000E+00 | 4 | 3.508E+01 :LATITUDE (DEG) |
| 5 | 0. | 5 | 1.066E+02 :LONGITUDE (DEG) |
| 6 | 0. | 6 | 1.050E+02 :STANDARD LONGITUDE (DEG) |
| 7 | 0. | 7 | 3.508E+01 :COLLECTOR TILT ABOVE HORIZONTAL (DEG) |
| 8 | 0. | 8 | 0. |
| 9 | 0. | 9 | 5.000E+00 :COLLECTOR HEAT REMOVAL FACTOR (KW/(M**2*C)) |
| 10 | 0. | 10 | 2.100E-03 :CELL TEMP COEFF (1/DEG CENT) |
| 11 | 0. | 11 | 2.200E-01 :CELL EFFIC @ 28C (.LE. 1.00) |
| 12 | 0. | 12 | 9.500E-01 :CELL ABSORPTIVITY (.LE. 1.00) |
| 13 | 0. | 13 | 1.000E+00 :FRAC OF RECEIVER COVERED WITH CELLS (.LE. 1.00) |
| 14 | 0. | 14 | 1.500E-02 :THERMAL LOSS COEFF (KW/M**2*C) |
| 15 | 0. | 15 | 1.000E+00 :NUMBER OF GLASS COVERS (DIM) |
| 16 | 0. | 16 | 1.000E+00 :COLLECTOR HEAT REMOVAL FACTOR (.LE. 1.00) |
| 17 | 0. | 17 | 9.800E-01 :ABSORB OF THERMAL-ONLY SURFACES (.LE. 1.00) |
| 18 | 0. | 18 | 1.000E+01 :FLOW RATE (CM**3/SEC*M**2) |
| 19 | 0. | 19 | 1.000E+00 :FLUID DENSITY (GM/CM**3) |
| 20 | 0. | 20 | 1.000E+00 :FLUID SPEC. HEAT (CAL/GM*C) |
| INTEGERS | | INTEGERS | |
| # | VALUE | # | VALUE |
| 1 | 2 | 1 | 2 |
| 2 | 2 | 2 | 2 |
| STORAGE HEAT LOSS COEFFICIENTS | | STORAGE HEAT LOSS COEFFICIENTS | |
| UT STORAGE | 0. | HEAT LOSS | AMB. TEMP |
| LT STORAGE | 1.000E-03 | (KWH/DEG CENT/HR) | (DEG. CENT) |
| | | -- 0. | 25.0 |
| | | -- 1.000E-03 | 25.0 |
| NOTE: FIRST HEAT LOSS NUMBER IS FOR HT TANK OF THE PARTICULAR STORAGE; SECOND IS FOR LT TANK OF THE SAME STORAGE. | | | |
| ELECTRIC H/C COP'S (KWH/KWH) | | ELECTRIC H/C COP'S (KWH/KWH) | |
| TEMP | HEAT | TEMP | COOL |
| 10.0 | 1.00 | 75.0 | 2.50 |
| 20.0 | 1.00 | 80.0 | 2.35 |
| 30.0 | 1.00 | 90.0 | 2.07 |
| 40.0 | 1.00 | 100.0 | 1.86 |
| 50.0 | 1.00 | 110.0 | 1.67 |
| 60.0 | 1.00 | 120.0 | 1.52 |
| 70.0 | 1.00 | -- | -- |

Table III-2.—Sample Output (Continued) (Cont.)

PHOTOVOLTAIC COGENERATION--HIGH RISE, ALB (TEST SYSTEM)

DATE: 8/17/78

TIME: 10: 9:14

| MONTH | ELECTRICITY AND FOSSIL FUEL BACKUP DEMANDS (KWH) | | | | LOAD FACTOR (DIM) | STORAGE VALUES | | |
|-------|--|------------|----------|------------------|----------------------------------|----------------|------------|-----------|
| | ELEC. BUY | FUCL. SELL | FUCL USE | EXCESS EE ENERGY | | ELECTRIC | LOW TEMP | HIGH TEMP |
| 1 | 1.574E+05 | 0. | 0. | 1.146E+04 | INITIAL VALUE (KWH): | 1.466E-01 | 7.916E-01 | 0. |
| 2 | 5.055E+04 | 0. | 0. | 5.891E+04 | FINAL VALUE (KWH): | 0. | 5.131E+03 | 0. |
| 3 | 6.922E+04 | 8.798E+00 | 0. | 6.670E+04 | MINIMUM VALUE (KWH): | 0. | -5.570E-01 | 0. |
| 4 | 2.857E+04 | 1.302E+02 | 0. | 2.212E+05 | MAXIMUM VALUE (KWH): | 1.200E+03 | 1.000E+04 | 0. |
| 5 | 3.627E+04 | 1.326E+01 | 0. | 3.429E+05 | TOTAL ENERGY PUT INTO (KWH): | 2.340E+05 | 9.853E+05 | 0. |
| 6 | 6.383E+04 | 0. | 0. | 3.951E+05 | TOTAL ENERGY TAKEN OUT OF (KWH): | 2.340E+05 | 9.843E+05 | 0. |
| 7 | 8.756E+04 | 0. | 0. | 2.677E+05 | MAXIMUM INPUT INTO PG (KWH/HR): | 1.961E+02 | 1.583E+03 | 0. |
| 8 | 1.042E+05 | 0. | 0. | 3.261E+05 | MAXIMUM OUTPUT INTO PG (KWH/HR): | 3.648E+02 | 9.999E+02 | 0. |
| 9 | 7.361E+04 | 0. | 0. | 1.678E+05 | | | | |
| 10 | 3.959E+04 | 4.195E+02 | 0. | 1.711E+05 | | | | |
| 11 | 5.916E+04 | 4.112E+02 | 0. | 4.584E+04 | | | | |
| 12 | 8.179E+04 | 0. | 0. | 1.546E+04 | | | | |
| TOTAL | 8.517E+05 | 2.329E+03 | 0. | 2.105E+06 | | | | |

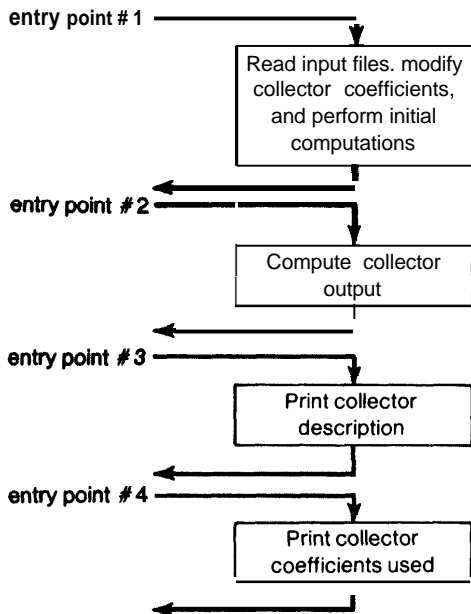
| MAXIMUM SPACE CONDITIONING LOADS | | |
|----------------------------------|-----------|-----------|
| COOLING (KWH): | ELECTRIC | THERMAL |
| | 5.040E+02 | 0. |
| HEATING (KWH): | ELECTRIC | TOTAL |
| | 8.306E+02 | 8.306E+02 |

| MONTH | TOTAL MONTHLY VALUES (KWH) | | | | | AVER TEMP (F.) | MAXIMUM SOLAR THERMAL OUTPUT (KWH): 1.598E+03 |
|-------|----------------------------|---------------|-----------|----------------------------|-----------|----------------|--|
| | PHOTOVOLT ELECTRIC | SOLAR THERMAL | ELECTRIC | INTERNAL DEMANDS HEAT/COOL | HOT WATER | | |
| 1 | 6.367E+04 | 2.564E+05 | 1.090E+05 | 1.637E+05 | 7.610E+04 | 33.5 | MAXIMUM SOLAR ELECTRIC OUTPUT (KWH): 3.802E+02 |
| 2 | 6.294E+04 | 2.508E+05 | 9.129E+04 | 1.483E+05 | 6.865E+04 | 41.5 | MAXIMUM ENGINE BOILER OUTPUT (KWH): 0. |
| 3 | 7.063E+04 | 2.778E+05 | 1.018E+05 | 1.630E+05 | 7.081E+04 | 41.5 | MAXIMUM NONENGINE BOILER OUTPUT (KWH): 0. |
| 4 | 8.283E+04 | 3.260E+05 | 9.241E+04 | 1.447E+05 | 5.962E+04 | 58. | MAXIMUM HOT WATER FUEL USE (KWH): 0. |
| 5 | 1.043E+05 | 4.183E+05 | 9.912E+04 | 2.339E+05 | 5.097E+04 | 65. | FOSSIL HEAT PUT INTO ENGINE (KWH): 0. |
| 6 | 1.027E+05 | 4.115E+05 | 1.022E+05 | 1.761E+05 | 4.024E+04 | 72. | SOLAR HEAT PUT INTO ENGINE (KWH): 0. |
| 7 | 7.771E+04 | 3.074E+05 | 1.345E+05 | 1.191E+05 | 3.619E+04 | 74. | STORAGE HEAT PUT INTO ENGINE (KWH): 0. |
| 8 | 8.637E+04 | 3.438E+05 | 1.404E+05 | 1.017E+05 | 1.619E+04 | 77. | MAXIMUM ELECTRICITY BOUGHT IN AN HOUR (KWH): 1.559E+03 |
| 9 | 5.517E+04 | 3.115E+05 | 7.383E+04 | 1.277E+05 | 4.824E+04 | 68. | MAXIMUM ELECTRICITY SOLD IN AN HOUR (KWH): 2.201E+02 |
| 10 | 6.761E+04 | 2.778E+05 | 3.393E+04 | 4.597E+04 | 5.090E+04 | 57. | MAXIMUM FUEL BOUGHT IN AN HOUR (KWH): 0. |
| 11 | 6.140E+04 | 2.443E+05 | 9.514E+04 | 1.101E+05 | 5.961E+04 | 46. | TOTAL ELECTRICITY BOUGHT (KWH): 8.517E+05 |
| 12 | 6.752E+04 | 2.740E+05 | 1.041E+05 | 1.957E+05 | 7.081E+04 | 36. | TOTAL ELECTRICITY SOLD (KWH): 2.329E+03 |
| TOTAL | 9.028E+05 | 3.592E+06 | 1.198E+06 | 1.017E+06 | 6.603E+05 | | TOTAL FUEL BOUGHT (KWH): 0. |

| Month | LOAD FACTOR OF STORAGE (KWH) | | | END OF MONTH VALUES OF STORAGE (KWH) | | |
|-------|------------------------------|-----------|-----------|--------------------------------------|-----------|-----------|
| | ELECTRIC | LOW TEMP | HIGH TEMP | ELECTRIC | LOW TEMP | HIGH TEMP |
| 1 | 1.53E-01 | 3.465E-01 | 0. | 1.351E+02 | 8.044E+03 | 0. |
| 2 | 1.95E-01 | 5.596E-01 | 0. | 3.776E+00 | 5.291E+03 | 0. |
| 3 | 1.957E-01 | 6.088E-01 | 0. | 3.807E+02 | 4.018E+03 | 0. |
| 4 | 2.266E-01 | 9.329E-01 | 0. | 4.825E+02 | 9.246E+03 | 0. |
| 5 | 2.463E-01 | 9.675E-01 | 0. | 3.178E+02 | 9.778E+03 | 0. |
| 6 | 8.299E-02 | 9.873E-01 | 0. | 0. | 9.704E+03 | 0. |
| 7 | 3.461E-02 | 9.824E-01 | 0. | 0. | 9.727E+03 | 0. |
| 8 | 2.241E-02 | 9.844E-01 | 0. | 0. | 9.705E+03 | 0. |
| 9 | 4.305E-02 | 8.776E-01 | 0. | 0. | 9.447E+03 | 0. |
| 10 | 1.672E-01 | 9.040E-01 | 0. | 0. | 9.076E+03 | 0. |
| 11 | 1.825E-01 | 7.153E-01 | 0. | 0. | 1.976E+03 | 0. |
| 12 | 1.900E-01 | 5.318E-01 | 0. | 0. | 5.131E+03 | 0. |

STOP
SRC'S:56.4

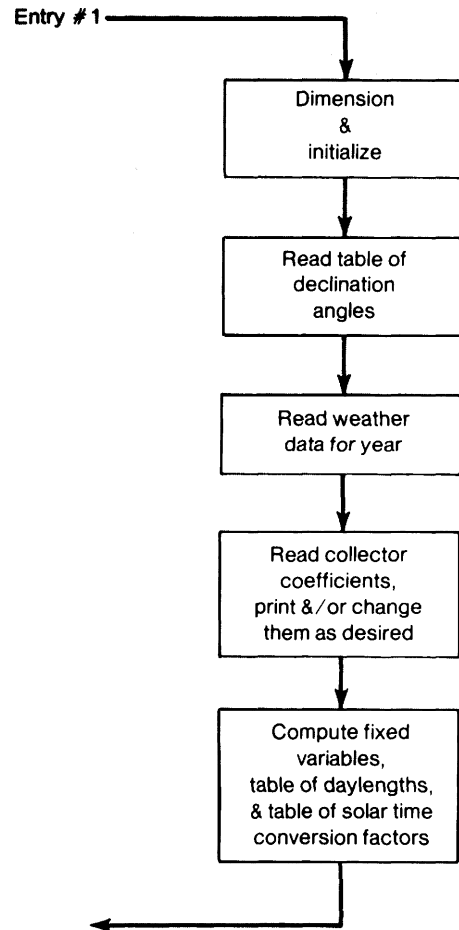
Figure III-5.—Entries to Collector Subroutines COLL1, COLL2, and COLL3



tion angles for each day of the year (line 2014). The direct normal radiation (RADDN) and the hourly total horizontal radiation (RADTH) for the first hour in the year are read from file 25, which contains RADDN and RADTH for each hour of the year in the region being studied. (This file also contains temperature and wind velocity data, which are read into the RADDN array but are then overlaid.) The file containing the collector coefficients is then specified from the terminal or from a stored file. A negative number will set all coefficients to zero. Lines 2020 to 2025 allow the operator to list the collector coefficients read from the file, and to make changes in the assumed collector performance characteristics if this is required.

Changes to the collector coefficients are input using lines 2057 to 2066. The COMMON statement (lines 2005 to 2008) places the variables named in the COMMON statement into the computer's memory space in the order given. The EQUIVALENCE statement [line 2010] then creates arrays SCEL and ISCEL, which contain the collector coef-

Figure III-6.—Flow Diagram for Entry Point #1 to COLL1, COLL2, and COLL3



ficient variables in exactly the order given in the COMMON statement. Lines 2057 to 2061 allow the values of any real coefficient to be changed by specifying the coefficient number (as given in the left column of lines 2033 to 2052) and the new value. Input of a negative value will make the program move to the integer variables. The integer variables of lines 2055 to 2056 are changed using lines 2062 to 2066. The modified coefficient files can be stored (lines 2067 to 2070) by specifying a positive file number. Zero or a negative number causes the modified values to be retained until execution of the main program terminates.

The program then calculates several quantities for use in the hourly computa-

tions of collector output. The latitude angle (LAT), collector tile angle (TILT), and the collector azimuth angle (AZ), which were input in degrees, are converted to radians for use in the Fortran program.

The collector absorber area AREACR is calculated by dividing the collector area by the concentration ratio. The quantity XMASSF = (fluid flow volume) x (specific heat) x (density) is computed.

ALPHAV is the effective thermal absorptivity computed from the absorptivity of the photovoltaic cells, (ELECAB), the absorptivity of the portion of the collector not covered with cells, (ALPHA), and the fraction of the collector absorber covered with cells, (FC). The program then calculates the length of each day of the year, (DAYLEN (I)), and the correction factor used to convert local time to solar time, (SONOON (1)). EQ(J) is the equation of time discussed in chapter VIII of volume 1. SONOON (1) converts the hour number to solar time using EQ(J), a constant shifting the time to the middle of the hour and accounting for the fact that hour #1 in each day in the weather arrays (RADDN and RADTH) corresponds to the hour from midnight to 1 a.m. and a term that accounts for locations at longitudes other than standard time zone longitudes.

The hourly computation of collector output begins with line 2101. The pattern of this computation is shown in figure I I 1-7. First RADTH and RADDN are checked to see if the Sun is shining. If both are small, the program sets the collector output(s) to zero, and the computation is complete for the hour. If there is sunlight available the program must compute the hour of the day (J) from the hour of the year (K). It does this by first computing the day number (1). The program next determines whether the hour being examined is less than half an hour after sunrise or before sundown; if this is the case, the program sets the output to zero and returns. (These hours are excluded from the calculation since the algorithm used to compute diffuse radiation can give anomalously high values under these conditions and the

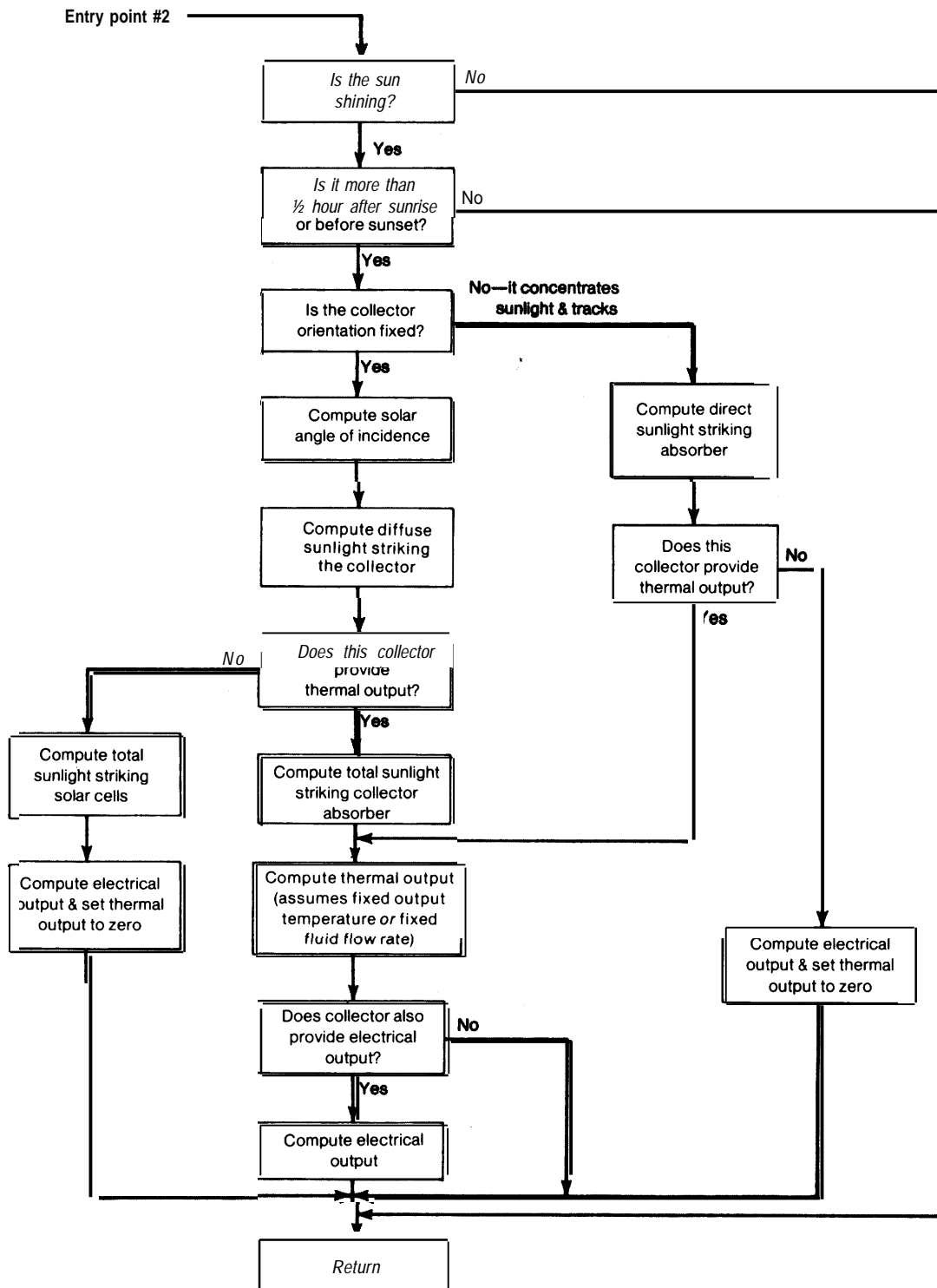
amount of energy available during these hours is negligibly small on an annual basis.) RI SANG (line 2110) is the solar hour angle at sunrise.

If it is determined that collector output should be calculated for hour K, the program must first determine what kind of collector is used. It is assumed that the collector is a flat-plate device if a concentration ratio (C RATIO) less than 1.5 is specified; otherwise, the collector is assumed to be a two-axis tracking collector that can collect only the direct radiation. If the collector is a concentrator, the program either branches to 222 to compute thermal output or goes to 224 to compute electric output if the collector provides only photovoltaic electric output (ISYS = 1).

The total useful sunlight striking a square meter of collector absorber (RADTOT) is calculated for concentrators at normal incidence to the Sun. For flat-plate collectors, the program calculates the cosine of the incident angle (COSINC) on lines 2115 to 2127. If COSTHE is negative, representing an instance where the Sun is behind the Collector, the program sets the output(s) to zero and exits. The diffuse radiation (RADDIF-lines 2128, 2129) striking the tilted collector is calculated as given in equations VII I-A-I 4 and VII I-A-I 5 of volume 1, and is set to zero if it is calculated to be negative. If the collector is a passively cooled photovoltaic array (ISYS = 1), the program skips to line 2149 to calculate the electric output. Calculation of the total radiation striking the collector absorber (RADTOT) depends on whether there are one or two covers (COVERN less than or greater than 1.5). The exponents of COSINC (lines 2132, 2134) are greater than one to represent the angular dependence of the cover transmission on the incident angle and the factors '0.89 and 0.80 represent this angular dependence integrated over a hemisphere for the diffuse radiation as given by equations VII I-A-I 7 and VII I-A-I 8 of volume 1.

The total collector output is computed in lines 2135 to 2152. The output of collectors

Figure III-7 .-Flow Diagram for Computing Hourly Collector Output Using COLL1



that provide only thermal output is computed with the fractional cell coverage ratio (FC) set to zero in the expressions used for collectors that also provide electric output.

The useful thermal output Q_A of a unit area of collector absorber operated at constant output temperature can be computed from the heat balance equation:

$$\alpha I = F_c \eta I + Q_A + U_L (T - T_a) \quad (32)$$

where α is the average absorptivity for the collector (ALPHAV), I is the level of insolation on the absorber (RADTOT), η is the photovoltaic cell efficiency, F_c is the fraction of the absorber area covered with cells (FC), U_L is the thermal loss coefficient (U LOSS), T is the average temperature of the collector absorber and photovoltaic cells (TCELL), and T_a is the ambient air temperature (TAIR).

The value of I is given by the following relations for flat-plates or concentrating systems:

$$I = I_b \cos \theta_i \tau(\theta_i) + I_d \tau_d \quad (\text{flat plates})$$

$$I = I_D C_r \eta_o \quad (\text{concentrating systems})$$

where:

I_D = direct normal solar intensity (kW/m²),

θ , = angle between the Sun and the normal to the Collector,

$\tau(\theta_i)$ = transmissivity of cell covers for direct radiation (at angle θ_i),

I_d = intensity of diffuse solar radiation (kW/m²),

τ_d = transmissivity of cell covers for diffuse radiation ($\tau(\theta_i)$ integrated over all incident angles),

C_r = geometric concentration ratio of concentrator optics, and

η_o = optical efficiency of the concentrator.

The cell efficiency η is given by:

$$\eta = \eta(280)(1 - \beta[\bar{T} - 28]) \quad (33)$$

where $\eta(280)$, is the cell efficiency at 28°C (CELLEF) and β is the cell temperature coefficient (BETA).

The average absorber temperature (TCELL) is:

$$\bar{T} = T_f + Q_A/k_s \quad (34)$$

where T_f is the average collector fluid temperature (TTEMP) and k_s is the thermal conductivity (XKE) between the absorber surface and the fluid.

Combining equations (32) through (34) and multiplying by the total absorber area, the thermal output QSR (line 2142) is given by:

$$QSR = A_A F_R \frac{I[\alpha - F_c \eta(28)(1 - \beta(T_f - 28))] - U_L (T_f - T_a)}{1 - (F_c I \eta(28) @ - U_L)/k_s} \quad (35)$$

where A_A is the absorber area (AR EACR). Note that the program sets $F_R = 1$ (line 2096) for this case.

For the case of constant flow rate, QSR is developed somewhat differently. The output Q_A can now be written (see discussion of equation VII I-A-27 of volume I).

$$Q_A = F_r [I \alpha - \eta F_c I - U_L (T_f - T_a)] \quad (36)$$

where F_r is the collector heat removal factor and T_f is the temperature of the fluid at the Collector inlet. The cell efficiency can be expressed as:

$$\eta = \eta(28)[1 - \beta(T_f + \Delta T/2 + Q_A/k_s - 28)] \quad (37)$$

where the fluid temperature rise across the collector is:

$$\Delta T = \frac{Q_A}{\rho C_p f} \quad (38)$$

where ρ is the fluid density, C_p is the fluid specific heat, and f is the fluid flow rate. XMASSF (lines 2086, 2140, 2146 corresponds to the denominator of equation (38)). CRATIO and the constant are required to convert the inputs provided to the units kW/°Cm² [absorber].

The electric output for those collectors that provide both thermal and electric output Q_E (ESR) is (line 2147).

$$Q_E = A_A F_r I \eta \quad (39)$$

The electric output of passively cooled Collectors can also be computed from equation (39). However, the cell temperature T is:

$$\bar{T} = T_a + \frac{\alpha I - F_c \eta I}{k_e} \quad (40)$$

where k_e is now the overall thermal conductivity between the cells and ambient air. Combining (33), (39), and (40), the electric output (lines 2151, 21 52) is:

$$Q_e = \frac{A_A F_c I \eta(28) [1 - \beta(T_a + \alpha I / k_e - 28)]}{1 - F_c I \beta \eta(28) / k_e} \quad (41)$$

The output(s) are passed back to the main program after ensuring that they are non-negative (lines 2153 to 21 54). The exit at line 2158 is used if the output computation is skipped for lack of sunlight.

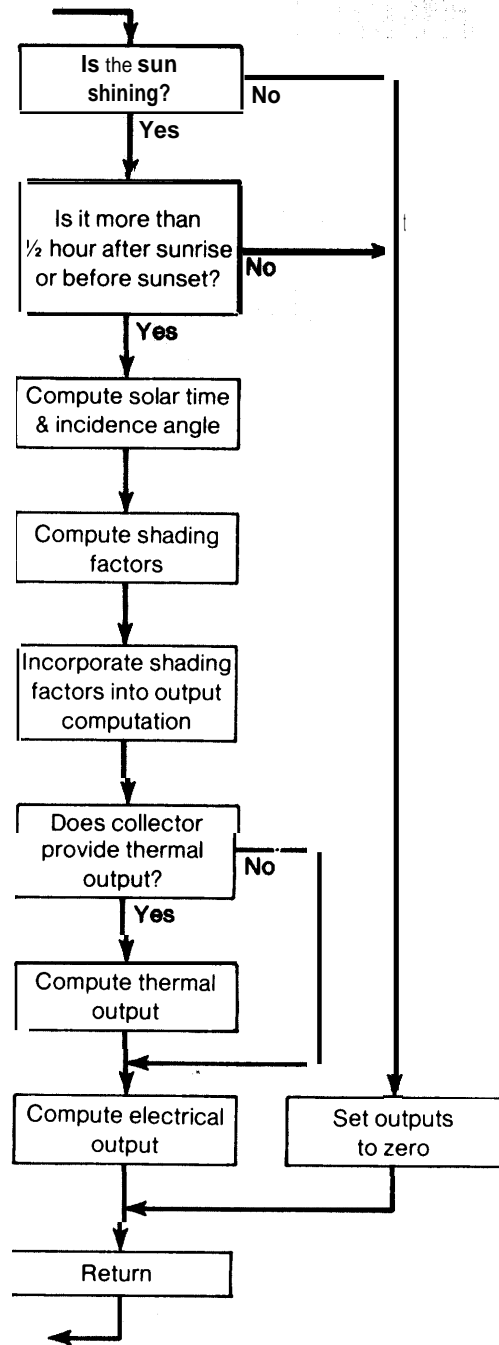
The "output statements" (lines 2162 to 2178) are simply a brief description of the type of collector that has been modeled. The monthly and annual totals of collector output are given in the main program. The "output summary" provides a printout of the collector coefficients that were used in making the run, if requested in the operating instructions for the main program. The three angles shown (lines 2184 to 2186) are converted back to degrees before writing the output summary.

The COLL2 Collector Subroutine

This subroutine computes the output of single axis-tracking collectors with either a north-south polar axis orientation or with a horizontal east-west collector axis. The collectors may provide thermal output, electricity from photovoltaic cells, or both thermal and electric output. This subroutine differs from COLL1 principally in the hourly computations performed. Computation of the incident angle is simpler, computation of shading by adjacent collectors is performed, and a slightly more elaborate computation of thermal losses is performed (to increase accuracy if the Collector is operated over a wide range of output temperatures). A listing of the program appears in appendix I I I-B and a flow diagram for the

entry which calculates collector output is shown in figure I I 1-8.

Figure III-8.—Flow Diagram for Computing Hourly Collector Output Using COLL2



The first part of the program (lines 2000 to 2025) again initializes and contains the first two input prompts. A few variable names differ from COLL1.

The second part of the program contains the format for reading and revising values of collector coefficients.

The section starting with line 2082 differs from the COLL1 program because COLL2 does not require a specified collector tilt and azimuth angle. XMINV is simply $1/(2 \cdot XMASSF)$ with XMASSF as defined in COLL1. RRR is the fraction of the collector absorber-pipe length that is covered with photovoltaic cells and is zero for collectors that provide only thermal output.

Computation of incident angles is simpler than in COLL1. Line 2113 computes the cosine of the Sun's incident angle for a north-south polar axis collector using equation VII I-A-8. If the collector has an east-west axis, (IEW =1) COSINC is recomputed in line 2118 using equation VII I-A-9.

Collector Shading

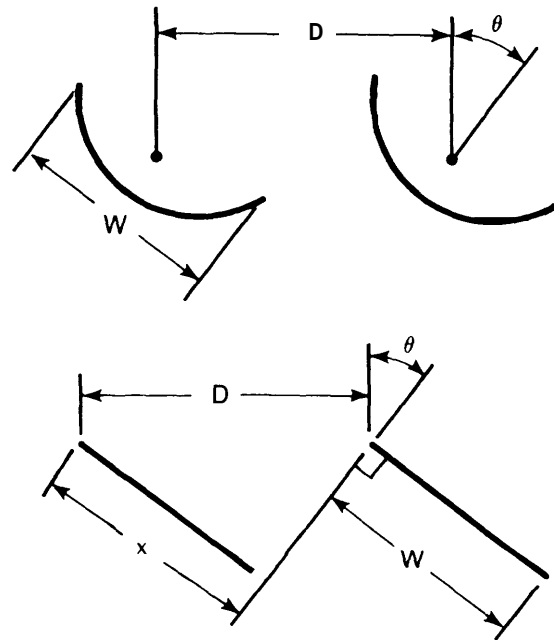
Two types of shading can occur in any array of the troughs or single-axis tracking collectors treated in COLL2: 1) shading caused by a row of collectors located to the south of another row of polar-axis collectors; and 2) shading by the adjacent collector during early morning and late afternoon hours (e. g., the collector to the north or south of an east-west axis collector). In theory both of these factors can be eliminated by increasing the spacing between collectors, but in most cases this is not a practical solution because of the great increase in land use that it requires.

For polar tracking arrays, shading of northerly rows by southern rows of collectors is minor if the space between the rows is equal to the row width and spacing within a row is reasonable. For east-west tracking arrays, the trough axes are horizontal, and only shading by adjacent collectors is significant. The program therefore

assumes that row shading can be eliminated by proper spacing.

The geometry of adjacent-collector shading is illustrated in figure III-9. Assuming that the collector aperture width is W (APWID) and the collector spacing is D (COSPAC), it can be shown that for long collectors the unshaded fraction of the collector is:

Figure III-9.—Sectional View of Parabolic Trough Collectors for Shading Computation



$$\Gamma_1 = \begin{cases} 1 & \text{if } x \geq D \\ x/D & \text{if } x < D \end{cases} \quad (42)$$

where $x = D \cos \theta$, and θ is the rotation of the collector about its axis (PHI).

The end losses of one-axis collectors are given by equation VII I-A-20 in volume 1. The fraction of light which can reach the absorber is:

$$\Gamma_2 = 1 - (D/L_c) f |\tan \theta_c| [1 + 1/(48f^2)] \quad (43)$$

where $f = F/D$ is the f-number of the system and L_c is the collector length. The combined effect of both types of shading and end losses is computed in the line 2132. Note

that line 2125 tests for a condition where the Sun is behind a polar axis collector and sends the program to a RETURN statement if this occurs.

The section beginning with line 2136 completes the computation of the sunlight absorbed by the collector and begins the calculation of thermal output. TRANSM is the fraction of light transmitted through the absorber cover assuming that the cover is approximately perpendicular to the light ray when the collector is pointing directly at the Sun. It is assumed that there is a single cover and TRANS is the transmissivity of the cover at normal incidence. FCIONO is non-zero

only if the collector contains photovoltaic cells and if the entire length of the cells is illuminated. It is zero when some cells are shaded by end effects since the electrical output in this case would be very small. When FCIONO is non-zero, it is the product of the cell efficiency (CELLEF), the fraction FC of the absorber width covered with cells, the light intensity incident on the cells, and the ratio of cell length to the collector length (C EL L/CO LEN).

ALPHIO is the average energy absorbed by a unit area (M') of the absorber and corresponds to the product αI discussed for COLL1. ALPHIO is given by (lines 2141 to 2150):

$$\text{ALPHIO} = \begin{cases} (C_r/L_t) \rho \Gamma_1 \tau_{1D} \cos \theta_i [\alpha (\Gamma_2 L_t - F_c L_c) + F_c \alpha_c L_c] & \text{if } (\Gamma_2 - 0.5)L_t \geq L_c/2 \\ C_r \rho \tau_{1D} \cos \theta_i \alpha \Gamma_1 \Gamma_2 & \text{if } (\Gamma_2 - 0.5)L_t < -L_c/2 \\ (C_r/L_t) \rho \tau_{1D} \cos \theta_i \{ \alpha (L_t - F_c L_c)/2 + F_c \alpha_c [(\Gamma_2 - 0.5)L_t + L_c/2] \} \Gamma_1 & \text{if } |\Gamma_2 - 0.5|L_t < L_c/2 \end{cases} \quad (44)$$

where:

C_r = ratio of collector aperture to absorber area (concentration ratio, (C RATIO))

L_t = total length of collector absorber (COLEN)

L_c = absorber length covered with photovoltaic cells (CELLL)

$\cos \theta_i$ = cosine of incident angle to Sun (COSINC)

α = absorptivity of absorber surface not covered with cells (ALPHA)

α_c = absorptivity of cells (ELECAB)

F_c = fraction of area $L_c \times$ (width) actually covered with cells.

It is assumed that a row of photovoltaic cells of length L_c are centered in the L_t near absorber whose length is L_t . It can be seen that $(\Gamma_2 - 0.5)L_t \geq L_c/2$ corresponds to the entire cell length, one end section and part of the other end section receiving sunlight. $(\Gamma_2 - 0.5)L_t < -L_c/2$ corresponds to less than one end section being illuminated, and $|\Gamma_2 - 0.5|L_t < L_c/2$ corresponds to one end section and part of the cell length being in the reflected sunlight.

If the collector provides only electric output, (ISYS = 1), the computation of thermal

output is skipped. otherwise, the appropriate collector temperature TTEMP is computed. The calculation of TTEMP depends on whether the collector operates with fixed fluid flow rate (1 FLOW = 1) or with fixed output temperature (1 FLOW = 2).

The thermal output of collectors operated with fixed output temperature is computed in lines 2159 to 2163. The computation of QL2, which is proportional to the thermal losses (equal to, if there are no solar cells), utilizes two thermal loss coefficients. The efficiency of a collector is not a linear function of temperature; a typical efficiency function is illustrated in figure I I I-10. Particular care must be taken to account for the nonlinearity if the collectors are operated over a wide 'range of temperatures. The algorithm used by the program approximates the efficiency curve with two straight line segments as shown in the figure. The effective incremental thermal losses in the two temperature ranges are computed as follows:

$$J_1 = \frac{(\eta_0 - \eta_1) C_r I_D}{T_1 - T_0} \quad (45)$$

$$u_2 = \frac{\eta_1 C_r I_D}{T_2 - T_1}$$

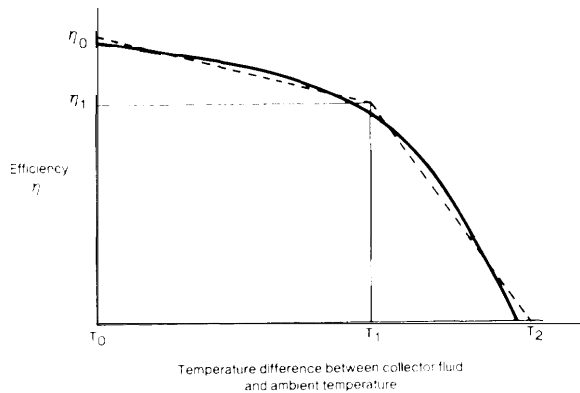
If the difference between the average collector temperature and the air temperature ($T_f - T_a$) is greater than the difference $T_1 - T_0$,

then both U_1 and U_2 are used to compute the thermal output. Using the notation which has been developed in the discussions of COLL1 and COLL2, the thermal output is

$$QSR = \frac{A_c}{C_r} \frac{\alpha(1-F_c)I\eta(28)[1-\beta(T_f-28)]-U_1(T_f-T_0)-U_2[T_f-T_a-(T_f-T_0)]}{1-F_cI\eta(28)\beta/k_e} \quad (46)$$

if $T_f - T_a > T_1 - T_0$

Figure III-10.—Typical Collector Efficiency Curve



This equation can be derived in a fashion similar to that used in the discussion of COLL1. If $T_f - T_a \leq T_1 - T_0$, then U_2 is not used and the thermal loss portion of the equation reduces to $U_1(T_f - T_a)$. If one wishes to run the program using a single thermal loss coefficient, set $U_1 = U_2$ and set T_0 and T_1 to arbitrary values.

The thermal output of collectors operated at a fixed flow rate is calculated in lines 2168 to 2173. For this case, the thermal output is given by:

$$QSR = \frac{A_c}{C_r} \frac{\alpha(1-F_c)I\eta(28)[1-\beta(T_f-28)]-U_1(T_f-T_0)-U_2[T_f-T_a-(T_f-T_0)]}{1 + U_2/(2\rho f C_p C_r) - F_c I\eta(28) \beta [1/k_e + 1/(2\rho f C_p C_r)]} \quad (47)$$

if $T_f - T_a \leq T_1 - T_0$. As for fixed output temperature, the thermal loss portion reduces to $U_1(T_f - T_a)$ if $T_f - T_a < T_1 - T_0$. The program can also be operated with $U_1 = U_2$ as above. This algorithm implicitly assumes that the flow rate is great enough that the temperature rise across the collector is not so large that the loss calculation will be significantly affected if $T_f - T_a$ is nearly as large as $T_1 - T_0$.

The electric output of collectors that also provide thermal output is computed on line 2175 as:

$$ESR = (A_c/C_r) F_c I\eta(28) [1 - \beta(T_f + \frac{C_r QSR}{k_e A_c} - 28)] \quad (48)$$

The electric output of passively cooled Collectors is calculated on line 2178 as:

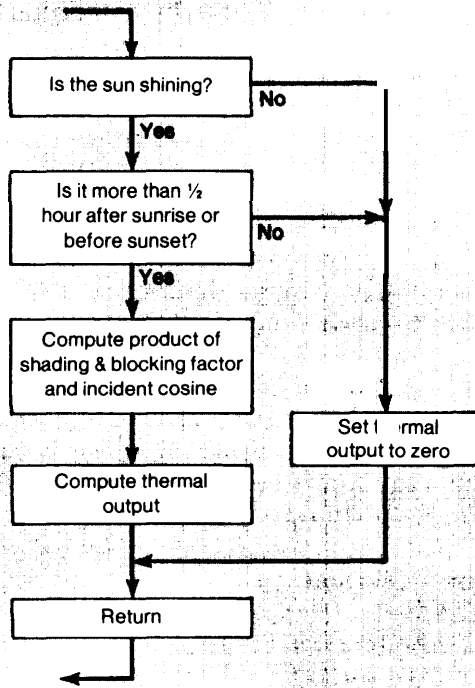
$$ESR = \frac{A_c}{C_r} \frac{F_c I\eta(28) [1 - \beta(T_a + \alpha/k_e - 28)]}{1 - F_c I\eta(28) \beta/k_e} \quad (49)$$

Collector Subroutine COLL3

This subroutine computes the thermal output of a heliostat field. It does not perform a detailed computation of the shading, blocking, and incidence angles for each heliostat in the field, but rather utilizes output curves computed for a particular field by the University of Houston and modifies these results to account for different latitudes. Since it computes only thermal output and uses a rather simple approximation for the shading and incident angle factors, this subroutine is both shorter and simpler than the other two collector subroutines. The program is listed in appendix III-B and the flow diagram for the output computation of COLL3 is shown in figure III-11.

The first part of the subroutine again performs initializations and reads input data.

Figure III-11.—Flow Diagram for Computing Hourly Output of a Heliostat Field



Lines 2013 to 2015 contain data for use in the computation of the absorbed sunlight. Since this subroutine is considerably simpler, it requires only about a third of the input coefficients (lines 2035 to 2042) of the other two subroutines. The solar time and other quantities used in the hourly computa-

tion are calculated in lines 2055 to 2065.

This subroutine performs checks to see if the Sun is shining and if it is more than half an hour after sunrise or before sunset just as the other subroutines. The major difference is the manner in which the incident sunlight is computed. N , TD , TB , and TC are all used to compute the factor $GAMCOS$, which represents the average incident cosine factor and shading factor for the entire heliostat field. $GAMCOS$ is calculated using line segments to determine the maximum input available at each time of the day as discussed in chapter VII I-A and shown in figure VI II-A-4 of volume 1. Once $GAMCOS$ is known, the thermal output QSR is simply the absorbed radiation minus the thermal losses:

$$QSR = \rho \alpha A_c I_D GAMCOS - (A_c/C_c) U_1 (T_{fo} - T_a) \quad (50)$$

where T_{fo} is the Collector output temperature.

Note that this subroutine uses the collector area $AREAC$ instead of the absorber area $AREACR$ in the computation. The thermal losses are based on the output temperature $TFOUT$ since it is assumed that these systems will operate at fixed output temperature and the thermal loss coefficient $ULOSS$ was specified for a particular temperature. Since radiation is the major thermal loss in many such systems, $ULOSS$ is a strong function of the output temperature.

Proof of Valve Opening Sequence

For a given set of valve settings in the diagram illustrated in figure 2, the amount of electricity (E) and the amount of thermal energy (Q) provided by the system can be written in terms of the amount of high-temperature energy entering the system (Q_H) as follows:

$$E = Q_H \beta \eta_1 (1 + \gamma \alpha_1 \eta_2) \quad (A-1)$$

$$Q = Q_H [\beta \eta_1 (\alpha_2 + (1 - \gamma) \alpha_1) + (1 - \beta)] \quad (A-2)$$

The valve settings depend on the ratio of Q to E, the energy required to meet the loads. Clearly if $Q = 0$ the optimum valve settings are $\gamma = 1$ and $\beta = 1$. This situation also holds as long as the minimum amount of thermal energy exhausted in producing the needed electrical output exceeds Q.

Therefore,

$$\text{If } 0 \leq Q/E \leq \alpha_2 / (1 + \alpha_1 \eta_2) \quad (A-3)$$

$$\text{Then } \beta = 1 \\ \gamma = 1$$

If Q/E exceeds $\alpha_2 / (1 + \alpha_1 \eta_2)$, either γ or β must be less than one. At the point where Q/E equals $\alpha_2 / (1 + \alpha_1 \eta_2)$ it is known that the optimum settings are $\gamma = 1$ and $\beta = 1$. If E is held constant and Q is increased by an incremental amount (ΔQ), and incremental change will be required in Q_H and either γ or β or possibly both γ and β . The incremental change in Q_H required to meet a load E and $Q + \Delta Q$ can be computed from equation (A-1) as follows:

$$\Delta E = 0 \\ = (\Delta Q_H / Q_H) E + (\Delta \beta / \beta) E + \Delta \gamma [Q_H \beta \eta_1 \eta_2 \alpha_1] \quad (A-4)$$

$$-\Delta Q_H / Q_H = [1 / \beta] \Delta \beta + \frac{\alpha_1 \eta_2}{1 + \gamma \alpha_1 \eta_2} \Delta \gamma \quad (A-5)$$

As both $\beta = 1$ and $\gamma = 1$, equation (A-5) reduces to:

$$-\Delta Q_H / Q_H = \Delta \beta + \frac{\alpha_1 \eta_2}{1 + \alpha_1 \eta_2} \Delta \gamma \quad (A-6)$$

In the case γ is not equal to 1, the coefficient of $\Delta \gamma$ would still be less than the coefficient of $\Delta \beta$ if $\alpha_1 \eta_2$ is less than one. This will always be the case if η_1 is greater than η_2 (a situation which will hold in all practical cases.) Because energy is conserved we know that

$$\eta_1 + \alpha_1 \eta_1 \leq 1 \quad (A-7)$$

or equivalently that

$$\alpha_1 \eta_1 < 1 \quad (A-8)$$

Therefore, if $\eta_2 > \eta_1$ it must be true that $\alpha_1 \eta_2 < 1$. Since the coefficient of $\Delta \gamma$ is always less than the coefficient of $\Delta \beta$ in equation (A-5), Q_H is minimized by changing γ while holding β constant at its initial value of one. Therefore:

If $Q/E > \alpha_2 / (1 + \alpha_1 \eta_2)$, and $Q/E < (\alpha_1 + \alpha_2)$, then

$$\beta = 1 \\ \gamma = \frac{E(\alpha_1 + \alpha_2) - Q}{\alpha_1(Q\eta_2 + E)} \quad (A-9)$$

When (A-9) indicates that $\gamma < 0$ (i.e., $Q > E(\alpha_1 + \alpha_2)$), β must be adjusted. Therefore, if:

$$Q/E > (\alpha_1 + \alpha_2), \text{ then} \quad (A-10) \\ \gamma = 0$$

$$\beta = \frac{E}{E(1 - \eta_1(\alpha_1 + \alpha_2)) + \eta_1 Q}$$

This proves the sequence stated in the text VIZ, For small values of Q_0/E_0 both β and γ are one. As the ratio increases to a point where demands cannot be met with this valve setting without discarding electrical energy, the valve characterized by γ should be adjusted first, keeping $\beta = 1$. The quantity β should only be reduced from 1 when the optimum setting for $\gamma = 0$.

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1.      % PROGRAM NAME: TOTIO.JB
2.      % JOHN C. BELL
3.      % ENERGY PROGRAM
4.      % OFFICE OF TECHNOLOGY ASSESSMENT
5.      % COMPILED
6.      z   DATE: 1/12/78
7.      z   TIME: 13: 6: 1
8.      % PROGRAM TOTIO.JB FOR RUNNING SOLAR AND NON-SOLAR SYSTEMS
9.      % FILE HANDLING REQUIREMENTS:
10.     % 12--FILE NUMBER FOR GENERAL INPUT IN TOTIO.JB, THE LOAD
11.     % SUBROUTINES, AND THE COLLECTOR SUBROUTINES. NORMALLY
12.     % THIS IS EQUATED TO IN$ FOR TERMINAL INPUT.
13.     % 13--FILE NUMBER FOR GENERAL OUTPUT IN TOTIO.JB, THE LOAD
14.     % SUBROUTINES, AND THE COLLECTOR SUBROUTINES. NORMALLY
15.     % THIS IS EQUATED TO OUT$ FOR TERMINAL OUTPUT.
16.     % 20--FILE HOLDING HEATING/COOLING LOADS, PROCESS LOADS, AND
17.     % MISCELLANEOUS ELECTRIC LOADS
18.     % 25--FILE HOLDING WEATHER AND INSOLATION DATA
19.     % 50--FILE FOR OUTPUTTING HOURLY ELECTRIC BACKUP/SELL DATA
20.     % (REQUIRED ONLY FOR UTILITY IMPACT ANALYSIS AND DEBUGGING)
21.     % XX--FILES HOLDING SYSTEM COEFFICIENTS, CELL COEFFICIENTS, AND
22.     % ELECTRIC HEATING/COOLING COP'S ARE PROMPTED FOR IN THE
23.     % MAIN PROGRAM
24.     %
25.     %
26.     % TOTIO.JB MUST BE LINKED TO THE FOLLOWING:
27.     z   UPDATE.JB--ALWAYS
28.     .|   ONE LOAD SUBROUTINE
29.     z   LOADS.JB--SINGLE FAMILY HOUSE, INSULATED SINGLE FAMILY
30.     % HOUSE, TOWNHOUSE, HIGH OR LOW RISE APARTMENT
31.     % LOADSC. JB--SHOPPING CENTER
32.     .|   ONE COLLECTOR SUBROUTINE
33.     % COLL1.JB--FLJT PLATE COLLECTORS AND TWO-DIMENSIONAL
34.     % TRACKING COLLECTORS
35.     % COLL2.JB--ONE DIMENSIONAL TRACKING COLLECTORS
36.     % COLL3.JB--HELIOSTATS
37.     % ONE SYSTEM SUBROUTINE
38.     % HFSYS--HEAT ENGINES WITH FOSSIL BACKUP
39.     % HESYS--HEAT ENGINES WITH ELECTRIC BACKUP
40.     % PVSYS--ALL PHOTOVOLTAIC SYSTEMS
41.     % HWSYS--SOLAR HOT WATER SYSTEMS
42.     %
43.     %
44.     % MISCELLANEOUS INFORMATION
45.     z   --ALL LOADS AND MAXIMUM OUTPUTS ARE IN KILOWATT-HOURS AND
46.     % KILOWATTS
47.     % --QSH HOLDS THE SPACE CONDITIONING LOAD
48.     % --NEGATIVE MEANS A HEATING LOAD
49.     % --POSITIVE MEANS A COOLING LOAD
50.     % --HWLOAD HOLDS THE PROCESS (HOT WATER) LOAD
51.     % --E HOLDS THE MISCELLANEOUS ELECTRIC LOAD PLUS THE FAN AND
52.     % PUMP LOAD
53.     % --ELLOAD HOLDS THE MISCELLANEOUS ELECTRIC LOAD
54.     z
55.     %
1000.   DIMENSION E(8760),HWLOAD( 168) ,M(13),IMTH(12)
1001.   DIMENSION COEF(30),ICOEF(8) ,TITLE(15)
1002.   DIMENSION FUELMO(12),TOTEM( 12) ,TOTSM( 12),TALTE(12)
1003.   DIMENSION ESRM(12),QSRM( 12),QCCM( 14),QCHM( 14),EEM(12) ,QPM(12), %
1004.   TEMPM(12)

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1005.   DIMENSION CPH(2,25),CPC(2, 25)
1006.   DIMENSION ESE(12),LSE(12),HSE( 12) ,ESM(12),LSM(12) ,HSM(12),OLDST(3)
1007.   IMPLICIT REAL(L)
1008.   COMMON/AXXX/COPA, EHWEFF, HCOPM,CCOPM,EFFB,ENGMAX, EFF1,EFF2,ALPHA1, %
1009.   ALPHA2,HTQSTM,LTHTS,HTHTS, LTQSTM,LTLLTS,HTLTS,HLHHT, %
1010.   FHWEFF,HLLTH, EPFBE,ESTORM, EPFBAT, PCSIZ, EFFPC,HEATMX, %
1011.   COOLMX,FAN,TL,TH,KXX,NHTQ,NLTQ, IGRID, ISOIAR,IA,ISMTH, %
1012.   IHR,IOFFPK
1013.   EQUIVALENCE (COEF(1),COPA) ,(ICOEF(1),NHTQ)
1014.   COMMON/CXXX/COPAA,COPEE ,EBM, EBEM,EEE,EFFEX,TENCM, BENGM,ENGM, %
1015.   ESR, ESTOR,EEFF,FFHW, FHET, FUEL,HTSSTM,HTQ,HTQI,HTQ, %
1016.   HTQSO, HTQSTO,LTQI,LTQO ,LTQSO,LTQSTO,QA, QC,QC I,QC2, %
1017.   QC2Z,QE,QP,QS,QSR,RESID9, SHET,STHET,TOTTEO,TOTBEO, %
1018.   TOTEO,HLHTL,HLTL,EFFLOT, EFFST,IPRINT
1019.   COMMON/DXXX/BOLMAX,CPC ,CPH,EEM,EHM, EKMAX,EKMIN, ESE,ESI,ESIM, %
1020.   ESM,ESO,ESOM, ESRM,ESTMAX, ESTMIN, ESTORI,FUELMO, %
1021.   HRRUN, HSE,HSM,HTMAX, HTMIN,HTQIM,HTQOM, HTQSTI , %
1022.   IEC,IEH, IEMST,IHRAV, IHRCT, IOUTS, J10,J20,J30,LSE, LSM, %
1023.   LTMAX,LTMIN,LTQIM, LTQOM, LTQSTI,AMESR,AMQSR,QCCM, QCHM, %
1024.   QC1W,QC1X,QC1Y,QC2W,QC2X, QC2Y,QPM,QSRM,TALTE,TBAT, %
1025.   TEEB,TEMPM,TESR,THQT,TLTQ,TOTE,TOTEM,TOTS,TOTSM, %
1026.   TOP,TQSR,TTEMP
1027.   COMMON/EXXX/TAIRF
1028.   COMMON/XDATA/E,HWLOAD
1029.   DATA M/1,745,1417,2161,2881 ,3625,4345,5089, 5833,6553,7297,8017,8761 /
1030.   DATA ITBOUT,HTSSTM/1, 1.0E+30/@HTSSTM IS TEMPORARY HT STORAGE
1031.   READ(12, 98,PROMPT='TITLE: ') TITLE
1032.   98 FORMAT(15A4)
1033.   READ(12, 99,PROMPT='SAVE HOURLY ELECTRICAL OUTPUT: ') ITST
1034.   IF (ITST.NE.'YES') GO TO 9081
1035.   IHROUT=1
1036.   READ(12, 99,PROMPT='PRINT OUTPUT TABLES: ') ITST
1037.   IF (ITST.EQ.'NO') ITBOUT=0
1038.   IF (ITBOUT.EQ.0) GO TO 4113
1039.   9081 READ(12, 99,PROMPT=%
1040.   'PRINT MONTHLY TOTALS OF SOLAR/DEMAND VARIABLES: ') ITST
1041.   IF (ITST.EQ.'YES') IHRAV=1
1042.   READ(12,99,PROMPT=%
1043.   'PRINT AVERAGE ANE END OF MONTH VALUES OF STORAGE: ') ITST
1044.   IF (ITST.EQ.'YES') IEMOST=1
1045.   READ(12,99,PROMPT='PRINT INPUT SUMMARY: ') ITST
1046.   IF (ITST.EQ. 'YES') IOUTS=1
1047.   4113 READ(12, 99,PROMPT='USE SEASONAL PARAMETERS: ') ITST
1048.   IF (ITST.NE.'YES') GO TO 1112
1049.   READ(12, *,PROMPT='MONTHS TO INPUT CHANGES: ') IMTH
1050.   1112 READ(12,*,PROMPT='FILE NUMBER FOR SYSTEM COEFFICIENTS: ') IF
1051.   IF (IF.LE.0) GO TO 1066
1052.   REWIND IF
1053.   READ(IF) COEF,ICOEF
1054.   1066 READ(12, 99,PROMPT='LIST/CHANGE VARIABLES AND VALUES: ') ITST
1055.   99 FORMAT(A4)
1056.   IF (ITST.EQ.'YES') GO TO 1081
1057.   IF (ITST.EQ.'NO') GO TO 1082
1058.   IF (ITST.EQ. 'NON') GO TO 1080
1059.   GO TO 1066
1060.   1081 WRITE(13,909) (COEF(I),I-1,29)
1061.   909 FORMAT(' REAL NUMBERS_ ' / %
1062.   ' #',4X,'VALUE',4X,'DEFINITION' /%
1063.   ' 1',IPEIO. 3,' :ABSORPTION A/C COP (DIM)'/%
1064.   ' 2',IPEIO.3, ' :ELECTRIC HOT WATER HEATER EFFICIENCY (.LE.1.00)'/%)

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1065.      3 ,IRE10. 3, ' :MULTIPLIER FOR ELECTRIC HEATING COP ``s (DIM)``/%
1066.      4 ,IPE10. 3, ' :MLTLTIPLIER FOR ELECTRIC COOLING COP ``s (DIM)``/%
1067.      5 ,IFE10. 3, ' :BOILER EFFICIENCY (.LE.1.00)``/%
1068.      6 ,IPE10. 3, ' :MAXIMUM ToppING ENGINE OUTPUT (KW)``/%
1069.      7 ,IPE10. 3, ' :EFFICIENCY OF ENGINE #1 (.LE.1.00)``/Z
1070.      8 ,IPE10. 3, ' :EFFICIENCY OF ENGINE #2 (.LE.1.00)``/%
1071.      9 ,IPE10. 3, ' :ALPHA 1--HIGH TEMP WASTE HEAT COEFF. (DIM)``/%
1072.     10 ,IPE10. 3, ' :ALPHA 2--LOW TEMP WASTE HEAT COEFF. (DIM)``/%
1073.     11 ,IPE10. 3, ' :CAPACITY OF HIGH TEMPERATURE STORAGE (KWH)``/%
1074.     12 ,IPE10. 3, ' :LOW TEMP. OF HIGH TEMP. STORAGE (DEG CENT)``/%
1075.     13 ,IPE10. 3, ' :HIGH TEMP. OF HIGH TEMP. STORAGE (DEG CENT)``/%
1076.     14 ,IPE10. 3, ' :CAPACITY OF LOW TEMPERATURE STORAGE (KWH)``/%
1077.     15 ,IPE10. 3, ' :LOW TEMP. OF LOW TEMP. STORAGE (DEG CENT)``/%
1078.     16 ,IPE10. 3, ' :HIGH TEMP. OF LOW TEMP. STORAGE (DEG CENT)``/%
1079.     17 ,IPE10. 3, ' :HEAT LOSS--HIGH TEMP. STORAGE (KWH/DEG CENT/HR)``/%
1080.     18 ,IPE10. 3, ' :EFFICIENCY OF FOSSIL HOT WATER HEATER (.LE.1.00)``/%
1081.     19 ,IPE10. 3, ' :HEAT LOSS--LOW TEMP. STORAGE (KWH/DEG CENT/HR) ``/%
1082.     20 ,IPE10. 3, ' :ENGINE BOILER EFFICIENCY (.LE.1.00)``/%
1083.     21 ,IPE10. 3, ' :CAPACITY OF ELECTRIC STORAGE ('KWH)``/%
1084.     22 ,IPE10. 3, ' :EFFICIENCY OF ELECTRIC STORAGE (-LE.1.00)``/%
1085.     23 ,IPE10. 3, ' :CAPACITY OF ELECTRIC POWER CONDITIONER (1(W)``/%
1086.     24 ,IPE10. 3, ' :EFFICIENCY OF POWER CONDITIONING (.LE.1-00)``/Z
1087.     25 ,IPE10. 3, ' :MAXIMUM HEATING LOAD (KW)``/%
1088.     26 ,IPE10. 3, ' :MAXIMUM COOLING LOAD (KW)``/%
1089.     27 ,IPE10. 3, ' :FAN COEFFICIENT (KW FAN/KW OUTPUT)``/%
1090.     28 ,IPE10. 3, ' :LOW TEMP. FOR OPEN WINDOWS--A/C CUTOFF (DEG F)``/%
1091.     29 ,IPE10. 3, ' :HIGH TEMP. FOR OPEN WINDOWS--HT CUTOFF (DEG F)``%
1092. WRITE(13,910) (ICOEF(J),J=1. H)
1093. 910 FORMAT(' _____ INTEGERS_ - , %
1094.      #',4X, ' VALUE',4X,'DEFINITION'``/%
1095.      1 ,16,4X, ' :HIGH TEMPERATURE STORAGE (MIX(2), NO MIX(1))``/%
1096.      2 ,16 ,4X, ' :LOW TEMPERATURE STORAGE (MIX(2), NO MIX(1))``/%
1097.      3 ,16 ,4X, ' :BACKUP (FOSSIL FUBI(0), ELECTRIC(1), BATH)``/%
1098.      4 ,16 ,4X, ' :SOLAR COLLECTOR (NONE(0),FP(1) ,D(2), 2D(3),HEL(4)) ``/%
1099.      5 ,16 ,4X, ' :AIR CONDITIONING ON(1) OR OFF(2)``/%
1100.      6 ,16,4X, ' :REGULAR LOADS(0) OR SMOOTHED LOADS(1)``/%
1101.      7 ,16,4X, ' :SINGLE FAMILY(0), HIGH RISE(1), SHOPPING center'``/%
1102.      8 ,16 4X, ' :BUY OFFPEAK ELECTRICITY (NO(0), YES(1))'
1103. 1082 READ(12,*,PROMPT=,VAR. # AND VARIABLE: ') IV,V
1104. IF (IV.LE.0) GO TO 1067
1105. IF (IV.GT.30) GO TO 1082
1106. COEF(IV)=V
1107. GO TO 1082
1108. 1067 ReAd(12,*,PROMPT'VAR. # AND IVARIABLE: ') IV,I
1109. IF (IV.LE.0) GO TO 1077
1110. IF (IV.GT.8) GO TO 1067
1111. ICOEF(IV)=I
1112. CO TO 1067
1113. 1077 READ(12,*,PROMPT- 'FILE NUMBER To STORE SYSTEM COEFF: ') IV
1114. IF (IV.LE.0) GO TO 1080
1115. REWIND IV
1116. WRITE(IV) COEF,ICOEF
1117. 1080 CALL LOADS (TL,TH,FAN,HPATMX, COOLMX, ISMTH, IHR)
1118. IF ((NHTQ.NE.1).OR. (HLHTh.LE.1.E-9) .OR. %
1119. (HTQSTM.LE. 1E-9)) GO TO 876
1120. READ(5,*,PROMPT= %
1121. 'HEAT LOSS FOR LT TANK OF HIGH Temp STORAGE (KWH/DEG CENT/HR): ') %
1122. HLLTL
1123. 876 IF ((NLTQ.NE. 1).OR. (HLLTh. LE.1.E-9).OR. %
1124. (LTQSTM.LE. 1E-9)) GO TO 877

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1125. READ(5,*,PROMPT- %
1126. 'HEAT LOSS FOR LT TANK OF LOW TEMP STORAGE (KWH/DEG CENT/HR): ') %
1127. HLLTL
1128. 877 ATEMPH=25
1129. ATEMPL=25
1130. IF ((HLLHTh.GT.0).AND. (HTQSTM.GT.0)) %
1131. READ(5,*,PROMPT='AMBIENT TEMP. FOR HT STORAGE (DEG CENT): ') %
1132. ATEMPH
1133. IF ((HLLHTh.GT.0).AND. (LTQSTM.GT.0)) %
1134. READ(5,*,PROMPT-'AMBIENT TEMP. FOR LT STORAGE (DEG CENT): ') %
1135. ATEMPH
1136. TEMP=HLLTS
1137. IF (NHTQ.EQ.0) NHTQ=2
1138. IF (NLTQ.EQ.0) NLTQ=2
1139. IF (HTQSTM.GT.0.1) TEMP=HHTHS
1140. IF (ISOLAR.NE.0) CALL COLL(ISYS)
1141. IF (IOFFPK.EQ.1) CALL OFFPK
1142. READ(12,*,PROMPT-'FILES FOR ELECTRIC H/C COP'S: ')IEH,IEC
1143. IF (IEH.LE.0) GO TO 6654
1144. REWIND IEH
1145. READ(IEH) CPH
1146. 6654 IF (IEC.LE.0) GO TO 6655
1147. REWIND IEC
1148. READ(IEC) CPC
1149. 6655 00 114 1-1,25
1150. IF (IEH.GT.0) CPH(2,1)-HCOPM*CPH(2,I) /(1-HCOPM*CPH(2,I)*FAN)
1151. IF (IEC.GT.0) CPC(2,I)-CCOPM*CPC(2,I) /(I-2. 5*CCOPM*CPC(2,I)*FAN)
1152. 114 CONTINUE
1153. READ(12,*,PROMPT=%
1154. 'INITIAL VALUES OF LOW TEMP, HIGH TEMP, AND ELEC STORAGE (KWH): ') %
1155. LTQSTO,HTQSTO,ESTOR
1156. ESTORI-ESTOR
1157. ESTO=ESTOR
1158. LTQSTI-LTQSTO
1159. LTQSO=LTQSTO
1160. HTQSTI-HTQSTO
1161. HTQSO=HTQSTO
1162. EFFEX=1.
1163. EFFLOT=1.0
1164. EFFST=1.0
1165. LTMIN-LTQSTM
1166. HTMIN-HTQSTM
1167. ESTMIN=ESTORM
1168. EFFP-EFFPC*EFFBAT
1169. KKK=1
1170. J10=1 @FIRST MONTH
1171. J20=12 @LAST MONTH
1172. J30=1 @INTERVAL
1173. K10=1 @FIRST HOUR
1174. K2X=0 @LAST HOUR-ZERO FOR WHOLE MONTH
1175. K30=1 @INTERVAL
1176. 1111 CONTINUE @CHANGE MONTHS AND HOURS HERE
1177. ~*****
1178. % BEGIN CYCLING THROUGH THE MONTHS
1179. %*****
1180. DO 1000 I=J10,J20,J30
1181. M3=N(I+1)-M(I)
1182. K20=K2X
1183. IF (K2X.EQ.0) K20=M3
1184. M31=(K20-K10+1)/K30 @ TOTAL HOURS IN THE MONTH

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1185.  %*****
1186.  % BEGIN CYCLING THROUGH THE HOURS OF THE MONTH
1187.  %*****
1188.  DO 100 J-K10,K20,K30
1189.  K-M(I)+J-1 @ K IS THE HOUR OF THE YEAR
1190.  KCT-(K-1)/168
1191.  KCT-K-168*KCT
1192.  IDAY-1+(K-1)/24
1193.  QP-HWLOAD(KCT)*(1+0.372*COS (.017214*(IDAY-30)))
1194.  CALL LOADS1(K,EEE,QSH,TA)
1195.  TAIRF=-459.4+1. 8*TA
1196.  IF(QSH.GT.0. ) GO TO 20
1197.  QC=QSH @SETS QC POSITIVE FOR HEATING CASE
1198.  COPAA=1.0
1199.  COPEE=0
1200.  IF (IEH.GT.0) CALL COPT(TAIRF,CPH,COPEE)
1201.  GO TO 30
1202.  20 QC-QSH
1203.  IF (IA.EQ.2) QC=0
1204.  COPEE=0
1205.  COPAA-COPA
1206.  IF (IEC.GT.0) CALL COPT(TAIRF,CPC,COPEE)
1207.  30 IF (ISOLAR.EQ.0) GO TO 146
1208.  IF (HTQSTM.GE.0.1) GO TO 133
1209.  IF (LTQSTM.LE.0. 1) GO TO 4140
1210.  F-LTQSTO/LTQSTM
1211.  IF (NLTO.EQ.1) GO TO 4135
1212.  TIN=LTLTS+F*(HTLTS-LTLTS )
1213.  GO TO 140
1214.  4135 TIN=LTLTS
1215.  IF (F.LT.0) TIN=LTLTS+F*(HTLTS-LTLTS )
1216.  GO TO 140
1217.  133 F-HTQSTO/HTQSTM
1218.  IF (NHTQ.EQ.1) GO TO 135
1219.  TIN=LHTS+F*(HTHTS-LHTS )
1220.  GO TO 140
1221.  135 TIN=LHTS
1222.  IF (F.LT.0) TIN=LHTS+F*(HTHTS-LHTS)
1223.  GO TO 140
1224.  4140 TIN=LTLTS
1225.  140 IF ((LTQSTO.GT.0.99*LTQSTM) .AND. (COPAA.LE.0.001) .AND. %
1226.  (QSH.GE.0) .AND. (ISYS.EQ. 2)) TIN=TA-263
1227.  CALL COLL01(K,TIN,TEMP,TA,QSR, ESR)
1228.  AMQSR=AMAX1(AMQSR,QSR)
1229.  ANESR=AMAX1 (AMESR,ESR)
1230.  LX) TO 147
1231.  146 QSR=0
1232.  ESR=0
1233.  147 E(K)=0.
1234.  TESR=TESR+ESR
1235.  TQSR=TQSR+QSR
1236.  TEEE=TEEE+EEE
1237.  IF (QSH.GT.0) QCCM(14)-QCCM(14)+QC
1238.  IF (QSH.LT.0) QCHM(14)=QCHM(14)+QC
1239.  TQP=TQP+QP
1240.  TTEMP=TTEMP+TAIRF
1241.  IHRCT=IHRCT+1
1242.  BEEM(I)-EEL14(I)+EEE
1243.  QPM(I)-QPM(I)+QP
1244.  IF (QSH.GT.0) QCCM(I)=QCCM(I)+QC

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1245.  IF (QSH.LT.0) QCHM(I)-QCHM(I)+QC
1246.  QSRM(I)-QSRM(I)+QSR
1247.  ESRM(I)=ESRM(I )+ESR
1248.  TEMPM(I)-TEMPM(I)+TAIRF/M3 1
1249.  LTQSO=LTQSTO
1250.  HTQSO=HTQSTO
2000.  %*****h*****
2001.  CALL SYSTEM(K,QSH)
2002.  %*****
3000.  IF (QSH.LE.0) GO TO 9911
3001.  QC1X-AMAX1 (QC1X,QC1)
3002.  QC2X=AMAX1(QC2X,QC2+QC2Z )
3003.  GO TO 9910
3004.  9911 QC1Y=M1(QC1Y,QC1)
3005.  QC2Y=AMAX1(QC2Y,QC2+QC2Z)
3006.  9910 IF (QSH.LT.0) QC1W=AMAX1 (QC1W,QC1+QC2+QC2Z)
3007.  IF (QSH.GT.0) QC2W=AMAX1 (QC2W, QC1+QC2+QC2Z)
3008.  IF (IGRID.NE.1) EHM=AMAX1 (EHM,FFHW)
3009.  TBAT=TBAT+ESTOR
3010.  THTQ=THTQ+HTQSTO
3011.  TLTQ=TLTQ+LTQSTO
3012.  BOLMAX=AMAX1 (BOLMAX,FUEL-FUELI)
3013.  HTMAX=AMAX1 (HTMAX,HTQSTO)
3014.  HTMIN=AMIN1 (HTMIN,HTQSTO)
3015.  LTMAX=AMAX1 (LTMAX,LTQSTO)
3016.  LTMIN=AMIN1(LTMIN,LTQSTO)
3017.  ESTMAX=AMAX1 (ESTMAX,ESTOR)
3018.  ESTMIN=AMIN1 (ESTMIN,ESTOR)
3019.  IF (IGRID.EQ.0) GO TO 906
3020.  EKMAX=AMAX1( EKMAX,E(K))
3021.  EKMIN=AMIN1 (EKMIN,E(K))
3022.  906 FUELI=FUEL
3023.  LTQ-LTQSTO-LTQSO
3024.  ES=ESTOR-ESTO
3025.  ESTO=ESTOR
3026.  IF (LTQ.LT.0) GO TO 9400
3027.  LTQI=LTQI+LTQ
3028.  LTQIM=AMAX1 (LTQIM,LTQ)
3029.  GO TO 9401
3030.  9400 LTQ0=LTQ0-LTQ
3031.  LTQOM=AMAX1(LTQOM,-LTQ)
3032.  9401 IF (HTQ.LT.0) GO TO 9402
3033.  HTQI=HTQI+HTQ
3034.  HTQIM=AMAX1 (HTQIM,HTQ)
3035.  GO TO 9403
3036.  9402 HTQ0=HTQ0-HTQ
3037.  HTQOM=MAX1 (HTQOM,-HTQ)
3038.  9403 IF (ES.LT.0) GO TO 9404
3039.  ESI=ESI+ES
3040.  ESIM=AMAX1 (ESIM,ES)
3041.  CO TO 9405
3042.  9404 ESO=ESO-ES
3043.  ESOM=AMAX1 (ESOM,-ES)
3044.  9405 IF (E(K) .LT.0) GO TO 7011
3045.  IF (IGRID.EQ.0) GO TO 101
3046.  TOTE=TOTE+E(K)
3047.  GO TO 101
3048.  7011 TOTS=TOTS-E(K)
3049.  101 ESM(I)=ESM(I)+ESTOR
3050.  IF (HTQSTM.LE.1.E-9) GO TO 3052

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3051. F=HTQSTO/HTQSTM
3052. IF (ICOE(1).EQ.2) GO TO 3053
3053. IF (F.GT.1) GO TO 3053
3054. IF (F.LT.0) GO TO 3058
3055. HTQSTO=HTQSTO-(F*HLHTH*(HTHTS-ATEMPH)+(1-F)*HLHLL*(LTHTS-ATEMPH))
3056. GO TO 3052
3057. 3058 HTQSTO=HTQSTO-(HLHLL*((HTHTS-LTHTS)*F+LTHTS-ATEMPH))
3058. GO TO 3052
3059. 3053 HTQSTO=HTQSTO-(HLHTH*((HTHTS-LTHTS)*F+LTHTS-ATEMPH))
3060. 3052 IF (LTQSTM.LE.1.E-9) GO TO 3061
3061. F=LTQSTO/LTQSTM
3062. IF (ICOE(2).EQ.2) GO TO 3056
3063. IF (F.GT.1) GO TO 3056
3064. IF (F.LT.0) GO TO 3060
3065. LTQSTO=LTQSTO-(F*HLLTH*(HTLTS-ATEMPL)+(1-F)*HLLTL*(LTHTS-ATEMPL))
3066. GO TO 3061
3067. 3060 LTQSTO=LTQSTO-(HLLTL*((HTLTS-LTLTS)*F+LTLTS-ATEMPL))
3068. GO TO 3061
3069. 3056 LTQSTO=LTQSTO-(HLLTH*((HTLTS-LTLTS)*F+LTLTS-ATEMPL))
3070. 3061 LSM(I)=LSM(I)+LTQSTO
3071. HSM(I)=HSM(I)+HTQSTO
3072. 100 CONTINUE
3073. %*****
3074. % END CYCLE OF HOURS THROUGH THE MONTH
3075. % CALCULATE VARIOUS MONTHLY TOTALS
3076. %*****
3077. ESE(I)=ESTOR
3078. LSE(I)=LTQSTO
3079. HSE(I)=HTQSTO
3080. TOTEM(I)=TOTE-TOTEI
3081. TOTEI=TOTE
3082. TOTSM(I)=TOTS-TOTSI
3083. TOTS=TOTS
3084. FUELMO(I)=FUEL-FUELI
3085. FUELI=FUEL
3086. TALTE(I)=RESID9-RESID8
3087. RESID8=RESID9
3088. ESM(I)=ESM(I)/(AMAX1(1,ESTORM)*M31)
3089. LSM(I)=LSM(I)/(AMAX1(1,LTQSTM)*M31)
3090. HSM(I)=HSM(I)/(AMAX1(1,HTQSTM)*M31)
3091. HRRUN=HRRUN+M31
3092. IF (I+1.NE.IMTH(KKK)) GO TO 1000
3093. WRITE(13,3777) IMTH(KKK)
3094. 3777 FORMAT(' ENTER SEASONAL PARAMETERS FOR MONTH: ',I2)
3095. DO 447 KZJ=1,3
3096. 447 OLDST(KZJ)=COEF(13+KZJ)
3097. KKK=KKK+1
3098. 1113 READ(12,*,PROMPT='VAR. # AND VARIABLE: ') IV,V
3099. IF (IV.LE.0) GO TO 3778
3100. COEF(IV)=V
3101. GO TO 1113
3102. 3778 LTQSTO=(LTQSTM/(OLDST(3)-OLDST(2)))*%
3103. ((LTQSTO/LTQSTM)*(OLDST(3)-LTLTS))+%
3104. ((1-LTQSTO/LTQSTM)*(OLDST(2)-LTLTS))
3105. LTQSTM=LTQSTM*(HTLTS-LTLTS)/(OLDST(3)-OLDST(2))
3106. 1000 CONTINUE
3107. %*****
3108. % END CYCLE OF MONTHS THROUGH THE YEAR
3109. % CALCULATE VARIOUS YEARLY TOTALS AND DO OUTPUT
3110. %*****

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3111. CALL MDDYY (INOM, IYAD, IRY)
3112. CALL HHMSS (IRH, INIM, ICES)
3113. WRITE(13,2660) TITLE, INOM, IYAD, IRY
3114. 2660 FORMAT (/ /1X,15A4, ' DATE: ',12,'-',12,'/',12)
3115. WRITE(13,2666) IRH, INIM, ICES
3116. 2666 FORMAT (6I X, ' TIME: ',12, ': ',12/)
3117. IF (ITBOUT.NE.1) GO TO 4112
3118. IF (IPRINT.EQ.1) WRITE(13,2777)
3119. 2777 FORMAT (/ ' PHOTOVOLTAIC SYSTEM' )
3120. IF (I PRINT.EQ.2) WRITE(13,2778)
3121. 2778 FORMAT (/ ' HEAT ENGINE SYSTEM' )
3122. IF (I PRINT.EQ.3) WRITE(13,2779)
3123. 2779 FORMAT (/ ' HOT WATER SYSTEM' )
3124. IF (I GRID.EQ.0) WRITE(13,2780)
3125. 2780 FORMAT ( ' FOSSIL FUEL BACKUP' )
3126. IF (IGRID.EQ.1) WRITE(13,2781)
3127. 2781 FORMAT(' ELECTRIC BACKUP')
3128. IF (IGRID.EQ.3) WRITE(13,2782)
3129. 2782 FORMAT(' ELECTRIC AND FOSSIL FUEL BACKUP')
3130. IF (ISOLAR.NE.0) CALL COLLO2
3131. CALL LOADS2
3132. IF (IOFFPK.EQ.1) CALL OFFPK2
3133. IF (IOUTS.NE.1) GO TO 4112
3134. WRITE(13,3)
3135. 3 FORMAT(/// ' SYSTEM COEFFICIENTS:' )
3136. WRITE(13,909) (COEF(I), I=1,29)
3137. WRITE(13,910) (ICOE(I), I=1,8)
3138. IF (ISOLAR.EQ.0) GO TO 4112
3139. WRITE(13,4)
3140. 4 FORMAT(/// ' COLLECTOR COEFFICIENTS:' )
3141. CALL COLLO3
3142. IF ((HTQSTM.LE.1E-9).AND. (LTQSTM.LE.1E-9)) GO TO 4112
3143. WRITE(13,950)
3144. 950 FORMAT(/11X,'STORAGE HEAT LOSS COEFFICIENTS' //21X,%
3145. 'HEAT LOSS',12X, 'AMB. TEMP'/17X, '(KWH/DEG CENT/HR)'> 7X,%
3146. '(DEG. CENT)')
3147. IF (NHTQ.EQ.2) WRITE(13,951) HLHTH,ATEMPH
3148. 951 FORMAT(' HT STORAGE',9X,1PE10.3,14X,OPF5.1)
3149. IF (NHTQ.EQ.1) WRITE(13,952) HLHTH,HLLTL,ATEMPH
3150. 952 FORMAT(' HT STORAGE',2X,1PE10.3,'--',1PE10.3,8X,OPF5.1)
3151. IF (NLTO.EQ.2) WRITE(13,953) HLLTH,ATEMPL
3152. 953 FORMAT(' LT STORAGE',9X,1PE10.3,14X,OPF5.1)
3153. IF (NLTO.EQ.1) WRITE(13,954) HLLTH,HLLTL,ATEMPL
3154. 954 FORMAT(' LT STORAGE',2X,1PE10.3,'--',1PE10.3,8X,OPF5.1)
3155. IF ((NHTQ.EQ.1).OR. (NLTO.EQ.1)) WRITE(13,955)
3156. 955 FORMAT(// ' NOTE: FIRST HEAT LOSS NUMBER IS FOR HT TANK' %
3157. ' OF THE PARTICULAR' // ' STORAGE: ',%
3158. 'SECOND IS FOR LT TANK OF THE SAME STORAGE.')
3159. 4112 CALL OUTTAB(ITBOUT, IHRUT)
3160. END

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1.      , PROGRAM ' : AME : OUTT 113. JB
2.      % I( ) H', I. BELL
3.      . ENERGY PROGRAM
4.      (OFF I C F ( ) F TECHNOLOGY AS S F S MENT
5.      COMPILED
6.      DATE : 1 / 12/78
7.      TIME : 13 : b:25
8.      PROGRAM OUTTAB. JB FOR TABULAR OUTPUT OF DATA
9.      " BY US IN C S EGMEN T EDITING. THIS PROGRAM
10.     WILL ALLOW OUTPUT OF ALL DATA
11.
12.
13.
1 000.  SUBROUTINE FOUR I AB(ITBOUT, IHRCT)
1 001.  DIMENSION (E760)
1 002.  DIMENSION (1.1), TOTEM(12), TOTSM(12), TALTE(12)
1 003.  DIMENSION (12), (S SLY (12), QCCM (14), QCHM (14), EHEM (12), QPM (12),
1004.  TEMPM(12), IEXP (14)
1005.  DIMENSION (2, 15), CPM (2, 25)
1 006.  DIMENSION (12), LSE (12), HSE (12), LSM (12), LSN (12), HSM (12)
1007.  IMPLICIT REAL (L)
1008.  COMMON /XXXX /TEMPV1 (10), HTQSTM, TEMPV2 (2), LTQSTM, TEMPV3 (6), %
1009.  LSTFORM > TEMPV4 (5), FAN, TEMPV5 (3), ITMPV1 (2), IGRID, %
1010.  ITMPV2 (5)
1011.  (COMMON / CXXX / ('O PAA, LOPEE, EBM, EBEM, EEE, EFFEX, TENG, BENG, ENGM, %
1 012.  ESR, ESTOR, EEPF, FPHM, FHEI, FUEL, HTS, STM, HTQ, HTQI, H I QO, %
10 13.  HTQSO, HTQSTO, LTQI, I T QO, LTQSO, LTQSTO, QA, QC, QCI, QC2, %
1014.  QC2Z, QE, QP, QS, QSR, RES ID9, SHLT, STHET, TOTTEO, TOTBEO, %
1015.  H) E O, HLHTL, HLTL, L EFFLOT, EFFST, IPRIN T
1016.  COMMON / DXXX / BOLMAX, C PC, C PH, EEM, EHM, EKMAX, EKMIN, ESE, ES I, ES IM, %
1017.  ESM, ES O, ESOM, ESRM, ESTMAX, ESTMIN, ESTORI, EL' ELMO, %
1018.  HRUN, HSF, HSM, HTMAX, HTM is, HTQ I M, HTQOM, HTQST I, %
1019.  IEC, I EH, I EOMST, IHRAV, IHRCT, IOUTS, J 10, J20, J30, LSE, LSM, %
1020.  LTMAX, LTM I>, LTQIM, L, TQOM, LTQST L, AMESR, AMQSR, QCCM, QCHM, %
102 1 -  QC I I*, QC I X, QC I Y, QC 2 W, QC 2 X, QC 2 Y, QPM, (QSRM, TALTE, TBAT, %
1022.  TEEE, TEMPM, TFSR, THTQ, TLQ, TOPE, TOTEM, TOTS, TOTS) !, %
1023.  TQP, TQSR, TTEMP
1024.  COMMON /XDATA / F, HWLO AD
3000.  IF (ITBOUT .NE. 1) GO TO 5000
3001.  IF (IOUTS .NE. 1) GO TO 2011
3002.  IF ((IEH .EQ. 1) .AND. (IEC .LT. 1)) GO TO 2011
3001.  *****
3004.  WRITE (13, 22)
3005.  22 FORMAT ( // 7X, ' ELECTRIC I (H /, GO 1' ' S (KWH /KWH) ' )
3006.  % SIT F (13, 23)
3007.  23 FORM A I (4X, 'TEMP', 4X, 'HEAT', 8X, 'TEMP', ..), 'COOL' )
3008.  I(S = 0)
3009.  IHS = 0
3010.  IF (IHC .LT. 1) I (* S = 1)
3011.  IF (IEH .LT. 1) IHS = 1
3012.  DO 119 I = 1, 25
3013.  IF (CPM (1, I) .LT. -.99) ICS = 1
3014.  IF (CPH (1, I) .LT. -.99) IHS = 1
3015.  IF ((IHS .EQ. 1) .AND. (ICS .EQ. 1)) GO TO 120 I I
3016.  IF ((IHS .NE. 1) .AND. (ICS .NE. 1)) WRITE (13, 14)
3017.  CPH (1, I), CPM (2, I) / (I + PE (2, I) * FAN), %
3018.  CPM (1, I), CPM (2, I) / (I + 7.5 * CPM (2, I) * FAN)
3019.  IF (IHS .EQ. 1) WRITE (13, 25) (PH (1, I), (PH (2, I) / (I * PH (2, I) * t W)
3020.  IF (IHS .EQ. 1) WRITE (13, 26) (PH (1, I), CPM (2, I) / (I + 2.5 * PM (2, I) * FAN)
3021.  11 9 (ON F LSL E

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3022.  24 FORMAT ( 3X, F 5.1, 2X, F6.2, 7X, F5.1, 2X, F6.2)
3023.  25 FORMAT ( 3X, F5.1, 2X, F6.2, 9X, ' --', 6X, ' --' )
3024.  26 FORMAT ( 5X, ' --', 6X, ' --', 8X, F5.1, 2X, F6.2)
3025.  Z*****
3026.  2011 EFACT=AMAX1 (1, ESTORM)
3027.  BATLF=TBAT / (HRRUN * EFACT)
3028.  EFACT=AMAX1 (1, HTQSTM)
3029.  HTLF=THTQ / (HRRUN * EFACT)
3030.  EFACT=AMAX1 (1, LTQSTM)
3031.  LTLF=TLTQ / (HRRUN * EFACT)
3032.  EFACT=AMAX1 (1, TENG)
3033.  ENGLFT=TOTTEO / (HRRUN * EFACT)
3034.  EFACT=AMAX1 (1, BENG)
3035.  ENGLFB=TOTBEO / (HRRUN * EFACT)
3036.  EFACT=AMAX1 (1, ENGM)
3037.  ENGLF=TOTEQ / (HRRUN * EFACT)
3038.  EFACT=O
3039.  DO 4110 I = J10, J20, J30
3040.  IF (ABS (TALTE (I)) .LE. 1.00) TALTE (I) = 0
3041.  4110 EFACT=EFACT+TALTE (I)
3042.  WRITE (13, 4113)
3043.  4113 FORMAT ( // 7X, ' ELECTRICITY AND FOSS 11, FUEL BACKUP DEMANDS (KWH) ' )
3044.  WRITE (13, 1005)
3045.  1005 FORMAT ( ' MONTH', 4X, ' ELEC . BUY ', 4X, ' ELEC . SF. LL ', 4X, ' FUEL USE ', %
3046.  3X, ' EXCESS LT ENERGY ' )
3047.  WRITE (13, 1006) (1, TOTEM(I), TOTSM (1), FUELMO (I), TALTE (I), I = 110, J20, J30)
3048.  1006 FORMAT ( ' ', 13, 4X, IPE 10.3, 4X, IPE 10.3, 4X, IPE 10.3, 5X, IPE 10.3)
3049.  WRITE (13, 1007) TOTE, TOTS, FUEL, EFACT
3050.  1007 FORMAT ( ' TOTAL', 2X, IPE 10.3, 4X, IPE 10.3, 4X, IPE 10.3, 5X, IPE 10.3)
3051.  IF (IGRID .EQ. 0) .AND. (I PRINT .EQ. 1) WRITE (13, 4007)
3052.  4007 FORMAT ( ' NOTE: ELEC SELL IS DC ELECTRICITY THAT CAN ' T ', %
3053.  ' BE STORED IN THE BATTERY ' )
3054.  %*****
3055.  QCHM (13) = QCHM (14) / IHRCT
3056.  QCCM (13) = QCCM (14) / IHRCT
3057.  DO 66 I = 1, 14
3058.  TEST = QCCM (I)
3059.  IF (QCHM (I) .GT. QCCM (I)) TEST = QCHM (I)
3060.  DO 65 J = 1, 10
3061.  IF (TEST / (10 * J) .LT. .1) GO TO 64
3062.  65 CONTINUE
3063.  64 IEXP (I) = J - 1
3064.  DI V = 10 * (J - 1)
3065.  QCHM (I) = QCHM (I) / DI V
3066.  QCCM (I) = QCCM (I) / DI V
3067.  66 CONTINUE
3068.  IF (IHRAV .NE. 1) GO TO 9059
3069.  WRITE (13, 7705)
3070.  7705 FORMAT ( // 26X, ' TOTAL MONTHLY VALUES (KWH) ', 24X, ' AVER ' / %
3071.  7X, ' PHOTO VOLT', 6X, ' SOLAR ', 6X, ' ', %
3072.  ' INTERNAL DEMANDS ', ' ', 7X, ' TEM P ' / %
3073.  ' MONTH ', IX, ' ELECTRIC ', 6X, ' THERMAL ', 5X, ' ELECTRIC ', %
3074.  5X, ' HEAT / COOL ', 5X, ' HO R WATER ', 7X, ' (F. ) ' )
3075.  WRITE (13, 7707) (1, ESRM (I), QSRM (I), EEM (I), QCHM (I), QCCM (I), %
3076.  IEXP (I), QPM (I), TEMPM (I), I = J10, J20, J30)
3077.  7707 FORMAT ( ( ' ', 4X, I2, 2X, 2 (IPE 10.3, 3X), IPE 10.3, 2X, OPF4.2, ' / ' , %
3078.  OPF4.2, ' E+00', T 57, I 1, 2X, IPE 10.3, 7X, OPF4.1) )
3079.  ZWR I R E (13, 7710) TFSR / IHRCT, TQSR / IHRCT, TEEE / IHRCT, QCHM (13), %
3080.  Z QCCM (13), TEXP (13), TQP / IHRCT, ITEMP / IHRCT
3081.  87 710 FORMAT ( ' YR AV ', 2 (IPE 10.3, 3X), IPE 10.3, 2X, OP F4.2, ' / ' , %

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3082. % OPF4.2,'E+00',T57,11,2X,1PE10.3,7X,OPF4.1)
3083. GO TO 9053
3084. 9059 WRITE(13,7706)
3085. 7706 FORMAT(//31X,'YEARLY TOTAL (KWH) / %
3086. 7X,'PHOTOVOLT',6X,'SOLAR',6X,'
3087. 'INTERNAL DEMANDS',
3088. 7X,'ELECTRIC',6X,'THERMAL',5X,'ELECTRIC', %
3089. 5X,'HEAT/COOL',5X,'HOT WATER',7X,'(F.)')
3090. 9053 WRITE(13,7715) TESR,TQSR,TEER,QCHM(14),QCCM(14),IEXP(14),TQP
3091. 7715 FORMAT(' TOTAL',2(1PE10.3,3X),1PE10.3,2X,OPF4.2,' / ', %
3092. OPF4.2,'E+00',T57,11,2X,1PE10.3,7X,' -- ')
3093. %*****
3094. IF (IEMST.NE.1) GO TO 9054
3095. WRITE(13,4089)
3096. 4089 FORMAT(//17X,' LOAD FACTOR ',19X,'END OF MONTH VALUES' / %
3097. 7X,' _____', 'OF STORAGE ( KWH )', ' _____', %
3098. 3X,' _____', ' OF STORAGE ( KWH )', ' _____', '
3099. ' MONTH ', 1 X, ' - %
3100. 'ELECTRIC',4X,'LOW TEMP',4X,'HIGH TEMP',3X, %
3101. 'ELECTRIC',4X,'LOW TEMP',4X,'HIGH TEMP')
3102. WRITE(13,4080) (I,ESM(1),LSM(1),HSM(1),ESE(1),LSE(1),HSE(1), %
3103. I=J10,J20,J30)
3104. 4080 FORMAT(2X,12,2X,6(1PE10.3,2X)))
3105. %*****
3106. 9054 WRITE(13,9000)
3107. 9000 FORMAT(//47X,'STORAGE VALUES')
3108. WRITE(13,9001)
3109. 9001 FORMAT(36X,'ELECTRIC',6X,'LOW TEMP',6X,'HIGH TEMP')
3110. WRITE(13,9002) BATTLE,HTLF,HTLF
3111. 9002 FORMAT(' LOAD FACTOR (DIM):',14X,3(2X,1PE10.3,2X))
3112. WRITE(13,9003) ESTOR,LTQSTI,HTQSTI
3113. 9003 FORMAT(' INITIAL VALUE (KWH):',12X,3(2X,1PE10.3,2X))
3114. WRITE(13,9004) ESTOR,LTQSTO,HTQSTO
3115. 9004 FORMAT(' FINAL VALUE (KWH):',14X,3(2X,1PE10.3,2X))
3116. WRITE(13,9006) ESTMIN,LTMIN,HTMIN
3117. 9006 FORMAT(' MINIMUM VALUE (KWH):',12X,3(2X,1PE10.3,2X))
3118. WRITE(13,9005) ESTMAX,LTMAX,HTMAX
3119. 9005 FORMAT(' MAXIMUM VALUE (KWH):',12X,3(2X,1PE10.3,2X))
3120. WRITE(13,9007) ES1,LTQ1,HTQ1
3121. 9007 FORMAT(' TOTAL ENERGY PUT INTO (KWH):',4X,3(2X,1PE10.3,2X))
3122. WRITE(13,9008) ES0,LTQ0,HTQ0
3123. 9008 FORMAT(' TOTAL ENERGY TAKEN OUT OF (KWH):',3(2X,1PE10.3,2X))
3124. WRITE(13,9009) ESIM,LTQM,HTQM
3125. 9009 FORMAT(' MAXIMUM INPUT INTO PC (KWH/HR):',1X,3(2X,1PE10.3,2X))
3126. WRITE(13,9010) ESOM,LTQM,HTQM
3127. 9010 FORMAT(' MAXIMUM OUTPUT INTO PC (KWH/HR):',3(2X,1PE10.3,2X))
3128. %*****
3129. IF (TOTEO.LT.0.1) GO TO 8056
3130. WRITE(13,8001)
3131. 8001 FORMAT(//47X,'ENGINE VALUES')
3132. WRITE(13,8002)
3133. 8002 FORMAT(38X,'LOAD',10X,'TOTAL',8X,'MAXIMUM' / %
3134. 37X,'FACTOR',7X,'OUTPUT',7X,'OUTPUT')
3135. WRITE(13,8003) ENGLFT,TOTTEO,TENGM
3136. 8003 FORMAT(' TOPPING ENGINE:',17X,3(2X,1PE10.3,2X))
3137. WRITE(13,8004) ENGLFB,TOTBEO,BENGM
3138. 8004 FORMAT(' BOTTOMING ENGINE:',15X,3(2X,1PE10.3,2X))
3139. WRITE(13,8005) ENGLF,TOTEO,ENGM
3140. 8005 FORMAT(' TOTAL ENGINES:',18X,3(2X,1PE10.3,2X))
3141. WRITE(13,8006)

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3142. 8006 FORMAT (' *NOTE : LOAD FACTOR IS BASED ON ACTUAL MAXIMUM ' , '
3143. ' , NOT ON DESIGN MAXIMUM ' )
3144. %*****
3145. 8056 WRITE ( 13, 107 I )
3146. 1071 FORMAT ( / / 23X, ' MAXIMUM SPACE CONDITIONING LOADS ' /
3147. 21X, ' ELECTRIC ' , 7X, ' THERMAL ' , 2X, ' TOTAL ' )
3148. WRITE ( 13, 9011 ) QC1X, QC2X, QC1Y, QC2Y, QC1W
3149. 9011 FORMAT ( ' COOLING ( KWH ) : ' , 4X, 3 ( 2X, 1PE10.3, 2X ) / %
3150. ' HEATING ( KWH ) : ' , 4X, 3 ( 2X, 1PE10.3, 2X ) )
3151. %*****
3152. WRITE ( 13, 8886 ) AMQSR , A. ESR
3153. 8886 FORMAT ( / / ' MAXIMUM SOLAR THERMAL OUTPUT ( KWH ) : ' , 1PE10.3 / %.
3154. ' MAXIMUM SOLAR ELECTRIC OUTPUT ( KWH ) : ' , 1PE10.3 )
3155. WRITE ( 13, 3031 ) EBEM
3156. 3031 FORMAT ( ' MAXIMUM ENGINE BOILER OUTPUT ( KWH ) : ' , 1PE10.3 )
3157. WRITE ( 13, 3023 ) EBM
3158. 3020 FORMAT ( ' MAXIMUM NONENGINE BOILER OUTPUT ( KWH ) : ' , 1PE10.3 )
3159. WRITE ( 13, 3914 ) EHM
3160. 3914 FORMAT ( ' MAXIMUM HOT WATER FUEL USE ( KWH ) : ' , 1PE10.3 )
3161. WRITE ( 13, 8862 ) PHET , SHET , SHFT
3162. 8862 FORMAT ( ' FUEL HEAT PUT INTO ENGINE ( KWH ) : ' , 1PE10.3 / %.
3163. ' SOLAR HEAT PUT INTO ENGINE ( KWH ) : ' , 1PE10.3 / %
3164. ' STORAGE HEAT PUT INTO ENGINE ( KWH ) : ' , 1PE10.3 )
3165. WRITE ( 13, 1086 ) EKMAX , -EKMIN
3166. 1086 FORMAT ( ' MAXIMUM ELECTRICITY BOUGHT IN AN HOUR ( KWH ) : ' , 1PE10.3 %
3167. / ' MAXIMUM ELECTRICITY SOLD IN AN HOUR ( KWH ) : ' , 1PE10.3 )
3168. WRITE ( 13, 1020 ) BOLMAX
3169. 1020 FORMAT ( ' MAXIMUM FUEL BOUGHT IN AN HOUR ( KWH ) : ' , 1PE10.3 )
3170. IF ( IGRID .EQ. 0 ) TOT S=0
3171. WRITE ( 13, 4091 ) TOIE, TOES, FUEL
3172. 4091 FORMAT ( ' TOTAL ELECTRICITY BOUGHT ( KWH ) : ' , 1PE10.3 / %
3173. ' TOTAL ELECTRICITY SOLD ( KWH ) : ' , 1PE10.3 / %
3174. ' TOTAL FUEL BOUGHT ( KWH ) : ' , 1PE10.3 / % )
3175. %*****
3176. IF ( IHROUT.NE.1 ) GO TO 4000
3177. 5000 WRITE ( 50 ) E, AMQSR, AMESR 'OUTPUT FOR UTILITY ANALYSIS
3178. X*****
3179. 4000 RETURN
3180. END

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1.      % PROGRAM NAME: LOADS. JB
2.      % JOHN C. BELL
3.      % F. NERGY PROGRAM
4.      % OFF ICE OF TECHNOLOGY ASSESSMENT
5.      % COMP I LED
6.      %   DATE : 1 /27/78
7.      %   TIME: 17:29:26
8.      % PROGRAM LOADS. JB FOR SETTING UP THE ELECTRIC, THERMAL, AND
9.      %   PROCESS LOADS FOR: SINGLE FAMILY, TOWNHOUSE, OR
10.     %   LOW RISE APARTMENT BUILDINGS; HIGH RISE APARTMENT
11.     %   BUILDINGS; OR, SHOPPING CENTERS
12.     %
13.     %
000.    SUBROUTINE LOADS(TL,TH,FAN,HEATMX,COOLMX,ISMTH,IHR)
001.    DIMENSION ELLOAD(168),ELOAD1(24),ELOAD2(24),WLOAD1(24),%
002.    WLOAD2(24),HWLOAD(168),E(8760),TA1(8760)
003.    COMMON/XDATA/E,HWLOAD
004.    EQUIVALENCE (ELOAD1(1),ELLOAD(1)),(ELOAD2(1),ELLOAD(145)),%
005.    (WLOAD1(1),HWLOAD(1)),(WLOAD2(1),HWLOAD(145))
006.    %
1007.   % SET UP LOADS FOR HOURLY COMPUTATION
1008.   %
1009.   READ(25) TA1,TA1
1010.   IF (ISMTH.EQ.1) GO TO 601
1011.   READ(20) E, ELOAD1, ELOAD2,WLOAD1,WLOAD2
1012.   KCT=0
1013.   DO 600 I=25,144
1014.   KCT=KCT+1
1015.   IF (KCT.EQ.25) KCT=1
1016.   HWLOAD(I)=WLOAD1(KCT)
1017.   ELLOAD(I)=ELOAD1(KCT)
1018.   600 CONTINUE
1019.   GO TO 701
1020.   601 READ(20) E,ELLOAD,HWLOAD
1021.   701 KCT=0 @ZERO MEANS THE YEAR STARTS ON MONDAY AS THE 168 MAT. DO
1022.   TLOAD=0.0
1023.   IF (IHR.NE.0) GO TO 602
1024.   FANH=FAN*HEATMX
1025.   FANC=2.5*FAN*COOLMX
1026.   GO TO 702
1027.   602 READ(12,*,PROMPT=%
1028.   'MAXIMUM PUMP/FAN LOAD--HEATING, COOLING (KW FAN/TOTAL OUTPUT): ') %
1029.   FANH,FANC
1030.   FANHH=-FANH*HEATMX
1031.   FANCC=FANC*COOLMX
1032.   702 TL1=(459.4+TL)/1.8
1033.   TH1=0.001+(459.4+TH)/1.8
1034.   KCT=0
1035.   RETURN
1036.   %
1037.   % SET UP LOADS FOR EACH HOUR
1038.   %
1039.   ENTRY LOADS I(K,EEE,QSH,TA)
1040.   TA=TA1(K)
1041.   KCT=KCT+1
1042.   IF (KCT.GE.169) KCT=1
1043.   IF (IHR.EQ.2) GO TO 444
1044.   IF ((TA.GE.TL1).AND.(TA.LE.TH1)) GO TO 900
1045.   IF ((TA.LT.TL1).AND.(TLOAD+E(K).GT.0)) GO TO 900
1046.   IF ((TA.GT.TH1).AND.(TLOAD+E(K).LT.0)) GO TO 900

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1047.   444 TLOAD=TLOAD+E(K)
1048.   IF (IHR.NE.2) GO TO 704
1049.   KDAY=1+(KCT-1)/24
1050.   KHRD=KCT-(KDAY-1)*24
1051.   KDAY=KDAY-7*(KDAY-1)/7
1052.   IF ((KDAY.LE.6).AND.((KHRD.LT.8) OR. (KHRD.GE.23)).AND.%
1053.   (TLOAD.GT.0)) TLOAD=0
1054.   IF ((KDAY.EQ.7).AND.((KHRD.LT.13 .OR.(KHRD.GT.19)).AND.%
1055.   (TLOAD.GT.0)) TLOAD=0
1056.   IF (((K.LE.5831).AND.(K.GT.3625) .AND.((KHRD.LT.8) .OR. (KHRD.GE.23))%
1057.   .AND.(TLOAD.LT.0)) TLOAD=0
1058.   IF (ABS(TLOAD).LT.0.0001) GO TO 40
1059.   FANH=FANHH/TLOAD
1060.   FANC=FANCC/TLOAD
1061.   704 IF (TLOAD.GT.0) GO TO 20
1062.   PCLD=-TLOAD/HEATMX
1063.   IF ((PCLD-0.1).LT.0) GO TO 40
1064.   EEE=ELLOAD(KCT)+FANH*PCLD
1065.   QSH=TLOAD
1066.   TLOAD=0.0
1067.   GO TO 800
1068.   20 PCLD=TLOAD/CDOLMX
1069.   IF ((PCLD-0.1).LT.0) GO TO 40
1070.   EEE=ELLOAD(KCT)+FANC*PCLD
1071.   QSH=TLOAD
1072.   TLOAD=0.0
1073.   GO TO 800
1074.   900 TLOAD=0
1075.   40 EEE=ELLOAD(KCT)
1076.   QSH=0
1077.   800 RETURN
1078.   %
1079.   % OUTPUT STATEMENTS
1080.   %
1081.   ENTRY LOADS2
1082.   IF (IHR.EQ.0) WRITE(13,959)
1083.   959 FORMAT(' LOADS SET UP FOR SINGLE FAMILY HOUSE')
1084.   IF (IHR.EQ.1) WRITE(13,960)
1085.   960 FORMAT(' LOADS SET UP FOR HIGH RISE APARTMENT BUILDING')
1086.   IF (IHR.EQ.2) WRITE(13,970)
1087.   970 FORMAT(' LOADS SET UP FOR SHOPPING CENTER')
1088.   IF ((IHR.NE.0).AND.(FAN.GT.0)) WRITE(13,961)
1089.   961 FORMAT(' CAUTION: FAN LOAD (#27) IS NOT ZERO')
1090.   WRITE(13,971)
1091.   971 FORMAT(' THE MISCELLANEOUS ELECTRIC LOADS AND THE HOT WATER LOADS')
1092.   IF (ISMTH.EQ.0) WRITE(13,972)
1093.   972 FORMAT(' ARE NOT SMOOTHED')
1094.   IF (ISMTH.EQ.1) WRITE(13,973)
1095.   973 FORMAT(' ARE SMOOTHED')
1096.   RETURN
1097.   END

```

UPDATE. PB-PNC/UG F002 08/17/78 14:49:43

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1.      % PROGRAM NAME: UPDATE.JB
..     % JOHN C. BELL
3.     % ENERGY PROGRAM
4.     % OFFICE OF TECHNOLOGY ASSESSMENT
5.     % COMPILED
6.     %   DATE:  8/ 4/78
7.     %   TIME: 17:29:48
8.     % PROGRAM UPDATE.JB FOR HANDLING STORAGE INPUT/OUTPUT
9.     %
10.    %
11.    %
12.    %   S I ZE=ENERGY STORAGE CAPACITY
13.    %   CURRNT=AMOUNT OF ENERGY CURRENTLY IN STORAGE
14.    %   L) ELTA=ENERGY ADDED TO STORAGE (IF POSITIVE)
15.    %   DE LTA=ENERGY REMOVED FROM STORAGE (IF NEGATIVE)
16.    %   RES ID= ENERGY WHICH CAN NOT BE STORED (IF NEGATIVE )
17.    %   RESID=ENERGY WHICH CAN NOT BE PROVIDED FROM STORAGE
18.    %   (IF POSITIVE)
19.    %   EFFPC 1=ONE-WAY EFFICIENCY OF POWER CONDITIONER
20.    %   OR HEAT EXCHANGER
21.    %   EFFBT=TWO-WAY BATTERY OR THERMAL STORAGE EFFIC IENCY
22.    %
23.    %
24.    %
25.    %
2000.  % SUBROUTINE UPDATE (* I Z E , CURRNT , DELTA, RESID , EFF PC 1, EFF BT, PCS IZ 1 )
2001.  % IF ( S I ZE . GT . ( 1. 01 ) ) GO TO 800
2002.  % RES ID=-DELTA
2003.  % CURRNT=0
2004.  % RETURN
2005.  % 800 RES ID=0
2006.  % IF((CURRNT<S I ZE..AND.(DELTA , GT .0 ) ) GO TO 700
2007.  % IF ( (CURRNT<=0.00).AND.(DELTA, LT .0 ) ) GO TO 700
2008.  % IF ( ABS ( DELTA ) . LT . 0. 0001 ) RETURN

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UPDATE. PB-PNC/UGF002 08/17/78 14:49:43

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2009.  % IF (DELTA, LT . 0)GO TO 100
2010.  % TEST0=DELTA-PCSIZ 1 /EFFPC 1
2011.  % IF(TEST0, GT . 0 )GO TO 50
2012.  % TEST 1= EFFPC 1 *EFFBT*DELTA+CURRNT
2013.  % IF ( TEST 1, GT . S I ZE)GO TO 20
2014.  % CURRNT =TEST 1
2015.  % RETURN
2016.  % 20 RES ID= ( S I Z E-C URRT -EFFPC 1*EFFBT*DELTA ) / ( EFFPC *EFFB T )
2017.  % CURRNT =S I ZE
2018.  % RETURN
2019.  % 50 TEST 1= EFFBT*PCSIZ 1+CURRNT
2020.  % IF ( TEST2 , GT . S I Z E )GO TO 20
2021.  % RESID= ( -1 ) *TEST 0
2022.  % CURRNT =TEST 2
2023.  % RETURN
2024.  % 100 IF ( ( DELTA+PCS IZ 1 ) . LT . 0 )GO TO 150
2025.  % TEST 3=DELTA+EFFPC 1 *CURRNT
2026.  % IF (TEST 3 . LT . 0 )GO TO 120
2027.  % CURRNT=DELTA/EFFPC 1 +CURRNT
2028.  % RETURN
2029.  % 120 RES ID= (-1 ) *TEST 3
2030.  % CURRNT=0
2031.  % RETURN
2032.  % 150 TEST4=CURRNT-PCS121 / EFFPC 1
2033.  % IF ( TEST4 . LT . 0)GO TO 220
2034.  % RES ID=- (DELTA+ PCSIZ 1 )
2035.  % CURRNT=TEST4
2036.  % RETURN
2037.  % 220 RESID=-DELTA-EFFPC 1* CURRNT
2038.  % CURRNT=0
2039.  % RETURN
2040.  % 700 RESID=-DELTA
2041.  % RETURN
2042.  % END

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COPT.PB-PNC/UGFD02 08/17/78 14:48:40

```
1.      % PROGRAM NAME: COPT.JB
2.      % JOHN C. BELL
3.      % ENERGY PROGRAM
4.      % OFFICE OF TECHNOLOGY ASSESSMENT
5.      % COMPILED
6.      %   DATE : L21LOJ77
7.      %   TIME : 14:10:24
8.      % PROGRAM CONTROL JOB FOR OPTIMIZING THE COP ( EFF ) FOR A
9.      %   GIVEN TEMPERATURE ( T ) FROM THE COP CURVE ( CP ( 2,25 ) )
10.     %
11.     %
12.     %
13.     %
1000.   SUBROUTINE COPT ( T , CP , EFF )
1001.   DIMENSION CP ( 2, 25 )
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COPT . PB-PNC /UGF002 08/ 17/ 78 14 : 48 : 40

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1002.   IF ( T. LE. CP ( 1,1 ) ) GO TO 112
1003.   DO 14 I= 1, 25
1004.   IF ( CP ( 1, I ) . LT. .99. ) GO TO 113
1005.   LX=1
1006.   IF ( ( T. GE. CP ( 1, I ) ) . AND. ( T. LT. CP ( 1,1+1 ) ) ) GO TO 111
1007.   14 CONTINUE
1008.   111 EFF=CP(2,I)+(CP(2,I+1)-L P(2,I)) %
1009.   * ( T-CP ( 1, I ) ) / ( CP ( 1, I+1 ) -CP ( 1, I ) )
1010.   RETURN
1011.   112 EFF=CP(2, 1 )
1012.   RETURN
1013.   113 EFF=CP ( 2, LX)
1014.   RETURN
1015.   END
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1.      % PROGRAM NAME: HESYS.JB
2.      % JOHN C. BELL
3.      % ENERGY PROGRAM
4.      % OFFICE OF TECHNOLOGY ASSESSMENT
5.      % COMPILED
6.      % DATE: 12/19/77
7.      % TIME: 12:58:24
8.      % PROGRAM HESYS.JB FOR RUNNING HEAT ENGINE SYSTEMS WITH
9.      % ELECTRIC BACKUP
10.
11.
12.
1000.   51 UNROUT IN E SYSTEM ( K , QSH )
1001.   DIMENSION E ( 8760 ) , HLOAD ( 168 )
1002.   IMPLICIT REAL ( L )
1003.   COMMON /AXXX/COPA , EHWEFF , HCOPM , CCOPM , EFFB , ENGMX , EFF1 , EFF2 , ALPHA1 , 2
1004.   ALPHA2 , HTQSTM , LHTS , HTHTS , LTQSTM , I TLTS , HT LTS , HLH1H , %
1005.   FHWFF , HLLTH , EFFBE , ES FORM , t FFBAT , PC SIZ , EFF PC , HEA IMX , %
1006.   COOLMX , FAN , TL , 1 H , XXX , NHTQ , NI TQ , IGR J 1 ) , ISO LAR , IA , I SMTH , %
1007.   I HR , IOFFPK
1008.   COMMON /L XIX / COPAA , GO IOR E , FHM , EBEM , 1* EE , EFFEX , IENGM , B FNGM , ENGM , %
1009.   ESR , ES TOR , EI FF , F1HW , FHEI , FUEL , HFSSTM , HTQ , HTQ1 , H IQO , %
1010.   HTQSO , HTQSTO , LTQ1LTQO , LTQSO , LTQSTO , QA , QC , QC 1 , QC 2 , %
1011.   QC2 / , @EQP,QS,QSR,RESID9 , SHFT , STHT , TO ITEO , TOTBEO , %
1012.   TO ITEO , HL HTL , HLLTL , EFF1 ( 1T , EFFST , I PRINT
1013.   COMMON XDATA / E , HWLOAD
1014.   DATA IAIPI ( N1 , 2 /
2000.   QC1=0
2001.   QC2=0
2002.   IQC2=1
2003.   QHOUR=OF1
2004.   IF ( U ) PAA.' r. 0.001 ) GO TO 32
2005.   QHOUR= ( P+Q ) / COPAA
2006.   32 CALL UPDATE ( L IQSTM , LIQSTO , -QHOUR , RESIDQ , EFFEX , EFFLOT , LTQSTM )
2007.   QP1=AMAX1 ( 0 , QP - ( ( J HOUR-RESIDQ ) )
2008.   IF ( QP1 .Lh. 0.001 ) QC=QC-COPAA*(QHOUR-RESIDQ-QP )
2009.   QP=QP1
2010.   IF ( QSH . GT . 0 ) QC2Z=QSH-QC
2011.   IF ( QSH . LE . 0 ) QC2Z=-QSH-QC
2012.   %*****
2013.   %***** HEAT ENGINE SECT ION--VERY COMPLICATE D ! ! !
2014.   %*****
2015.   %*****
2016.   %
2017.   SOL E=QSR+H IQSTO
2018.   HTQSTO=0
2019.   IF ( SOL1 . GT . QP ) GO TO 2000
2020.   % QP=QP-SOL E
2021.   SOL E=0
2022.   QC1=QC
2023.   IF ( QSH . GT . 0 ) QC2=QSH-QC
2024.   IF ( QSH . LE . 0 ) QC2=-QSH-QC
2025.   E() UT=0
2026.   IQC 2=0
2027.   EEE=EEE+QP/EHWEFF
2028.   QP=0
2029.   GO TO 900
2030.   2000 IF ( COPAA.GT .0.01 ) GO T( 3 2100
2031.   QC 1=QC
2032.   COPAA=1.0

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2033.   %*****
2034.   z**** C&- THE BOTTOM ING CYCLE BE ON ALL T H r WAY
2035.   Z****
2201   IF ( QP . GT . SOLE*EFF1 *ALPHA1 ) GO TO 2001
2037.   BETAV=1
2038.   GAMMA=1
2039.   GO TO 2050
2040.   Z*****
2041.   %***** CAN THE BOT TOMING CYCLE BE ON PART WAY?
2042.   Z*****
2043.   2001 IF ( QP . GT . SOLE* EFF1 * ( ALPHA1+ALPHA2 ) ) GO TO 2002
2044.   BETAV=1
2045.   GAMMA= ( SOLE *EFF1 * ( ALPHA1+ALPHA2 ) -QP ) / ( SO LE*EFF1*ALPHA1 )
2046.   GO TO 2050
2047.   Z****
2048.   %***** BOT TOMING CYCLE OFF !
2049.   %*****
2050.   2002 BETAV= ( SO LE-QP ) / ( SOLE* ( 1-EFF1 * ( ALPHA1+ALPHA2 ) ) )
2051.   GAMMA=0
2052.   Z****
2053.   %***** CHECK FOR ENGINE CLIPPING
2054.   Z****
2055.   2050 IF ( BETAV*SOLE*EFF1 .GT . ENGMX ) GO TO 2090
2056.   Z****
2057.   z**** COMPUTE ELECTRIC AND LT THERMAL OUPUTS
2058.   %*****
2059.   2051 BOUT=BETAV*SOLE *EFF1 * ( 1+GAMMA*EFF2*ALPHA1 )
2060.   z****
2061.   %***** CHECK IF ALL ELECTRICITY CAN BE USED
2062.   %*****
2063.   XLAX=AMIN1 ( PC SIZ/EFFPC , ( ESTORM-ESTOR ) / EEFF )
2064.   IF ( BOUT . GT . EEE+QC1 /COPE E+XLAX ) GO TO 2095
2065.   %*****
2066.   %***** CYCLE AND GO TO NEXT HOUR
2067.   %*****
2068.   GO TO 900
2069.   %*****
2070.   z**** FIX ENGINE CLIPPING CONDITION--HAVE TO CHECK
2071.   %***** WHETHER REVISION AFFECTS MEETING THE THERMAL LOAD
2072.   z****
2073.   2090 IF ( QP . GT . ALPHA2*ENGMX ) GO TO 2091
2074.   BETAV=1
2075.   GAMMA=1
2076.   GO TO 2058
2077.   2091 IF ( QP . GT . ENGMX*(ALPHA1+ALPHA2 ) ) GO TO 2094
2078.   BETAV=1
2079.   GAMMA= ( EN GMX* ( ALPHA1+ALPHA2 ) -QP ) / ( ALPHA1 *F NGMAX )
2080.   GO TO 2058
2081.   2094 GAMMA=0
2082.   BE TAV=ENGMX/ ( ENGMX* ( 1-EFF1 * ( ALPHA1+ALPHA2 ) ) +EFF1 *Qp )
2083.   2058 CALL UPDATE ( HTQSTM , HTQSTO , SOLE-ENGMX/(EFF1 * BETAV) , %
2084.   RES IDQ , EFFEX , EFFST , HTQSTM )
2085.   CALL UPDATE ( LTQSTM , LTQSTO , -RESIDQ , RESID , EFFEX , EFFLOT , LTQSTM )
2086.   RESID9=RES ID9-RESID
2087.   SOL E=ENGMX/ ( EFF1 *BETAV )
2088.   GO TO 2051
2089.   %*****
2090.   %***** Fix overproduction OF ELECTRICITY IF HI ENERGY
2091.   %***** CAN BE STORED; IF HT STORAGE FULL, GO BACK AND
2092.   %***** SELL THE AVAILABLE EL ECTRICITY TO THE GRID

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2213. BETAV= 1
2214. GAMMA=0
2215. EOUT=(COPEE*(EEE+XLAX )@ C+QP*COPAA)/%
2216. (COPEE+COPAA*(ALPHA1+ALPHA2 ))
2217. QC1=QC-COPAA*(EOUT*(ALPHA1+ALPHA2)-QP)
2218. QC2=QC-QC1
2219. GO TO 2468
2220. 2418 GAMMA=0
2221. BETA V= EOUT/ ( EOUT*(1-EFF1*(ALPHA1+ALPHA2 ))+EFF1*QP)
2222. QC2=0
2223. QC1=QC
2224. 2468 CALL UPDATE (HTQSTM,HTQSTO, SOLE-EOUT/ %
2225. (BETAV*EFF1*(1+GAMMA*ALPHA1*EFF2)),RESIDQ,EFFEX,EFFST,HTQSTM)
2226. SOLE=EOUT/(BETAV*EFF1*(1+GAMMA*ALPHA1*EFF2))-RESIDQ
2227. IF (RESIDQ.LT.0) GO TO 2101
2228. GO TO 900
2229. %*****
2230. %*****
2231. %***** REACH THIS SECTION WHEN EFF2*COPEE>COPAA>0
2232. %*****
2233. %*****
2234. 2501 QC1=0
2235. QC2=QC
2236. IF (QP+QC/COPAA.GT.SOLE*EFF1*ALPHA2 ) GO TO 2502
2237. BETAV=1
2238. GAMMA=1
2239. GO TO 2550
2240. 2502 IF (QP.GT.SOLE*EFF1*ALPHA2 ) GO TO 2503
2241. BETAV= 1
2242. GAMMA= 1
2243. QC1=QC-COPAA*(SOLE*EFF1*ALPHA2-QP)
2244. QC2=QC-QC1
2245. GO TO 2550
2246. 2503 IF (QP.GT.SOLE*EFF1*(ALPHA1+ALPHA2 )) GO TO 2504
2247. BETAV= 1
2248. GAMMA= (SOLE*EFF1*(ALPHA1+ALPHA2)-QP)/(SOLE*EFF1*ALPHA1)
2249. QC1=QC
2250. QC2=0
2251. GO TO 2550
2252. 2504 GAMMA=0
2253. BETAV=(SOLE-QP)/(SOLE*(1-EFF1*(ALPHA1+ALPHA2)))
2254. QC1=QC
2255. QC2=0
2256. 2550 IF (BETAV*SOLE*EFF1.GT.ENGMAX) GO TO 2590
2257. 2551 EOUT=BETAV*EFF1*SOLE*(1+GAMMA*ALPHA1*EFF2)
2258. XLAX=AMINI (PCSI7/EFFPC, (ESTORM-ESTOR)/EFF)
2259. IF (EOUT.GT.EEE+XLAX+QC1/COPEE ) GO TO 2595
2260. GO TO 900
2261. %*****
2262. %***** FIX ENGINE CLIPPING CONDITION--HAVE TO CHECK
2263. %***** WHETHER REVISION AFFECTS MEETING THE THERMAL LOAD
2264. %*****
2265. 2590 IF (ENGMAX.LT. EEE+(QC-AMAX1 ((ALPHA1+ALPHA2)*ENGMAX-QP, 0) %
2266. *COPAA)/COPEE) GO TO 2705
2267. QC1=0
2268. QC2=QC
2269. IF (QP+QC/COPAA.GT.ALPHA2*ENGMAX) GO TO 2591
2270. BETAV=1
2271. GAMMA=1
2272. GO TO 2558

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2273. 2591 IF (QP.GT.ALPHA2*ENGMAX) GO TO 2592
2274. BETAV=1
2275. GAMMA=1
2276. QC1=QC-COPAA*(ALPHA2*ENGMAX-QP)
2277. QC2=QC-QC1
2278. GO TO 2558
2279. 2592 IF (QP.GT. ENGMAX*(ALPHA1+ALPHA2 )) GO TO 2593
2280. BETAV=1
2281. GAMMA=(ENGMAX*(ALPHA1+ALPHA2)-QP)/(ALPHA1*ENGMAX)
2282. QC1=QC
2283. QC2=0
2284. GO TO 2558
2285. 2593 GAMMA=0
2286. BETAV=ENGMAX/(ENGMAX*(1-EFF1*(ALPHA1+ALPHA2))+EFF1*QP)
2287. QC1=QC
2288. QC2=0
2289. 2558 CALL UPDATE (HTQSTM,HTQSTO, SOLE-ENGMAX/(BETAV*EFF1 ), %
2290. RESIDQ,EFFEX, EFFST,HTQSTM)
2291. CALL UPDATE (LTQSTM,LTQSTO, -RESIDQ,RESID,EFFEX,EFFLOT, LTQSTM)
2292. RESID9=RESID9-RESID
2293. SOLE-ENGMAX/ (BETAV*EFF1 )
2294. GO TO 2551
2295. %*****
2296. %***** FIX OVERPRODUCTION OF ELECTRICITY IF HT ENERGY
2297. %***** CAN BE STORED; IF HT STORAGE FULL, GO BACK AND
2298. %***** SELL THE AVAILABLE ELECTRICITY TO THE GRID
2299. %*****
2300. 2595 IF (HTQSTO.GE.HTQSTM*0.99 ) GO TO 900
2301. EOUT=EEE+XLAX
2302. QC1=0
2303. QC2=QC
2304. IF (QP+QC/COPAA.GT.ALPHA2*EOUT/ (1+ALPHA1*EFF2)) GO TO 2596
2305. BETAV=1
2306. GAMMA=1
2307. GO TO 2600
2308. 2596 EOUT=EEE+XLAX+QC/COPEE
2309. IF (QP.GT.ALPHA2*EOUT/(1+ALPHA1*EFF2 )) GO TO 2597
2310. BETAV=1
2311. GAMMA=1
2312. EOUT=(COPEE*(EEE+XLAX)+QC+QP*COPAA) / %
2313. (COPEE+(COPAA*ALPHA2)/(1+ALPHA1*EFF2 ))
2314. QC1=QC-COPAA*(ALPHA2*EOUT/ (1+ALPHA1*EFF2)-QP)
2315. QC2=QC-QC1
2316. GO TO 2600
2317. 2597 IF (QP.GT.EOUT*(ALPHA1+ALPHA2 )) GO TO 2598
2318. BETAV=1
2319. GAMMA=(EOUT*(ALPHA1+ALPHA2)-QP)/(ALPHA1*(EOUT+EFF2*QP) )
2320. QC1=QC
2321. QC2=0
2322. GO TO 2600
2323. 2598 GAMMA=0
2324. BETAV=EOUT/(EOUT*(1-EFF1*(ALPHA1+ALPHA2))+EFF1*QP)
2325. QC1=QC
2326. QC2=0
2327. 2600 CALL UPDATE (HTQSTM,HTQSTO, SOLE-EOUT/ %
2328. (BETAV*EFF1*(1+GAMMA*ALPHA1*EFF2)),RESIDQ,EFFEX,EFFST,HTQSTM)
2329. SOLE=EOUT/(BETAV*EFF1*(1+GAMMA*ALPHA1*EFF2))-RESIDQ
2330. IF (RESIDQ.LT.0) GO TO 2501
2331. GO TO 900
2332. %*****

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2333.      %*** USE THERMAL ENERGY TO MEET SPACE CONDITIONING
2334.      %*** LOAD---THIS IS NOT THE MOST EFFICIENT ROUTE BUT MUST
2335.      %***** BE USED AS 1_ PIG LINE SIZE PREVENTS THE OPTIMAL ROUTE FROM
2336.      %***** BEING TAKEN!
2337.      X*****
2338.      2705 GAMMA=0
2339.      QC1=AMAX1(ENGMAX-EEF, 0) *COP EF
2340.      QC2=QC-QC1
2341.      SOLEU=ENGMAX*(1/EFF1-(ALPHA1+ALPHA2))*QP+QC2/{.OPAA
2342.      IF(SOLEU.GE.SOLE)GO TO 2710
2343.      BETAV=ENGMAX/(EFF1*SOLEU)
2344.      CALL UPDATE (HTQSTM, HTQSTO, SOLE-SOLEU, RESIDQ, EFFEX, EFFST, HTOSFM)
2345.      CALL UPDATE (LTQSTM, LTQSTO, -RESIDQ, RESID, EFFEX, EFFLOT, LTQSTM)
2346.      RESID9=RESID9-RESID
2347.      SOLE=SOLEU
2348.      GO TO 2551
2349.      2710 BETAV=ENGMAX/(SOLE*EFF1)
2350.      QC2=((1-BETAV)*SOLE-QP+(ALPHA1+ALPHA2)*ENGMAX)*COPAA
2351.      QC1=QC-QC2
2352.      GO TO 2551
2353.      .: *****
2354.      % FTSO MAXIMUM ENGINE CONDITIONS AND STORAGE MAXIMUMS
2355.      %*****
2356.      900 QOUT=SOLE*((1-BETAV)+BETAV*EFF1*(ALPHA2+ALPHA1*(1-GAMMA)))
2357.      CALL UPDATE (ESTORM, ESTOR, EOUT-EEF-QC1/COPEE, RESIDQ, EFFPC, %

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2358.      EFFBAT, PCS I/I)
2359.      IF(COPAA.LT.0.1)COPAA=1.0
2360.      CALL UPDATE (LTQSTM, LTQSTO, QOUT-QP-IQC2*(0.2/coPAA, RESIDQ, EFPB), %
2361.      EFFLOT, LTQSTM)
2362.      RESID9=RESID9-RESIDQ
2363.      E(K)=RESIDQ
2364.      EY=GAMMA*ALPHA1*EFF2
2365.      EZ=EOUT/(EFF1*(1+EY))
2366.      TENGM=AMAX1(TENGM, EZ*EFF1)
2367.      BENGM=AMAX1(BENGM, EY*EZ*EFF1)
2368.      ENGM=AMAX1(ENGM, EOUT)
2369.      TOTTEO=TOTTEO+EZ*EFF1
2370.      TOTBEO=TOTBEO+EY*EZ*EFF1
2371.      TOTEO=TOTEO+EOUT
2372.      HTQ=HTQSTO-HTQSO
2373.      SHE=AMIN1(EZ, QSR)
2374.      HTQ9=0
2375.      IF(HTQ.LT.0)HTQ9=-HTQ
2376.      STHE=AMIN1(EZ-SHE, HTQ9)
2377.      FHET=0
2378.      SHET=SHET+SHE
2379.      SHET=SHET+STHE
2380.      6813 CONTINUE
2381.      RETURN
2382.      END

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1.      % PROGRAM NAME: HFSYS.JB
2.      % JOHN C. BELL
3.      % ENERGY PROGRAM
4.      % OFFICE OF TECHNOLOGY ASSESSMENT
5.      % COMPILED
6.      %   DATE: 12/19/77
7.      %   TIME: 12:58:45
8.      % PROGRAM HFSYS.JB FOR RUNNING HEAT ENGINE SYSTEMS WITH
9.      %   FOSSIL FUEL BACKUP
10.
11.
12.
1000.   SUBROUTINE SYSTEM(K,QSH)
1001.   DIMENSION E(8760),HWLOAD(168)
1002.   IMPLICIT REAL(L)
1003.   COMMON/AXXX/COPA, EHWEFF, HOCOPM, CCOPM, EFFB, ENGMX, EFF1, EFF2, ALPHA1, %
1004.   ALPHA2, HTQSTM, LHTS, HHTS, LTQSTM, LHTS, HHTS, HLHT, %
1005.   FHWEFF, HLLTH, EFFBE, ESTORM, EFFBAT, PCSIZ, EFFPC, HEATMX, %
1006.   COOLMX, FAN, TL, TH, XXX, NHTQ, NLTQ, IGRJD, ISOLAR, IA, ISMTH, %
1007.   IHR, IOFFPK
1008.   COMMON/CXXX/COPAA, COPEF, EBM, EBEM, EEE, EFFEX, TENGM, BENGM, ENGM, %
1009.   ESR, ESTOR, EEPF, FFW, FHT, FUEL, HTSSTM, HTQ, HTQ1, HTQ2, %
1010.   HTQSO, HTQSTO, LTQ1, LTQ2, LTQSO, LTQSTO, QA, QC, QCL, QC2, %
1011.   QCZ, QF, QP, QS, QSR, RESID9, SHFT, SHET, TOTTEO, TOTBEO, %
1012.   TOTBO, HLHTL, HLLTL, EFFLOT, EFFST, IPRINT
1013.   COMMON/XDATA/E, HWLOAD
1014.   DATA IPRINT/2/
2000.   QC1=0
2001.   QC2=0
2002.   IQC1=1
2003.   QHOUR=QP
2004.   IF (COPAA.LE.0.001) GO TO 32
2005.   QHOUR=QP+QC/COPAA
2006.   % CALL UPDATE(LTQSTM,LTQSTO -QHOUR, RES IDQ, EFFEX, EFFLOT, LTQSTM)
2007.   QP1=AMAX1(0, QP-(QHOUR-RESIDQ))
2008.   IF (QP1.LE.0.001) QC=QC-COPAA* QHOUR-RES IDQ-QP)
2009.   QP=QP1
2010.   IF (QSH.GT.0) QCZ=QSH-QC
2011.   IF (QSH.LE.0) QCZ=-QSH-QC
2012.   *****
2013.   *****
2014.   ***** HEAT ENGINE SECTION--VERY COMPLICATED !!!
2015.   *****
2016.   % *****
2017.   % SOLE=QSR+HTQSTO
2018.   H, QSI0=0
2019.   IF (COPAA.LT.1.0) GO TO 9829
2020.   LEE=EFFB+QC/LOPFE
2021.   QCL=0
2022.   QCZ=0
2023.   IQC1=0
2024.   QC=0
2025.   COP L/ 1.0
2026.   9829 XLAX=AMIN1 (PCS IZ/EFFPC, (E STORM-ESTOR) /EFFB)
2027.   XOUT=AMIN1 (PCS IZ/EFFPC, ESTOR*EFFPC)
2028.   EK=AMIN1 (EEE/ (EFF1 * (1+ALPHA1*EFF2) ), QP+QC/COPAA)
2029.   IF (SOLE.CT.EK) GO TO 2197
2030.   F(K)=(EK-SOLE)/EFFB
2031.   SOLE=F K
2032.   197 IF (I*OPEL.LI.0.01) GO TO 2199
    
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2033.   Z****
2034.   %***** CHECK WHETHER THE THERMAL SPAC F CON U I E ION I NG
2035.   %***** * ROUT E I S THE MOS T EFF IC IENT
2036.   Y*****
2037.   IF ( COPAA . L E . FFF 1 * ( COPEE+ ( ALPHA 1+ALPHA 2 ) *COPAA ) ) GO TO 2401
2038.   QHOUR=QP+QC /COPAA
2039.   QC1=0
2040.   QC2=QC
2041.   IF ( QHOUR . GT . ALPHA2*EFF1*SOLE ) GO TO 2101
2042.   BETAV= 1
2043.   GAMMA= 1
2044.   GO TO 2109
2045.   2101 IF ( QHOUR . GT . SOLE*EFF 1 * ( ALPHA 1+ALPHA 2 ) ) GO TO 2102
2046.   BETAV= 1
2047.   GAMMA= ( SOT . E*EFF 1 * ( ALPHA 1+ALPHA 2 ) -QHOUR ) / ( SOLE*EFF 1 *ALPHA 1 )
2048.   GO TO 2109
2049.   2102 GAMMA=0
2050.   BETAV= ( SOLE-QHOUR ) / ( SOLE*( 1-EFF 1 * ( ALPHA 1+ALPHA 2 ) ) )
2051.   2109 IF (BETAV*SOLE*EFF 1 . GT . ENGMX ) GO TO 7090
2052.   9109 EOUT=BETAV*SOLE*EFF 1 * ( 1+GAMMA*ALPHA 1 *EFF2 )
2053.   IF ( EOUT . GT . EEE+XLAX ) GO TO 2120
2054.   IF ( EOUT . LT . EEE-XOUT ) GO TO 2130
2055.   GO TO 900
2056.   Z****
2057.   %***** FIX ENGINE CLIPPING CONDITION--HAVE TO CHECK
2058.   %***** WHETHER REVISION AFFECTS MEETING THE THERMAL LOAD
2059.   Z****
2060.   7090 IF (QHOUR.GT. ALPHA 2* ENGMX) GO TO 5091
2061.   BETAV= 1
2062.   GAMMA= 1
2063.   GO TO 7058
2064.   5091 IF ( QHOUR . GT . ENGMX* ( ALPHA 1+ALPHA 2 ) ) GO TO 7094
2065.   BETAV=1
2066.   GAMMA=(ENGMX*( ALPHA 1+ALPHA 2 ) -QHOUR) / (ALPHA 1* ENGMX)
2067.   GO TO 7058
2068.   7094 GAMMA=0
2069.   BETAV=ENGMX/ ( ENGMX* ( 1-EFF1 * (ALPHA 1+ALPHA 2) )+EFF1 *QHOUR )
2070.   7058 CALL UPDATE ( HTSSTM, HTSSTO , SOLE-ENGMX/ ( EFF1*BETAV ) , %
2071.   RESIDQ , EFFEX, EFFST , HTSSTM)
2072.   SO LE=ENGMX/ (EFF1*BETAV)
2073.   GO TO 9109
2074.   Z****
2075.   %***** FIX overproduction OF Electricity
2076.   Z****
2077.   2120 EOUT=EEE+XLAX
2078.   IF ( QHOUR . GT . ALPHA2*EOUT / ( 1+ALPHA1*EFF2 ) ) GO TO 2121
2079.   BETAV=1
2080.   GAMMA= 1
2081.   GO TO 2129
2082.   2121 IF ( QHOUR . GT . EOUT*(ALPHA 1+ALPHA 2 ) ) GO TO 2122
2083.   BETAV= 1
2084.   GAMMA= (EOUT* (ALPHA 1+ALPHA 2)-QHOUR) / (ALPHA 1* ( EOUT+EFF2*QHOUR ) )
2085.   GO TO 2129
2086.   2122 GAMMA=0
2087.   BETAV=EOUT/ (EOUT* ( 1-EFF 1 * (ALPHA 1+ALPHA 2) )+EFF1 *QHOUR )
2088.   2129 CALL UPDATE (HTQSTM, HTQSTO, SOLE-EOUT/ %
2089.   (BETAV*EFF1 * (1+GAMMA*ALPHA1*EFF2) ), RES IDQ, EFFEX, EFFST, HTQSTM)
2090.   CALL UPDATE (LTQSTM, LTQSTO, -RES IDQ, RES ID, EFFEX, EFFLOT, LTQSTM)
2091.   RESID9=RES ID9-RES ID
2092.   GO TO 900
    
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2093. %*****
2094. %***** FIX UNDERPRODUCTION OF Electricity--E-D BACKUP!
2095. %*****
2096. 2130 EOUT=EEE-XOUT
2097. IF (QHOOR.GT.ALPHA2*EOUT/(1+ALPHA1*EFF2)) GO TO 2131
2098. BETAV=1
2099. GAMMA=1
2100. GO TO 2139
2101. 2131 IF (QHOOR.GT.EOUT*(ALPHA1+ALPHA2)) GO TO 2132
2102. BETAV=1
2103. GAMMA=(EOUT*(ALPHA1+ALPHA2)-QHOOR)/(ALPHA1*(EOUT+EFF2*QHOOR))
2104. GO TO 2139
2105. 2132 GAMMA=0
2106. BETAV=EOUT/(EOUT*(1-EFF1*(ALPHA1+ALPHA2))+EFF1*QHOOR)
2107. 2139 CALL UPDATE(HTSSTM,HTSSTO,SOLE-EOUT/Z
2108. (BETAV*EFF1*(1+GAMMA*ALPHA1*EFF2)),RESIDQ,EFFEX,EFFST,HTSSTM)
2109. E(K)=E(K)+RESIDQ/EFFB
2110. GO TO 900
2111. ;*****
2112. %***** CHECK WHETHER THE BOTTOMING CYCLE IS MORE EFFICIENT
2113. %***** THAN THE THERMAL ROUTE--IF THE BOTTOMING cycle is
2114. %***** MORE EFFICIENT--I.E. EFF2*COPEE>COPAA>0--GO TO
2115. %***** STATEMENT 2501; OTHERWISE STAY HERE.
2116. %***** (NOTE: IT IS ASSUMED IN THESE SWITCHES
2117. %***** THAT EFF2<EFF1)
2118. ;*****
2119. 2401 IF (COPAA.LT.EFF2*COPEE) GO TO 2501
2120. QC1=0 @ QC1 IS SPACE CONDITIONING LOAD MET ELECTRICALLY
2121. QC2=QC @ QC2 IS SPACE CONDITIONING LOAD MET THERMALLY
2122. IF (QP+QC/COPAA.GT.SOLE*EFF1*ALPHA2) GO TO 2402
2123. BETAV=1
2124. GAMMA=1
2125. GO TO 2450
2126. 2402 IF (QP+QC/COPAA.GT.SOLE*EFF1*(ALPHA1+ALPHA2)) GO TO 2403
2127. BETAV=1
2128. GAMMA=(SOLE*EFF1*(ALPHA1+ALPHA2)-QP-QC/COPAA)/(SOLE*EFF1*ALPHA1)
2129. GO TO 2450
2130. 2403 IF (QP.GT.SOLE*EFF1*(ALPHA1+ALPHA2)) GO TO 2404
2131. BETAV=1
2132. GAMMA=0
2133. QC1=QC-COPAA*(SOLE*EFF1*(ALPHA1+ALPHA2)-QP)
2134. QC2=QC-QC1
2135. GO TO 2450
2136. 2404 GAMMA=0
2137. BETAV=(SOLE-QP)/(SOLE*(1-EFF1*(ALPHA1+ALPHA2)))
2138. QC2=0
2139. QC1=QC
2140. 2450 IF (BETAV*SOLE*EFF1.GT.ENGMAX) GO TO 7405
2141. 9450 EOUT=BETAV*SOLE*EFF1*(1+GAMMA*ALPHA1*EFF2)
2142. IF (EOUT.GT.EEE+XLAX+QC1/COPEE) GO TO 2410
2143. IF (EOUT.LT.EEE+QC1/COPEE-XOUT) GO TO 2420
2144. GO TO 900
2145. %*****
2146. %***** FIX ENGINE CLIPPING CONDITION--HAVE TO CHECK
2147. %***** WHETHER REVISION AFFECTS MEETING THE THERMAL LOAD
2148. %*****
2149. 7405 QC1=0
2150. QC2=QC
2151. IF (QP+QC/COPAA.GT.ALPHA2*ENGMAX) GO TO 7406
2152. BETAV=1

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2153. GAMMA=1
2154. GO TO 7458
2155. 7406 IF (QP+QC/COPAA.GT.ENGMAX*(ALPHA1+ALPHA2)) GO TO 7407
2156. BETAV=1
2157. GAMMA=(ENGMAX*(ALPHA1+ALPHA2)-QP-QC/COPAA)/(ALPHA1*ENGMAX)
2158. GO TO 7458
2159. 7407 IF (QP.GT.ENGMAX*(ALPHA1+ALPHA2)) GO TO 7408
2160. BETAV=1
2161. GAMMA=0
2162. QC1=QC-COPAA*(ENGMAX*(ALPHA1+ALPHA2)-QP)
2163. QC2=QC-QC1
2164. GO TO 7458
2165. 7408 GAMMA=0
2166. BETAV=ENGMAX/(ENGMAX*(1-EFF1*(ALPHA1+ALPHA2))+EFF1*QP)
2167. QC2=0
2168. QC1=QC
2169. 7458 CALL UPDATE(HTSSTM,HTSSTO,SOLE-ENGMAX/BETAV*EFF1),%
2170. RESIDQ,EFFEX,EFFST,HTSSTM)
2171. SOLE=ENGMAX/(BETAV*EFF1)
2172. GO TO 9450
2173. %*****
2174. %*****FIX Overproduction OF ELECTRICITY
2175. %*****
2176. 2410 EOUT=EEE+XLAX
2177. QC1=0
2178. QC2=QC
2179. IF (QP+QC/COPAA.GT.ALPHA2*EOUT/(1+ALPHA1*EFF2)) GO TO 2416
2180. BETAV=1
2181. GAMMA=1
2182. GO TO 2468
2183. 2416 IF (QP+QC/COPAA.GT.EOUT*(ALPHA1+ALPHA2)) GO TO 2417
2184. BETAV=1
2185. GAMMA=(EOUT*(ALPHA1+ALPHA2)-QP-QC/COPAA)/(ALPHA1*%
2186. (EOUT+EFF2*(QP+QC/COPAA)))
2187. GO TO 2468
2188. 2417 EOUT=EEE+XLAX+QC/COPEE
2189. IF (QP.GT.EOUT*(ALPHA1+ALPHA2)) GO TO 2418
2190. BETAV=1
2191. GAMMA=0
2192. EOUT=(COPEE*(EEE+XLAX)+QC+QP*COPAA)/%
2193. (COPEE+COPAA*(ALPHA1+ALPHA2))
2194. QC1=QC-COPAA*(EOUT*(ALPHA1+ALPHA2)-QP)
2195. QC2=QC-QC1
2196. GO TO 2468
2197. 2418 GAMMA=0
2198. BETAV=EOUT/(EOUT*(1-EFF1*(ALPHA1+ALPHA2))+EFF1*QP)
2199. QC2=0
2200. QC1=QC
2201. 2468 CALL UPDATE(LTQSTM,HTQSTO,SOLE-EOUT/%
2202. (BETAV*EFF1*(1+GAMMA*ALPHA1*EFF2)),RESIDQ,EFFEX,EFFST,HTQSTM)
2203. CALL UPDATE(LTQSTM,HTQSTO,-RESIDQ,RESID,EFFEX,EFFST,HTQSTM)
2204. RESID9=RESID9-RESID
2205. GO TO 900
2206. %*****
2207. %***** FIX UNDERPRODUCTION OF ELECTRICITY--NEED BACKUP!
2208. %*****
2209. 2420 EOUT=EEE-XOUT
2210. QC1=0
2211. QC2=QC
2212. IF (QP+QC/COPAA.GT.ALPHA2*EOUT/(1+ALPHA1*EFF2)) GO TO 2426

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2213. BETAV=1
2214. GAMMA=1
2215. GO TO 2478
2216. 2426 IF (Q P+QC/COPAA.GT.EOUT*(ALPHA 1+ALPHA 2) ) GO TO 2427
2217. BET AV=1
2218. GAMMA=(EOUT*(ALPHA 1+ALPHA 2)-Q P-QC/COPAA) / (ALPHA 1*%
2219. (EOUT+EFF2*(QP+QC/COPAA)))
2220. GO TO 2478
2221. 2427 F. OUT=EFF-XOUT+QC/COPEE
2222. IF (QP.(, T. EOUT*(ALPHA 1+ALPHA 2)) GO TO 2428
2223. BETAV=1
2224. GAMMA=0
2225. F. OUT=(COPEE*(EFF-XOUT)+QC+QP*COPAA) / %
2226. (COP EE+COPAA*(ALPHA 1+ALPHA 2) )
2227. QC 1=QC-COPAA*(EOUT*(ALPHA 1+ALPHA 2)-QP)
2228. QC 2=QC-QC 1
2229. GO TO 2478
2230. 2428 GAMMA=0
2231. BET AV=EOUT / (EOUT*(1-EFF 1*(ALPHA 1+ALPHA 2))+EFF 1*QP)
2232. QC 2=0
2233. QC 1=QC
2234. 2478 CALL UPDATE(HTSSTM, HTSSTO, SOLE-EOUT/ %
2235. (BETAV*EFF 1*(1+GAMMA*ALPHA 1*EFF 2)), RESIDQ, EFFEX, EFFST, HTSSTM)
2236. E(K)=E(K)+RESIDQ/EFFB
2237. GO TO 900
2238. %*****
2239. %*****
2240. %***** REACH THIS SECTION WHEN EFF2*COPEE>COPAA>0
2241. %*****
2242. %*****
2243. 2501 QC 1=0
2244. QC 2=QC
2245. IF (QP+QC/COPAA.GT.SOLE*EFF 1*ALPHA 2) GO TO 2502
2246. BETAV=1
2247. GAMMA=1
2248. GO TO 2550
2249. 2502 IF (QP.GT.SOLE*EFF 1*ALPHA 2) GO TO 2503
2250. BETAV=1
2251. GAMMA=1
2252. QC 1=QC-COPAA*(SOLE*EFF 1*ALPHA 2-QP)
2253. QC 2=QC-QC 1
2254. GO TO 2550
2255. 2503 IF (QP.GT.SOLE*EFF 1*(ALPHA 1+ALPHA 2) ) GO TO 250.
2256. BETAV=1
2257. GAMMA=(SOLE*EFF 1*(ALPHA 1+ALPHA 2)-QP)/(SOLE*EFF 1*ALPHA )
2258. QC 1=QC
2259. QC 2=0
2260. GO TO 2550
2261. 2504 GAMMA=0
2262. BETAV=(SOLE-QP)/(SOLE*(1-EFF 1*(ALPHA 1+ALPHA 2)))
2263. QC 1=QC
2264. QC 2=0
2265. 2550 IF (BETAV*SOLE*EFF 1.GT.ENGMAX) GO TO 7590
2266. 9550 EOUT=BETAV*EFF 1*SOLE*(1+GAMMA*ALPHA 1*EFF 2)
2267. IF (EOUT.GT.EEE+XLAX+QC 1/COPEE) GO TO 2595
2268. IF (EOUT.LT.EEE+QC 1/COPEE-XOUT) Go To 2590
2269. GO TO 900
2270. %*****
2271. %***** FIX ENGINE CLIPPING CONDITION--HAVE TO CHECK
2272. %***** WHETHER REVISION AFFECTS MEETING THE THERMAL LOAD

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2273. %*****
2274. 7590 QC 1=0
2275. QC 2=QC
2276. IF (QP+QC/COPAA.GT.ALPHA 2*ENGMAX ) GO TO 7591
2277. BETAV=1
2278. GAMMA=1
2279. GO TO 7558
2280. 7591 IF (QP.GT.ALPHA 2*ENGMAX) GO TO 7597
2281. BETAV=1
2282. GAMMA=1
2283. QC 1=QC-COPAA*(ALPHA 2*ENGMAX-QP)
2284. QC 2=QC-QC 1
2285. GO TO 7558
2286. 7597 IF (QP.GT.ENGMAX*(ALPHA 1+ALPHA 2)) GO TO 7593
2287. BETAV=1
2288. GAMMA=(ENGMAX*(ALPHA 1+ALPHA 2)-QP)/(ALPHA 1*ENGMAX)
2289. QC 1=QC
2290. QC 2=0
2291. GO TO 7558
2292. 7593 GAMMA=0
2293. BETAV=ENGMAX/ (ENGMAX*(1-EFF 1*(ALPHA 1+ALPHA 2))+EFF 1*QP)
2294. QC 1=QC
2295. QC 2=0
2296. 7558 CALL UPDATE(HTSSTM, HTSSTO, SOLE-ENGMAX/ (BETAV*EFF 1), %
2297. RESIDQ, EFFEX, EFFST, HTSSTM)
2298. SOLE=ENGMAX/ (BETAV*EFF 1)
2299. GO TO 9550
2300. %*****
2301. %***** FIX OVERPRODUCTION OF ELECTRICITY
2302. Z*****
2303. 2595 EOUT=EEE+XLAX
2304. QC 1=0
2305. QC 2=QC
2306. IF (QP+QC/COPAA.GT.ALPHA 2*EOUT/ (1+ALPHA 1*EFF 2) ) GO TO 2596
2307. BETAV=1
2308. GAMMA=1
2309. GO TO 2600
2310. 2596 EOUT=EEE+XLAX+Q 1/COPEE
2311. IF (QP.GT.ALPHA 2*EOUT/ (1+ALPHA 1*EFF 2)) GO TO 2597
2312. BETAV=1
2313. GAMMA=1
2314. EOUT=(COPEE*(EEE+XLAX)+QC+QP*COPAA) / %
2315. (COPEE+(COPAA*ALPHA 2)/(1+ALPHA 1*EFF 2) )
2316. QC 1=QC-COPAA*(ALPHA 2*EOUT/ (1+ALPHA 1*EFF 2)-QP)
2317. QC 2=QC-QC 1
2318. GO TO 2600
2319. 2597 IF (QP.GT.EOUT*(ALPHA 1+ALPHA 2) ) GO TO 2598
2320. BETAV=1
2321. GAMMA=(EOUT*(ALPHA 1+ALPHA 2)-QP) / (ALPHA 1*(EOUT+EFF 2*QP) )
2322. QC 1=QC
2323. QC 2=0
2324. GO TO 2600
2325. 2598 GAMMA=0
2326. BETAV=EOUT/(EOUT*(1-EFF 1*(ALPHA 1+ALPHA 2))+EFF 1*QP)
2327. QC 1=QC
2328. QC 2=0
2329. 2600 CALL UPDATE(HTQSTM, HTQSTO, SOLE-EOUT/ %
2330. (BETAV*EFF 1*(1+GAMMA*ALPHA 1*EFF 2)), RESIDQ, EFFEX, EFFST, HTQSTM)
2331. CALL UPDATE(LTQSTM, LTQSTO, -RESIDQ, RESID, EFFEX, EFFLOT, LTQSTM)
2332. RESID9=RESID9-RESID

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2333. GO TO 900
2334. %*****
2335. %***** FIX UNDER PRODUCTION OF ELECTRICITY --NEED BACKUP!
2336. %*****
2337. 2590 EOUT=EFFE-XOUT
2338. QC1=0
2339. QC2=QC
2340. IF (QP+QC/COPAA .GT. ALPHA2*EOUT / (1+ALPHA1*EFF2)) GO TO 2696
2341. BETAV=1
2342. GAMMA=1
2343. GO TO 2601
2344. 2696 EOUT=EFFE-XOUT+QC/COPEE
2345. IF (QP .GT. ALPHA2 *EOUT / (1+ALPHA1 *EFF2)) GO TO 2697
2346. BETAV=1
2347. GAMMA=1
2348. EOUT= (COPEE*(EHE-XOUT)+QC*QP*(COPAA)/%
2349. (LOPEE+(COPAA*ALPHA2)/(1+ALPHA1*EFF2))
2350. QC1=QC-COPAA*(ALPHA2 *EOUT / (1+ALPHA1*EFF2))-QP
2351. QC2=QC-QC1
2352. GO TO 2601
2353. 2697 IF(QP .GT. EOUT*(ALPHA1+ALPHA2)) GO TO 2698
2354. BETAV=1
2355. GAMMA= (EOUT*(ALPHA1+ALPHA2)-QP) / (ALPHA1*(EOUT+EFF2*QP))
2356. QC1=QC
2357. QC2=0
2358. GO TO 2601
2359. 2698 GAMMA=0
2360. BETAV=EOUT / (EOUT*( -EFF1*(ALPHA1+ALPHA2))+EFF *QP)
2361. QC1=QC
2362. QC2=0
2363. 2601 CALL UPDATE(HTSSTM, HTSSTO, SOLE-EOUT / *
2364. (BETA V*EFF1*(1+GAMMA*ALPHA1*EFF2)), RESIDQ, EFFEX, EFFST, HTSSTM)
2365. E(K)=E(K)+RESIDQ/FFFB
2366. GO TO 900
2367. %** * * * * *
2368. % FIND MAXIMUM ENGINER CONDITIONS AND STORAGE MAXIMUMS
2369. %*****
2370. 900 SOLE=EOUT / (BETAV*EFF1*(1+GAMMA*ALPHA1*EFF2))
2371. QOLT=SOLE*(1-BETA') + BETA V*EFF1*(ALPHA2+ALPHA1*(1-GAMMA))
2372. IF (COPEE .LT. 0.1) COPAA=1.0

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2373. CALL UPDATE ( ESTORM , ESTOR , EOUT-EEE-IQC1*QC1/COPEE , %
2374. RESIDE , EFFPC , EFFBA1 , PCSIZ )
2375. IF ( COPAA .LT. .01 ) COPAA=1.0
2376. CALL UPDATE ( LTQSTM , LTQSTO , QOUT-QP-QC2/ COPAA , RESIDQ , %
2377. EFFEX , EFFLOT , LTQSTM )
2378. RESID9=RESID9-RESIDQ
2379. EY=GAMMA*ALPHA1*EFF2
2380. EZ=EOUT / ( EFF1*(1+EY) )
2381. TENGM=AMAX1 ( TENGM , EZ*EFF1 )
2382. BENGM=AMAX1 ( BENGM , EY*EZ*EFF1 )
2383. ENGM=AMAX1 ( ENGM , SOUT )
2384. TOTIEO=TOTIEO+EZ*EFF1
2385. TOTBO=TOTBO+EY*EZ*EFF1
2386. TOTEO=TOTEO+EOUT
2387. EBM=AMAX1 ( EBM , E(K) ) *EFFB-EZ
2388. CALL UPDATE ( HTQSTM , HTQSTO , HTSSTO , RESIDQ , EFFEX , EFFST , HTQSTM )
2389. CALL UPDATE ( LTQSTM , LTQSTO , -RESIDQ , RESIDQ , EFFEX , EFFLOT , LTQSTM )
2390. RESID9=RESID9-RESID
2391. HTSSTO=0
2392. HTQ=HTQSTO-HTQSO
2393. FHE=AMIN1 ( E(K) *EFFB , EZ )
2394. EBEM=AMAX1 ( EBEM , FHE )
2395. SHE=AMIN1 ( EZ-FHE , QSR )
2396. HTQ9=0
2397. IF ( HTQ .LT. 0 ) HTQ9=-HTQ
2398. STHE=AMIN1 ( EZ-FHE-SHE , HTQ9 )
2399. FHET=STHE+FHE
2400. SHET=STHE+SHE
2401. STHET=STHET+STHE
2402. IF ( E(K) .LE. .1E-9 ) GO TO 6813
2403. DELTA=QP-AMAX1 ( 0 , LTQSO-LTQSTO ) -AMAX ( 0 , -HTQ )
2404. IF ( DELTA .LE. 0 ) GO TO 6814
2405. FPHW=DELTA/FHWEFF
2406. 6814 IF ( EFFB*E(K) .LT. EZ ) GO TO 682
2407. E(K)=E(K)+EZ*(1/EFFBE-1/EFFB)
2408. GO TO 6811
2409. 6812 E(K)=E(K)*EFFB/EFFBE
2410. 6811 FULL=FUEL+E(K)
2411. 6813 CONTINUE
2412. RETURN
2413. END

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1.      * PROGRAM NAME : HWSYS . JB
2.      % JOHN C . BELL
3.      % ENERGY PROGRAM
4.      % OFF I I E OF TECHNOLOGY ASSES SME NT
5.      %, COMPILED
6.      DATE : 12/ 19/77
7.      TIME : 12:59: 7
8.      % PROGRAM HWSYS . JB FOR RUNN I NG SOLAR HOT WATER SYSTEMS
9.      AND CONVENTIONAL SYSTEMS WITH }I. ECTR IC BACKUP
10.     % OR ELEC TR IC AND FosSIL FUE L BAC KUP .
11.
12.     %
1000.   SUBROUTINE SYSTEM(K,QSH)
1001.   DIMENSION E(8760),HWLOAD(168)
1002.   IMPLICIT REAL(L)
1003.   COMMON/AXXX/COPA, EHWEFF,HCOPM,CCOPM,EFFB,ENGMAX,FFF1,EFF2,ALPHA1,%
1004.     ALPHA2,HTQSTM,LHTS,HTWTS,LTQSTM,LTLIS,HLLIS,HLHTH,%
1005.     FHWEFF,HLLTH,EFFBE,ESTORM,EPFBAT,PCSIZ,EFFPC,HEATMX,%
1006.     COOLMX,FAN,TL,TH,XXX,NHTQ,NLTQ,IGRID,ISOLAR,IA,ISMTH,%
1007.     IHR,IOPFK
1008.   COMMON/CXXX/COPAA,COPEE,EBM,EBEM,EEE,EFFEX,TENGM,BENGM,ENGM,%
1009.     ESR,ESTOR,EEFF,FFHW,PHET,FUEL,HSSSTM,HTQ,HTQ1,HTQO,%
1010.     HTQSO,HTQSTO,LTQ1,LTQO,LTQSO,LTQSTO,QA,QC,QC1,QC2,%
1011.     QC2Z,QE,QP,QS,QSR,RESID9,SHET,STHET,TOTTEO,TOTBEO,%
1012.     TOTE0,HLLTL,HLLTL,EFFLOT,EFFST,IPRINT
1013.   COMMON/XDATA/E,HWLOAD
1014.   DATA IPRINT/3/
2000.   %*****

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2001.   QC1=0
2002.   QC2=0
2003.   CALL UFDATA(LTQSTM,LTQSTO,QSR=QP,RESIDQ,EFFEX,EFFLOT,LTQSTM)
2004.   QP=AMAX1(RESIDQ,0)
2005.   IF (RESIDQ.LT.0) RESID9=RESID9-RESIDQ
2006.   IF (IGRID.EQ.3) GO TO 600
2007.   %*****
2008.   E(K)=EEE+QC/COPEE+QP/EHWEFF
2009.   QC1=QC
2010.   GO TO 900
2011.   %*****
2012.   600 IF (COPEE.GT.0.01) GO TO 650
2013.   E(K)=EEE
2014.   FFHW=QP/FHWEFF
2015.   FUEL=FUEL+QC/(COPAA*EFFB)+FFHW
2016.   QC2=QC
2017.   GO TO 900
2018.   %*****
2019.   650 E(K)=EEE+QC/COPEE
2020.   FFHW=QP/FHWEFF
2021.   FUEL=FUEL+FFHW
2022.   QC1=QC
2023.   GO TO 900
2024.   %*****
2025.   % FIND MAXIMUM ENGINE CONDITIONS AND STORAGE MAXIMUMS
2026.   %*****
2027.   900 CONTINUE
2028.   RETURN
2029.   END

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PVSYS. PB-PNC/UGF002 08/17/78 14:42:21

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1.      % PROGRAY NAME: PVSYS.JB
2.      % JOHN C. BELL
3.      % ENERGY PROGRAM
4.      % OFFICE OF TECHNOLOGY ASSESSMENT
5.      % COMPILED
6.      %      DATE: 1/12/78
7.      %      TIME: 13: 6:43
8.      % PROGRAM PVSYS.JB FOR RUNNING PHOTOVOLTAIC SYSTEMS WITH
9.      %      ELECTRICITY, FOSSIL FUEL, OR BOTH FOR BACKUP
10.     %
11.     %
12.     %
1000.   SUBROUTINE SYSTEM(K,QSH)
1001.   DIMENSION E(8760),HWLOAD( 168)
1002.   IMPLICIT REAL(L)
1003.   COMMON/AXXX/COPA,EHWEFF,HCOPM,CCOPM,EFFB,ENGMX,EFF1,EFF2,ALPHA1,%
1004.   ALPHA2,HTQST?,LHTS,HTHS,LTQSTM,LTLT,HLTH,HLTH,%
1005.   FHWEFF,HLLTH,EFFBE,ESTORM,EFFBAT,PCSIZE,EFFPC,HEATMX,%
1006.   COOLMX,FAN,TL,TH,XXX,NHTQ,NLTQ,IGRID,ISOLAR,IA,ISMTH,%
1007.   IHR,IOPFPK
1008.   COMMON/CXXX/COPAA,COPEE,EBM,EBEM,EEE,EFFEX,TENGM,BENGM,ENGM,%
1009.   ESR,ESTOR,EEFF,FFHW,FHET,FUEL,HTSSTM,HTQ,HTQ1,HTQ0,%
1010.   HTQSO,HTQSTO,LTQ1,LTQ0,LTQSO,LTQSTO,QA,QC,QC1,QC2,%
1011.   QC2Z,QE,QP,QS,QSR,RESID9,SHET,STHET,TOTTEO,TOTBEO,%
1012.   TOTEQ,HLLTL,HLLTL,EFFLOT,EFFST,IPRINT
1013.   COMMON/XDATA/E,HWLOAD
1014.   DATA IPRINT/1/
2000.   QC1=0
2001.   QC2=0
2002.   QHOUR=QP
2003.   IF (COPAA.LE.0.001) GO TO 32
2004.   QHOUR=QP+QC/COPAA
2005.   32 CALL UPDATE(LTQSTM,LTQSTO,QSR-QHOUR,RESIDQ,EFFEX,EFFLOT,LTQSTM)
2006.   IF (RESIDQ.LT.0) RESID9=RESID9-RESIDQ
2007.   XTEMP=AMAX1(0,QP-(QHOUR-RESIDQ))
2008.   IF (XTEMP.LE.0.001) QC=AMAX1(0,QC-COPAA*(QHOUR-AMAX1(0,RESIDQ)-QP))
2009.   QP=XTEMP
2010.   IF (QSH.GT.0) QC2Z=QSH-QC
2011.   IF (QSH.LE.0) QC2Z=-QSH-QC
2012.   %*****
2013.   % PHOTOVOLTAIC CALCULATIONS
2014.   %*****
2015.   ESR=ESR*EFFPC
2016.   XTEMP=AMIN1(ESR,EEE)
2017.   ESR=ESR-XTEMP
2018.   EEE=EEE-XTEMP
2019.   IF (IGRID.EQ.0) GO TO 550
2020.   IF (IGRID.EQ.3) GO TO 570
2021.   XTEMP=AMIN1(ESR,QC/COPEE)
2022.   ESR=ESR-XTEMP
2023.   QC=QC-XTEMP*COPEE
2024.   XTEMP=AMIN1(ESR,QP/EHWEFF)
2025.   ESR=ESR-XTEMP
2026.   QP=QP-EHWEFF*XTEMP
2027.   CALL UPDATE(ESTORM,ESTOR,ESR/(EFFPC**2)-QC/COPEE-QP/EHWEFF-EEE,%
2028.   RESIDE,EFFPC,EFFBAT,PCSIZE)
2029.   E(K)=RESIDE
2030.   IF (RESIDE.LT.0) E(K)=RESIDE*EFFPC
2031.   QC1=QC
2032.   GO TO 900

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2033.   570 IF (COPEE.LT.0.001) GO TO 571
2034.   QC1=QC
2035.   XTEMP=AMIN1(QC/COPEE,ESR)
2036.   ESR=ESR-XTEMP
2037.   QC=QC-COPEE*XTEMP
2038.   CALL UPDATE(ESTORM,ESTOR,ESR/(EFFPC**2)-QC/COPEE-EEE,RESIDE,%
2039.   EFFPC,EFFBAT,PCSIZE)
2040.   E(K)=RESIDE
2041.   IF (RESIDE.LT.0) E(K)=RESIDE*EFFPC
2042.   FFHW=QP/FHWEFF
2043.   FUEL=FUEL+FFHW
2044.   GO TO 900
2045.   571 CALL UPDATE(ESTORM,ESTOR,ESR/(EFFPC**2)-EEE,RESIDE,EFFPC,%
2046.   EFFBAT,PCSIZE)
2047.   E(K)=RESIDE
2048.   IF (RESIDE.LT.0) E(K)=RESIDE*EFFPC
2049.   FFHW=QP/FHWEFF
2050.   QA=QC/(COPAA*EFFB)
2051.   FUEL=FL+EL+QA+FFHW
2052.   EBM=AMAX1(EBM,QA*EFFB)
2053.   QC2=QC
2054.   GO TO 900
2055.   550 IF (COPEE.LT.0.001) GO TO 555
2056.   QCS=QC
2057.   XTEMP=AMIN1(QC/COPEE,ESR)
2058.   ESR=ESR-XTEMP
2059.   QC=QC-COPEE*XTEMP
2060.   CALL UPDATE(ESTORM,ESTOR,ESR/(EFFPC**2)-QC/COPEE-EEE,RESIDE,%
2061.   EFFPC,EFFBAT,PCSIZE)
2062.   QC1=QCS
2063.   IF (RESIDE.LE.0) GO TO 559
2064.   XTEMP=AMAX1(0,RESIDE-QC/COFEE)
2065.   IF (XTEMP.LT.0.0001) QC=RESIDE*COPEE
2066.   QC1=QCS-QC
2067.   EEE=XTEMP
2068.   GO TO 672
2069.   555 CALL UPDATE(ESTORM,ESTOR,ESR/(EFFPC**2)-EEE,RESIDE,EFFPC,%
2070.   EFFBAT,PCSIZE)
2071.   IF (RESIDE.LE.0) GO TO 558
2072.   EEE=RESIDE
2073.   GO TO 672
2074.   559 QC=0
2075.   558 EEE=0
2076.   XTEMP=AMIN1(QP,-RESIDE*EHWEFF)
2077.   QP=QP-XTEMP
2078.   RESIDE=RESIDE+XTEMP/EHWEFF
2079.   CALL UPDATE(LTQSTM,LTQSTO,-RESIDE,RESIDQ,EFFEX,EFFLOT,LTQSTM)
2080.   RESID9=RESID9-RESIDQ
2081.   E(K)=RESIDE
2082.   672 FFHW=0
2083.   IF (COPAA.GT.0.001) GO TO 673
2084.   EEE=EEE+QC/COPEE
2085.   COPAA=1
2086.   QC1=QC1+QC
2087.   QC=0
2088.   673 IF (ALPHA2*EEE.GE.QC/COPAA+QP) GO TO 6722
2089.   IF (COPEE.GT.0.1) GO TO 6721
2090.   6729 X=QP-ALPHA2*EEE
2091.   IF (X.LT.0) GO TO 6728
2092.   FFHW=X/FHWEFF

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2093. QA=FFHW*(QC/COPAA) /EFFB
2094. GO TO 6727
2095. 6728 QA=(QC/COPAA+X)/EFFB
2096. 6727 QS=0
2097. GO TO 6723
2098. 6722 QA=0
2099. QS=ALPHA2*EEH-QP-QC/COPAA
2100. 6723 QE=EEE/EFF1
2101. QC2=QC
2102. GO TO 6730
2103. 6721 IF (EFF1*(COPEE+ALPHA2*COPAA) . LE . COPAA*EFFB) GO TO 6724
2104. IF (ALPHA2*(EEE+QC/COPEE) . LT . QP) GO TO 6725
2105. QA=0
2106. QE=(EEE+(QP+Q/COPAA-ALPHA2*EEE) / (ALPHA2+COPEE/COPAA)) /EFF1
2107. QS=0
2108. QC1=QC1+COPEE*(EFF1*QE-EEE)
2109. QC2=QC-QC1
2110. GO TO 6730
2111. 6725 QE=(EEE+QC/COPEE) /EFF1
2112. QA=(QP-ALPHA2*(EEE+QC/COPEE)) /FFWEFF
2113. FFHW=QA
    
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2114. QS=0
2115. QC1=QC1+QC
2116. 6730 FUEL= FUEL+QA+QE/ EFFBE
2117. CALL UPDATE (LTQSTM,LTQSTO, QS, RES IDQ, EFFFX, EFFLOT, LTQSTM)
2118. RES ID9=RES ID9-RES IDQ
2119. EZ=QE*EFF1
2120. TENG1=AMAX1(TENG, EZ)
2121. ENGM=TENG
2122. TOTTEO=TOTTEO+EZ
2123. TOTTEO=TOTTEO
2124. EBM=AMAX1(EBM, (QA-FFHW)*EFFB)
2125. EBEM=AMAX1(EBEM, QE)
2126. GO TO 900
2127. *****
2128. Z FIND MAXIMUM ENGINE CONDITIONS AND STORAGE MAXIMUMS
2129. Z*****
2130. 900 CONTINUE
2131. IF (10FFPK . EQ .1) CALL OFFPK1 (K> QP, QC, QSH, COPEE, EHWEFF)
2132. RETURN
2133. END
    
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1.      % PROGRAM NAME:COLL1.JB
2.      % JOHN C. BELL
3.      % ENERGY PROGRAM
4.      % OFFICE OF TECHNOLOGY ASSESSMENT
5.      % COMP 1 LED
6.      % DATE : 12/ 30/77
7.      % TIME : 1 : 18:6
8.      % PROGRAM COLL 1. JB FOR RUNNING FLAT PLATE COLLECTORS AND
9.      % TWO DIMENSIONAL TRACKING COLLECTORS WITH
10.     % ELECTRIC AND THERMAL OUTPUT
11.     %
12.     *
13.     *
2000.   SUBROUTINE LOLL ( I SYS1)
2001.   DIMENSION DAYLEN( 365 ),SONOON( 365 ),DECL( 365)
2002.   DIMENSION RADDN( 8760 ),RADTH( 8760)
2003.   DIMENSION EQ(4), A(4), B(4)
2004.   IMPLICIT REAL(L)
2005.   COMMON /B XXX/CRATIO , TRANS , AREAC , LAT , LONG , LONGST , TILT , AZ , XKE , BETA , %
2006.   CELLEF , ELECAB , FC , ULOSS , COVERN , FR , ALPHA , FLOWR , DENS , CP , %
2007.   ABC , ABD , APWID , COLEN , FOCLEN , COSPAC , RIMANG , REFLEC , CELLL , %
2008.   ALPHAV , YYY(5) , ISYS , IFLOW , IEW , IYYY(5)
2009.   DIMENSION SCEL(37) , ISCEL(8)
2010.   EQUIVALENCE (SCEL(1),CRATIO) , (ISCEL(1),ISYS)
2011.   DATA A,B/--2E-3,-.4197,-.32265E1,-.903E-1,0,-.7351E1,-.93912E1,-.3661/
2012.   PIE2=6.2831853
2013.   PIEV=360/(PIE2)
2014.   READ(24) DECL
2015.   REWIND 25
2016.   READ(25) RADDN,RADDN,RADDN,RADTH
2017.   READ(12,*,PROMPT='FILE NUMBER FOR COLLECTOR COEFFICIENTS: ') IF
2018.   IF (IV.LE.0) GO TO 1120
2019.   REWIND IF
2020.   READ(IF) SCEL,ISCEL
2021.   1120 READ(12,99, PROMPT='LIST/CHANGE VARIABLES AND VALUES: ') ITST
2022.   99 FORMAT(A4)
2023.   IF (ITST.EQ.'YES') GO TO 1123
2024.   IF (ITST.EQ.'NO') GO TO 1124
2025.   IF (ITST.EQ.'NON') GO TO 1140
2026.   GO TO 1120
2027.   1123 WRITE(13,900) CRATIO,TRANS,AREAC,LAT, LONG, LONGST,TILT, Z
2028.   AZ,XKE,BETA,CELLEF,ELECAB,FC,ULOSS,COVERN,%
2029.   FR,ALPHA,FLOWR>DENS,CP
2030.   WRITE(13,901) ISYS,IFLOW
2031.   900 E. RMAT(' REAL NUMBERS ')/%
2032.   ' #',4X,'VALUE',4X,'DEFINITION'/%
2033.   ' 1 ',IPE10.3,' :CONCENTRATION RATIO (DIM)'/%
2034.   ' 2 ',IPE10.3,' :OPTICAL EFFICIENCY OR TRANSMISS. (.LE.1.00) '/%
2035.   ' 3 ',IPE10.3,' :COLLECTOR AREA (M**2)'/%
2036.   ' 4 ',IPE10.3,' :LATITUDE (DEG)'/%
2037.   ' 5 ',IPE10.3,' :LONGITUDE (DEG)'/%
2038.   ' 6 ',IPE10.3,' :STANDARD LONGITUDE (DEG)'/%
2039.   ' 7 ',IPE10.3,' :COLLECTOR TILT ABOVE HORIZONTAL (DEG)'/%
2040.   ' 8 ',IPE10.3,' :COLLECTOR ANGLE WRT SOUTH (DEG)'/%
2041.   ' 9 ',IPE10.3,' :COLLECTOR HEAT REMOVAL FACTOR (KW/(M**2*C))'/%
2042.   ' 10 ',IPE10.3,' :CELL TEMP COEFF (1/DEG CENT)'/%
2043.   ' 11 ',IPE10.3,' :CELL EFFIC @ 28C (.LE.1.00)'/%
2044.   ' 12 ',IPE10.3,' :CELL ABSORPTIVITY (.LE.1.00)'/%
2045.   ' 13 ',IPE10.3,' :FRAC OF RECEIVER COVERED WITH CELLS (.LE.1.00)'/%
2046.   ' 14 ',IPE10.3,' :THERMAL LOSS COEFF (KW/M**2*C)'/%

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2047.   ' 15 ',IPE10.3,' :NUMBER OF GLASS COVERS (DIM)'/%
2048.   ' 16 ',IPE10.3,' :COLLECTOR HEAT REMOVAL FACTOR (.LE.1.00)'/%
2049.   ' 17 ',IPE10.3,' :ABSORB OF THERMAL-ONLY SURFACES (.LE.1.00)'/%
2050.   ' 18 ',IPE10.3,' :FLOW RATE (CM**3/SEC**2)'/%
2051.   ' 19 ',IPE10.3,' :FLUID DENSITY (GM/CM**3)'/%
2052.   ' 20 ',IPE10.3,' :FLUID SPEC. HEAT (CAL/GM*C)')
2053.   901 FORMAT(' _____ INTEGERS _____ '1%
2054.   ' #',4X,'VALUE',4X,'DEFINITION'/%
2055.   ' 1 ',I6,4X,' :OUTPUT--ELEC(1) , ELEC & THERMAL(2), THERMAL(3) '/Z
2056.   ' 2 ',I6,4X,' :CONST FLOW RATE(1), CONST OUTPUT TEMP(2)')
2057.   1124 READ(12,*,PROMPT='VAR # AND VARIABLE: ') IV,V
2058.   IF (IV.LE.0) GO TO 1125
2059.   IF (IV.GT.37) GO TO 1124
2060.   SCEL(IV)=V
2061.   GO TO 1124
2062.   1125 READ(12,*,PROMPT='VAR # AND IVARIABLE: ') IV,I
2063.   IF (IV.LE.0) GO TO 1126
2064.   IF (IV.GT.8) GO TO 1125
2065.   ISCEL(IV)=I
2066.   GO TO 1125
2067.   1126 READ(12,*,PROMPT='FILE NUMBER TO STORE COLLECTOR COEFF: ') IV
2068.   IF (IV.LE.0) GO TO 1140
2069.   REWIND IV
2070.   WRITE(IV) SCEL,ISCEL
2071.   %
2072.   % COMPUTE RISETIME AND SETTING TIME OF SUN AND SOLAR ANGLES
2073.   %
2074.   1140 LAT=LAT/PIEV
2075.   TILT=TILT/PIEV
2076.   AZ=AZ/PIEV
2077.   ISYS1=ISYS
2078.   SINLAT=SIN(LAT)
2079.   COSLAT=COS(LAT)
2080.   TANLAT=TAN(LAT)
2081.   SINTLT=SIN(TILT)
2082.   COSTLT=COS(TILT)
2083.   SINAZ=SIN(AZ)
2084.   COSAZ=COS(AZ)
2085.   AREACR=AREAC/CRATIO
2086.   XFLASSP=0.004186*FLOWR*CP>DENS*CRATIO
2087.   ALPHAV=PC>ELECAB+(1-FC)*ALPHA
2088.   DO 50 I=1,365,1
2089.   DO 2500 J=1,4
2090.   EQ(J)=A(J)*COS((PIE2*(J-1)*I)/365.25)+B(J)*SIN((PIE2*(J-1)*I)/365.25)
2091.   2500 CONTINUE
2092.   RISANG=ACOS((-TANLAT)*TAN(DECL (I)))
2093.   DAYLEN(1)=PIEV>RISANG/7.5
2094.   SONOON(1)=13.5-((EQ(1)+EQ(2)+EQ(3)+EQ(4)+4*(LONGST-LONG) )/60)
2095.   50 CONTINUE
2096.   IF (IFLOW.NE.1) FR=1
2097.   RETURN
2098.   %
2099.   % HOURLY COMPUTATION BEGINS
2100.   %
2101.   ENTRY COLLO1(K,TF1N,TFOUT,TA,QSR,ESR)
2102.   IF (RADTH(K).LE.0) GO TO 38
2103.   IF (RADDN(K)+RADTH(K).LE. 0.0001) GO TO 38
2104.   TAIR=TA-273
2105.   I=(K-1)/24
2106.   J=K-24*(I)

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2107. I=I+1
2108. FD=J-0.5-SONOON(I)+DAYLEN(I)^2
2109. IF( (TD.LT.0).OR.(TD.(I.DAYLEN(I))) GO TO 38
2110. RI SANG=AI(I)*(-TAN I AT)*TAN(DECL(I))
2111. IF(CRATIO.LT.1.) GO TO 61
2112. RADTOT=TRANS*RADDN(K)*C RAT IO
2113. T t ( I SYS . EQ . 1 ) GO TO 224
2114. GOTO 1
2115. b1 HRANG=(SONOON(I)-1)*RI SANG/(DAYLEN(T)/2)
2116. SINDEC=sIN(DECL(I))
2117. Cos DE=cOS(DECL(I))
2118. COSHRA=cOS(HRANG)
2119. C1=sINDEC*SI NLAT
2120. C2=cOSDEC*cosLAT*cosHRA
2121. COSTHE=C1+C2
2122. IF(COSTHE.LE.0) GO TO 38
2123. COSINC=C1*COSTLT-SINDEC*cosLAT*SINTLT*cosAZ+%
2124. C2*COSTLT+%
2125. COSDEC*SINLAT*SINTLT*cosAZ*cosHRA+%
2126. CO SDEC*SINTLT*SINAZ *SIN ( HRANG )
2 27. COS INC=AMAXI ( o , COSINC )
2 28. RADDIF=AMAXI ( ( ( RADTH ( K ) -RADDN ( K *C OS THE ) * ( 1+COS TLT ) / 2 ) %
2 29. +RADTH ( K ) * ( 1 -COS TLT ) / 10.0 )
2 30. I F ( T SYS . EQ . 1 ) GO TO 223
2 31. I F ( COVERN . GE . 1.5 ) GO TO 221
2 32. R A DTOT=TRANS*RADDN ( K ) * ( CO SINC * . 25 ) +RADD I F*o . 89* TRANS
2 33. GO TO 222
2 34. 221MDIOT=TRANS*RADDN(K)*(COS L NC ** 1 5)+RADD I F*o . 80* TRANS
2 35. 222 I F ( I FLOW . EQ . 1 ) GO TO 225
2 35. TTEMP=(TFIN+TFOUT)/2
2 37. DENOM=1-(FC*RADTOT*CELLF*F*BI T I-L' LOSS /XKE
2 38. GO TO 226
2139. 225 TTEMP=TFIN
2140. DENOM=1-FR*FC*BET i.* CELLF*RADTOT*( 1/XKF+0.5/XMASSF)
2141. 226 AT EMPO=RADTO : * ( AL PHAV-FC*CELLEF*( 1-BETA*(TEMP-28) ) )
2142. QSR=AMAXI ( FR*AR t ACR* ( AT EMPO-ULOSS*(TTEMP-TAIR) ) /DENOM, o )
2143. I F ( I FLOW . EQ . 2 ) . AND . ( AL EMPO-ULOS S* ( TFOUT-TAIR ) . LE . 0 ) ) QSR=0 .
2144. I F ( I SYS . NE . 2 ) GO TO 321
2145. I F ( I FLOW . EQ . 2 ) i ( F LL=TTEMP+QSR/( XKE*AREACR )
2146. I F ( I FLOW . EQ . 1 ) i ( < ELL=TFIN+QSR*( o . 5/XMASSF+1/XKE ) /AREACR
2147. ESR=AREACR * F *RADTOT*CELLEF*( 1-BETA*( TCELL-28 ) )
2148. GO TO 321
2149. 2 23 RADT I , =RADDN ( K ) *cos INC+RADDIF

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2 150. 224 QSR=0
2151. XNUMER=AREACR*RADTOT*FC*CELLEF*( 1-BETA*(1,\IR+ALPHAV*RADTOT/XKE-28) )
2152. *L SR=XNUMER/( 1-CELLEF*BETA*RAD O T/XKE )
2 153. 3211 I F ( QSR . LE . 0 ) QSR=0 .
2154. I F ( ESR . LE . 0 ) ESR=0 .
2155. RETURN
2156. 38 QSR=0
2157. ESR=0
2158. RETURN
2159. %
2160. % OUTPUT STATEMENT S
2161. %
2162. ENTRY COLLO 2
2163. I F ( I SYS . EQ . 1 ) GO TO 17
2164. I F ( I FLOW . EQ . 2 ) GO TO 17
2165. 17 I F ( CRATIO . GT . 1.5 ) WR ITE ( 13 , 454 )
2166. 454 FORMAT ( ' TWO-AXIS TRACKING SYSTEM ' )
2167. I F ( CRATIO . LT . 1.1 ) WR ITE ( 13 , 450 )
2168. 450 FORMAT ( ' FLAT PLATE COLLECTOR ' )
2169. I F ( I SYS . EQ . 1 ) WR ITE ( 13 , 451 )
2170. 451 FORMAT ( 1X , ' PASSIVE ELECTRIC-ONLY COLLEC TOR ' )
2171. I F ( I SYS . EQ . 2 ) WR ITE ( 13 , 452 )
2172. 452 FORMAT ( 1X , ' COMB INED THERMAL AND ELEC TRIC COLLECTOR ' )
2173. I F ( I SYS . EQ . 3 ) WR ITE ( 13 , 45 )
2174. 453 FORMAT ( 1X , ' THERMAL-ONLY COLLECTOR ' )
2175. I F ( I FLOW . EQ . 1 ) WR ITE ( 13 , 455 )
2176. 455 FORMAT ( ' CONSTANT FLOW RATE ' )
2177. I F ( I FLOW . EQ . 2 ) WR ITE ( 13 , 456 )
2178. 456 FORMAT ( ' CONSTANT OUTPUT TEMPERATURE ' )
2179. RETURN
2180. %
2181. % OUTPUT SUMMARY
2182. %
2183. ENTRY COLLO 3
2184. LAT=LAT*PIEV
2185. AZ=AZ*PIEV
2186. TILT=TILT*PIEV
2187. WR ITE ( 13 , 900 ) CRATIO , TRANS , AREAC , LAT , LONG , LONGST , TILT , %
2188. AZ , XKE , BETA , CELLEF , EL ECAB , FC , ULOS S , COVERN , %
2189. FR , ALPHA , FLOWR , DENS , CP
2190. WR ITE ( 13 , 901 ) I SYS , I FLOW
2191. RETURN
2192. END

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COLL2. PB-PNC/UGF002 08/17/78 14:47:14

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1.      Z PROGRAM NAME: COLL2.JB
7.      % JOHN C. BELL
3.      % EN ERGY PROGRAM
4.      % OFFICE OF TECHNOLOGY ASSESSMENT
5.      % COMPILED
6.      %   DATE:  1/ 4/78
7.      %   TIME: 23:51:24
8.      % PROGRAM COLL2.JB FOR RUNNING ONE-DIMENSIONAL TRACKING
9.      %   COLLECTORS WITH THERMAL AND ELECTRIC OUTPUT
10.     %
11.     %
12.     %
13.     %
2000.   SUBROUTINE COLL(ISYS1)
2001.   DIMENSION DAYLEN(365), SONOON(365), DECL(365)
2002.   DIMENSION RADDN(8760), RADTH(8760)
2003.   DIMENSION EQ(4), A(4), B(4)
2004.   IMPLICIT REAL(L)
2005.   COMMON/BXXX/CRATIO, TRANS, AREAC, LAT, LONG, LONGST, U1, U2, XKE, BETA, %
2006.   CELLEF, ELECAB, FC, ULOSS, COVERN, FR, ALPHA, FLOWR, DENS, CP, %
2007.   TO, T1, APWID, COLEN, FOGLN, COSPAC, RIMANG, REFLEC, CELLL, %
2008.   ALPHAV, YYY(5), ISYS, IFLOW, IEW, IYYY(5)
2009.   DIMENSION SCEL(37), ISCEL(8)
2010.   Equivalence (SCEL(1), CRATIO), (ISCEL(1), ISYS)
2011.   DATA A, B / -2F-3, .4197, -.32265E1, -.903E-1, 0., -.7351E1, -.93912E1, -.3661 /
2012.   PIE2=6.2831853
2013.   PIEV=360/(PIE2)
2014.   READ(24) DECL
2015.   REWIND 25
2016.   READ(25) RADDN, RADDN, RADDN, RADTH
2017.   READ(12, *, PROMPT=' FILE NUMBER FOR COLLECTOR COEFFICIENTS: ') IF
2018.   IF (IF.LE.0) GO TO 1120
2019.   REWIND IF
2020.   READ(IF) SCEL, ISCEL
2021.   1120 READ(12, 99, PROMPT=' LIST/CHANGE VARIABLES AND VALUES: ') ITST
2022.   99 FORMAT(A4)
2023.   IF (ITST.EQ.'YES') GO TO 1123
2024.   IF (ITST.EQ.'NO') GO TO 1124
2025.   IF (ITST.EQ.'NON') GO TO 1140
2026.   GO TO 1120
2027.   1123 WRITE(13, 900) CRATIO, TRANS, AREAC, LAT, LONG, LONGST, U1, %
2028.   U2, XKE, BETA, CELLEF, ELECAB, FC, %
2029.   ALPHA, FLOWR, DENS, CP, TO, T1, APWID, COLEN, Z
2030.   FOGLN, COSPAC, RIMANG, REFLEC, CELLL
2031.   WRITE(13, 901) ISYS, IFLOW, IEW
2032.   900 FORMAT(' _____ REAL NUMBERS _____ '/%
2033.   ' #', 4X, 'VALUE', 4X, 'DEFINITION' /%
2034.   ' 1', 1PE10.3, ' :CONCENTRATION RATIO (DIM)'/%
2035.   ' 2', 1PE10.3, ' :OPTICAL EFFICIENCY OR TRANSMISS. (.LE.1.00)'/%
2036.   ' 3', 1PE10.3, ' :COLLECTOR AREA (M**2)'/%
2037.   ' 4', 1PE10.3, ' :LATITUDE (DEG)'/%
2038.   ' 5', 1PE10.3, ' :LONGITUDE (DEG)'/%
2039.   ' b', 1PE10.3, ' :STANDARD LONGITUDE (DEG)'/%
2040.   ' 7', 1PE10.3, ' :U1--THERMAL LOSS COEFF PARAMETER (KW/(M**2*C) )'/%
2041.   ' 8', 1PE10.3, ' :U2--THERMAL LOSS COEFF PARAMETER (KW/(M**2*C) )'/%
2042.   ' 9', 1PE10.3, ' :CELL HEAT REMOVAL FACTOR (KW/C**M**2)'/%
2043.   ' 10', 1PE10.3, ' :CELL TEMP COEFF (1/DEG CENT)'/%
2044.   ' 11', 1PE10.3, ' :CELL EFFIC @ 28C (.LE.1.00)'/%
2045.   ' 12', 1PE10.3, ' :CELL ABSORPTIVITY (.LE.1.00)'/%
2046.   ' 13', 1PE10.3, ' :FRAC OF CELL AREA COVERED WITH CELLS (.LE.1.00)'/%

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COLL2. PB-PNC/UGF002 08/17/78 14:47:14

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2047.   ' 17', 1PE10.3, ' :ABSORP OF THERMAL-ONLY SURFACES (.LE.1.00)'/%
2048.   ' 18', 1PE10.3, ' :FLOW RATE (CM**3/SFC**M**2)'/%
2049.   ' 19', 1PE10.3, ' :FLUID DENSITY (CM/CM**3)'/%
2050.   ' 20', 1PE10.3, ' :FLUID SPEC. HEAT (CAL/GM-C)'/%
2051.   ' 21', 1PE10.3, ' :TO--THERMAL COEFF TEMPERATURES (DEG CENT)'/%
2052.   ' 22', 1PE10.3, ' :T1--THERMAL COEFF TEMPERATURES (DEG CENT)'/%
2053.   ' 23', 1PE10.3, ' :COLLECTOR WIDTH(M)'/%
2054.   ' 24', 1PE10.3, ' :COLLECTOR LENGTH(M)'/%
2055.   ' 25', 1PE10.3, ' :FOCAL LENGTH (H)'/%
2056.   ' 26', 1PE10.3, ' :CENTER TO CENTER SPACING OF COLLECTORS(M)'/%
2057.   ' 27', 1PE10.3, ' :RIM ANGLE--EDGE-FP-CENTER (DEG)'/%
2058.   ' 28', 1PE10.3, ' :OPTICAL REFLECTIVITY (.LE.1.00)'/%
2059.   ' 29', 1PE10.3, ' :CELL LENGTH (M)')
2060.   901 FORMAT(' _____ INTEGERS _____ '/%
2061.   ' #', 4X, 'VALUE', 4X, 'DEFINITION' /%
2062.   ' 1', 16, 4X, ' :OUTPUT--ELEC(1), ELEC & THERMAL(2), THERMAL(3)'/%
2063.   ' 2', 16, 4X, ' :CONST FLOW RATE(1), CONST OUTPUT TEMP(2)'/%
2064.   ' 3', 16, 4X, ' :EAST-WEST AXIS(1), NORTH-SOUTH POLAR AXIS(2)')
2065.   1124 READ(12, *, PROMPT=' VAR # AND VARIABLE: ') IV, V
2066.   IF (IV.LE.0) GO TO 1125
2067.   IF (IV.GT.37) GO TO 1124
2068.   SCEL(IV)=V
2069.   GO TO 1124
2070.   1125 READ(12, *, PROMPT=' VAR # AND IVARIABLE: ') IV, I
2071.   IF (IV.LE.0) GO TO 1126
2072.   IF (IV.GT.8) GO TO 1125
2073.   ISCEL(IV)=I
2074.   GO TO 1125
2075.   1126 READ(12, *, PROMPT=' FILE NUMBER TO STORE COLLECTOR COEFF: ') IV
2076.   IF (IV.LE.0) GO TO 1140
2077.   REWIND IV
2078.   WRITE(IV) SCEL, ISCEL
2079.   %
2080.   % COMPUTE RISETIME AND SETTING TIME OF SUN AND SOLAR ANGLES
2081.   %
2082.   1140 ISYS1=ISYS
2083.   LAT=LAT/PIEV
2084.   RIMANG=RIMANG/PIEV
2085.   TANLAT=TAN(LAT)
2086.   SINRIM=SIN(RIMANG)
2087.   COSRIM=COS(RIMANG)
2088.   DO 50 I=1, 365, 1
2089.   DO 2500 J=1, 4
2090.   EQ(J)=A(J)*COS((PIE2*(J-1)*1)/365.25)+B(J)*SIN((PIE2*(J-1)*1)/365.25)
2091.   2500 CONTINUE
2092.   RISANG=ACOS((-TANLAT)*TAN(DECL(I)))
2093.   DAYLEN(I)=PIEV*RISANG/7.5
2094.   SONOON(I)=13.5-((EQ(1)+EQ(2)+EQ(3)+EQ(4)+4*(LONGST-LONG))/60)
2095.   50 CONTINUE
2096.   U11=U1/CRATIO
2097.   U22=U2/CRATIO
2098.   XMINV=1/(-.008372*FLOWR*CP*DENS*CRATIO)
2099.   AREACR=AREAC/CRATIO
2100.   RRR=CELLL/COLEN
2101.   RETURN
2102.   %
2103.   % DAILY COMPUTATION BEGINS
2104.   %
2105.   ENTRY COLLO1(K, TFLN, TFOUT, TA, QSR, ESR)
2106.   IF ((RADTH(K).LE.0).OR.(RADDN(K).LE.0)) GO TO 38

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2107.    TAIR=TA-27 3
2108.    I= (K-1)/24
2109.    J=K-24*(I)
2110.    I=I+1
2111.    TD=J-0.5-SONOON(I)+DAYLEN(I)/2
2112.    IF ((TD.LT. 0) .OR. (TD.GT.DAYLEN(I))) GO TO 38
2113.    COSINC=COS(DECL(1))
2114.    RISANG=ACOS((-TANLAT)*TAN(DECL(1)))
2115.    HRANG=(SONOON(I)-J)*RISANG/(DAYLEN(I)/2)
2116.    IF(IEW.EQ.1)GO TO 350
2117.    GO TO 360
2118.    350  COSINC=(1-((COSINC)**2)*((SIN(HRANG))**2))**.5
2119.    %
2120.    % COMPUTE SHADING
2121.    z
2122.    PHI=LAT-ATAN(TAN(DECL(1)))*(1./COS(HRANG))
2123.    THE=ACOS(COSINC)
2124.    GO TO 370
2125.    360  IF(ABS(HRANG).GT.PIE2/4)GO TO 38
2126.    PHI=HRANG
2127.    THE=DECL(1)
2128.    370  SHAD1=AMIN1(1,COSPAC*ABS(COS(PHI))/APWID)
2129.    RADIUS=(2*FOCLEN)/(1.+COSRIM)
2130.    SHAD2=FOCLEN+((RADIUS*SINRIM)**2)/(12*FOCLEN))
2131.    SHAD2=AMAX1(0,1-(SHAD2*ABS(TAN(THE)))/COLEN))
2132.    SHADTO=SHAD1*SHAD2
2133.    %
2134.    % COMPUTE THERMAL LOSSES
2135.    z
2136.    TRANSM=TRANS*(COSINC**.25)
2137.    FCIONO=0
2138.    IF (SHAD2.GE.(RRR/2)+.5) %
2139.        FCIONO=(CRATIO/COLEN)*CELL*REFLEC*TRANSM*SHAD1* %
2140.            CELLEF*FC*RADDN(K)*COSINC
2141.    762  IF ((SHAD2-.5)*COLEN.GE.CELL/2) %
2142.        ALPHIO=(CRATIO/COLEN)*REFLEC*SHAD1*TRANSM*RADDN(K) %
2143.            *COSINC*(ALPHA*(SHAD2*COLEN-FC*CELL)+(FC*ELECAB*CELL) )
2144.    IF ((SHAD2-0.5)*COLEN.LT.-CELL/2) %
2145.        ALPHIO=CRATIO*REFLEC*TRANSM*RADDN(K) %
2146.            *COSINC*ALPHA*SHADTO
2147.    IF (ABS((SHAD2-.5)*COLEN).LE.CELL/2) %
2148.        ALPHIO=(CRATIO/COLEN)*REFLEC*TRANSM*RADDN(K)* %
2149.            COSINC*(ALPHA*(COLEN-FC*CELL)/2)+ %
2150.            FC*ELECAB*((SHAD2-0.5)*COLEN+CELL/2))*SHAD1
2151.    IF(ISYS.EQ.1)GO TO 7b1
2152.    TTEMP=TFIN
2153.    IF(IFLOW.EQ.2)TTEMP=(TFIN+TFOUT)/2
2154.    QL1=ALPHIO-FCIONO*(1-BETA*(TTEMP-28))
2155.    IF(IFLOW.EQ.1)GO TO 763
2156.    %
2157.    % CALCULATE ouTpuT FOR SYSTEM WITH FIXED ouTpuT TEMPERATURE
2158.    %
2159.    IF(TTEMP-TAIR.GE.T1-T0) %
2160.        Q1=U11*CRATIO*(T1-T0)+U22*CRATIO*(TTEMP-TAIR-(T1-T0) )
2161.    IF(TTEMP-TAIR.LT.T1-T0) %
2162.        Q1=U11*CRATIO*(TTEMP-TAIR)

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2163.    QSR=AREACR*(QL1-QL2)/(1-FCIONO*BETA/XKE)
2164.    GO TO 764
2165.    %
2166.    Z CALCULATE OUTPUT FOR FIXED FLOW RATE
2167.    %
2168.    763  QL2=U11*CRATIO*(T1-T0)+U22*CRATIO*(TTEMP-TAIR-(T1-T0) )
2169.    QSR=AREACR*(QL1-QL2)/(1+U22*XMINV-FCIONO*BETA*(1/XKE+XMINV/CRATIO))
2170.    TTEMP=TFIN+QSR*XMINV/AREAC
2171.    IF(TTEMP-TAIR.LT.T1-T0) %
2172.        QSR=AREACR*(QL1-U11)*CRATIO*(TFIN-TAIR)/(1+U11*XMINV-FCIONO* %
2173.            *BETA*(1/XKE+XMINV/CRATIO) )
2174.    TTEMP=TFIN+QSR*XMINV/AREAC
2175.    764  ESR=AREACR*FCIONO*(1-BETA*(TTEMP+QSR/(XKE*AREACR)-28))
2176.    GO TO 766
2177.    761  QSR=0
2178.    ESR=AREACR*FCIONO*(1-BETA*(TAIR-28+ALPHIO/XKE))/(1-FCIONO*BETA/(XKE*FC))
2179.    766  QSR=AMAX1(0,QSR)
2180.    ESR=AMAX1(0,ESR)
2181.    RETURN
2182.    38  QSR=0.
2183.    ESR=0.
2184.    RETURN
2185.    %
2186.    % OUTPUT STATEMENTS
2187.    %
2188.    ENTRY collo2
2189.    IF(IEW.EQ.1)WRITE(13,1132)
2190.    1132  FORMAT(' EAST-WEST AXIS TRACKING COLLECTOR')
2191.    IF(IEW.NE.1)WRITE(13,459)
2192.    459  FORMAT(' ONE-AXIS POLAR NORTH-SOUTH TRACKING COLLECTOR')
2193.    IF(ISYS.EQ.1)WRITE(13,451)
2194.    451  FORMAT(1X,'PASSIVE ELECTRIC-ONLY COLLECTOR')
2195.    IF(ISYS.EQ.2)WRITE(13,452)
2196.    452  FORMAT(1X,'COMBINED THERMAL AND ELECTRIC COLLECTOR')
2197.    IF(ISYS.EQ.3)WRITE(13,453)
2198.    453  FORMAT(1X,'THERMAL-ONLY COLLECTOR')
2199.    IF(IFLOW.EQ.1)WRITE(13,455)
2200.    455  FORMAT(' CONSTANT FLOW RATE')
2201.    IF(IFLOW.EQ.2)WRITE(13,456)
2202.    456  FORMAT(' CONSTANT OUTPUT TEMPERATURE')
2203.    RETURN
2204.    z
2205.    Z ouTpuT SUMMARY
2206.    z
2207.    ENTRY COLL03
2208.    LAT=LAT*PIEV
2209.    RIMANG=RIMANG*PIEV
2210.    WRITE(13,900)CRATIO,TRANS,AREAC,LAT,LONG,LONGST,U1, %
2211.        U2,XKE,BETA,CELLEF,ELECAB,FC, %
2212.        ALPHA,Flow,DENS,CP,TO,T1,APWID,COLEN, %
2213.        FOCLEN,COSPAC,RIMANG,REFLEC,CELL
2214.    WRITE(13,901)ISYS,IFLOW,IEW
2215.    RETURN
2216.    END

```

```

1.      % PROGRAM NAME: COLL3.JB
2.      % JOHN C. BELL
3.      % ENERGY PROGRAM
4.      % OFFICE OF TECHNOLOGY ASSESSMENT
5.      % COMPILED
6.      %   DATE: 12/29/77
7.      %   TIME: 12:29:42
8.      % PROGRAM COLL3.JB FOR RUNNING HELIOSTAT FIELDS
9.      %   WITH THERMAL OUTPUT ONLY
10.     %
11.     %
12.     %
13.     %
2000.   SUBROUTINE COLL (ISYS1)
2001.   DIMENSION DAYLEN(365),SONOON(365) ,DECL(365)
2002.   DIMENSION RADDN(8760),RADTH(8760)
2003.   DIMENSION EQ(4),A(4),B(4)
2004.   IMPLICIT REAL(L)
2005.   COMMON/BXXX/CRATIO,TRANS,AREAC,LAT,LONG,LONGST,TILT,AZ ,XKE,BETA,%
2006.   CELLEF,ELECAB,FC,ULOSS,COVERN,FR,ALPHA,FLOWR,DENS,CP,%
2007.   ABC,ABD,APWID,COLEN,FOCLEN,COSCAP,RIMANG,REFLEC ,CELLL,%
2008.   ALPHAV,YYY(5),ISYS,IFLOW, IEW,IYYY(5)
2009.   DIMENSION SCEL(37),ISCEL(8)
2010.   EquiValenCe (SCEL(1),CRATIO) ,(ISCEL(1),ISYS)
2011.   DATA A,B/-.2E-3, .4197,-.32265E 1,-.903E-1,0. ,-.7351E1,-.93912E1,-.3661 /
2012.   DIMENSION GAMMA(3, 7),DAYTIM(3, 7),NZDAY(365)
2013.   DATA GAMMA/.92,.56,0.,.92, .58, 0. ,.92, .68,0.,.91,-.72,0.,.87,-.7,0.,.82,
      .58,0. ,.78, .49,0./
2014.   DATA DAYTIM/ 1.7,5.36,7. 18,1.7,5.1,6.96, 1.7,3.93,6.56, 1.48,3.6,6.03, 1.51,
      3.48,5.57,1.74,3.6,5.17 ,1.39,3.6,4.781
2015.   DATA NZDAY/4*7, 31*6,30*5,31*4, 30*3,31*2,29*1,31*2,30*3, 31*4,30*5,31*6,26*7/
2016.   PIE2=6.2831853
2017.   PIEV=360/(PIE2)
2018.   READ(24) DECL
2019.   REWIND 25
2020.   READ(25) RADDN,RADDN,RADDN,RADTH
2021.   READ(12,*,PROMPT='FILE NUMBER FOR COLLECTOR COEFFICIENTS: ') IF
2022.   IF (IF.LE.0) GO TO 1120
2023.   REWIND IF
2024.   READ(IF) SCEL,ISCEL
2025.   1120 READ(12,99,PROMPT='LIST/CHANGE VARIABLES AND VALUES: ') ITST
2026.   99 FORMAT(A4)
2027.   IF (ITST.EQ. 'YES') GO TO 1123
2028.   IF (ITST.EQ. 'NO') GO TO 1124
2029.   IF (ITST.EQ. 'NON') GO TO 1140
2030.   GO TO 1120
2031.   1123 WRITE(13,900) CRATIO,AREAC,LAT,LONG,LONGST,ULOSS, %
2032.   ALPHA,REFLEC
2033.   900 FORMAT(' REAL NUMBERS' /%
2034.   ' #',4X,'VALUE' ,4X,'Definition' /%
2035.   ' 1 ',1PE10.3,' :CONCENTRATION RATIO (DIM)"/%
2036.   ' 3 ',1PE10.3,' :COLLECTOR AREA (M**2)"/%
2037.   ' 4 ',1PE10.3, ' :LATITUDE (DEG)"/%
2038.   ' 5 ', 1PE10.3, ' :LONGITUDE (DEG)"/%
2039.   ' 6 ', 1PE10.3, ' :STANDARD LONGITUDE (DEG)"/%
2040.   ' 14 ',1PE10.3, ' :THERMAL LOSS COEFF (KW/C**2)"/%
2041.   ' 17 ',1PE10.3,' :ABSORB OF THERMAL-ONLY SURFACES (.LE.1.00)"/%
2042.   ' 28 ',1PE10.3,' :COLLECTOR REFLECTIVITY (.LE.1.00)')
2043.   1124 READ(12,*,PROMPT='VAR # AND VARIABLE: ') IV,V
2044.   IF (IV.LE.0) GO TO 1126
2045.   IF (IV.GT.37) GO TO 1124

```

```

2046.   SCEL(IV)=V
2047.   GO TO 1124
2048.   1126 READ(12,*,PROMPT='FILE NUMBER TO STORE COLLECTOR COEFF: ') IV
2049.   IF (IV.LE.0) GO TO 1140
2050.   REWIND IV
2051.   WRITE(IV) SCEL,ISCEL
2052.   %
2053.   % FINISH INITIAL COMPUTATIONS
2054.   %
2055.   1140 LAT=LAT/PIEV
2056.   TANLAT=TAN(LAT)
2057.   ISYS1=ISYS
2058.   DO 50 1-1,365,1
2059.   DO 2500 J-1,4
2060.   EQ(J)=A(J)*COS ((PIE2* (J-1)*1)/365. 25)+B(J)*SIN((PIE2*(J-1)*1)/365.25)
2061.   2500 CONTINUE
2062.   RISANG=ACOS((-TANLAT)*TAN(DECL(I)))
2063.   DAYLEN(I)=PIEV*RISANG/7.5
2064.   SONOON(I)=13.5-((EQ(1)+EQ(2)+EQ( 3)+EQ(4)+4*(LoNGsT-LoNG) )/60)
2065.   50 CONTINUE
2066.   RETURN
2067.   %
2068.   % DAILY COMPUTATION BEGINS
2069.   %
2070.   ENTRY COLLO1(K,TFIN,TFOUT,TA,QSR,ESR)
2071.   IF ((RADTH(K).LE.0).OR.(RADDN(K).LE.0)) GO TO 38
2072.   TFIN=TFOUT
2073.   TAIR=TA-273
2074.   I=(K-1)/24
2075.   J=K-24*(I)
2076.   I=I+1
2077.   N=NZDAY(I)
2078.   TD=J-0.5-SONOON(I)+DAYLEN (I)/2
2079.   IF ((TD.LT.0).OR.(TD.GT.DAYLEN(1))) GO TO 38
2080.   TDAY=ABS (SONOON(I)-J)
2081.   TD=DAYLEN(I)/2.
2082.   TB=(TD/(DAYTIM(3,N)))*DAYTIM(1,N)
2083.   TC=(TD/(DAYTIM(3,N)))*DAYTIM(2,N)
2084.   IF(TDAY.LT.TB)GO TO 25
2085.   IF(TDAY.LE.TC)GO TO 26
2086.   GO TO 27
2087.   25 GAMCOS=0
2088.   GO TO 30
2089.   26 GAMCOS=(GAMMA(1,N)-GAMMA( 2,N))/(TC-TB)
2090.   TD=TB
2091.   GO TO 30
2092.   27 GAMCOS=(GAMMA(2,N)-GAMMA(3,N))/(TD-TC)- %
2093.   (GAMMA(2,N)-GAMMA(1,N))/(TDAY-TC) @correction FACTOR
2094.   TD=TC
2095.   30 GAMCOS=GAMMA(1,N)-GAMCOS*(TDAY-TD)
2096.   QSR=REFLEC*ALPHA*AREAC*GAMCOS*M.DDN (0.-%
2097.   (TFOUT-TAIR)*ULOSS*AREAC/CRATIO
2098.   GO TO 39
2099.   38 QSR=0.
2100.   39 IF(QSR.LE.0) QSR=0.
2101.   RETURN
2102.   %
2103.   % OUTPUT STATEMENTS
2104.   %
2105.   ENTRY COLLO2
2106.   WRITE(13,250)

```

COLL3. PB-PNC/UG F002 08/17/78 14:48:14

```
2107.      250  FORMAT (' HELIOSTAT FIELD' )
2108.      RETURN
2109.      z
2110.      % OUTPU 1 SUMMARY
2111.      %
2112.      ENTRY COLLO3
```

COLL3. PB-PNC/UGF002 08/17/78 14:48:14

```
2113.      LAT=LAT*PIEV
2114.      WRITE(13,900) CRATIO,AREAC,LAT,LONG, LONGST,ULOSS, Z
2115.      ALPHA,REFLEC
2116.      RETURN
2117.      END
```



```

1.      % PROGRAM NAME OFFPK.JB
2.      % JOHN C. BELL
3.      % ENERGY PROGRAM
4.      % OFFICE OF TECHNOLOGY ASSESSMENT
5.      % COMPILED
6.      z   DATE:      3/25/78
7.      z   TIME:     15:30:21
8.      % PROGRAM OFFPK.JB FOR BUYING OFFPEAK ELECTRICITY
9.      %
10.     %
11.     %
12.     %
13.     %
14.     %
15.     %
1000.   SUBROUTINE OFFPK
1001.   DIMENSION E(8760),CPC(2,25)
1002.   COMMON/DXXX/BOLMAX,CPC
1003.   COMMON/EXXX/TAIRF
1004.   COMMON/XDATA/E
1005.   DATA XMAX,ONE/1.0E10,1./
1006.   READ(12,99,PROMPT='HEATING, COOLING, AND HOT WATER: ') ITST
1007.   99  FORMAT(A4)
1008.   IF (ITST.EQ.'YES') IHC=1
1009.   READ(12,*,PROMPT='OFFPEAK CHARGING HOURS--BEGIN AND END: ') IHRB,IHRE
1010.   IHRTOT=IHRE-IHRB+1
1011.   RETURN
2000.   ENTRY OFFPK1(K,QP,QC,QSH,COPEE, EHWEFF)
2001.   IHR=K-((K-1)/24)*24
2002.   IF ((IHR.GE.IHRB).AND.(IHR.LE.IHRE)) GO TO 200
2003.   H2ON=H2ON+QP
2004.   CALL UPDATE(XMAX,WSTOR,-QP,RESID,ONE,ONE,XMAX)
2005.   E(K)=E(K)-(QP-RESID)/EHWEFF
2006.   IF (QSH.GT.0) GO TO 100
2007.   HEATN=HEATN+QC
2008.   CALL UPDATE(XMAX,HSTOR,-QC,RESLD,ONE,ONE,XMAX)
2009.   CO TO 101
2010.   100 IF (IHC.NE.1) RETURN
2011.   COOLN=COOLN+QC

```

```

2012.   CALL UPDATE(XMAX,CSTOR,-QC,RESID,ONE,ONE,XMAX)
2013.   101 RESID=(QC-RESID)/COPEE
2014.   E(K)=E(K)-RESID
2015.   QC2=QC2+RESID
2016.   QC1=QC1-RESID
2017.   RETURN
2018.   200 IF (IHR.NE.IHRB) CO TO 250
2019.   OFFBYH=AMAX1(0,(HEATN-HSTOR)/IHRTOT)
2020.   OFFBYW=AMAX1(0,(COOLN-CSTOR)/IHRTOT)
2021.   OFFBYW=AMAX1(0,(H2ON-WSTOR)/IHRTOT)
2022.   HEATN=0
2023.   COOLN=0
2024.   H2ON=0
2025.   250 E(K)=E(K)+OFFBYW/EHWEFF+OFFBYH
2026.   IF (IHC.NE.1) GO TO 275
2027.   CALL COPT(TAIRF,CPC,COPC)
2028.   E(K)=E(K)+OFFBYC/COPC
2029.   CSTOR=CSTOR+OFFBYC
2030.   TOFFPC=TOFFPC+OFFBYC/COPC
2031.   275 HSTOR=HSTOR+OFFBYH
2032.   TOFFPH=TOFFPH+OFFBYH
2033.   WSTOR=WSTOR+OFFBYW
2034.   TOFFPW=TOFFPW+OFFBYW/EHWEFF
2035.   IF (IHR.NE.IHRE) RETURN
2036.   HSTORM=AMAX1(HSTOR,HSTORM)
2037.   CSTORM=AMAX1(CSTORM,CSTOR)
2038.   WSTORM=AMAX1(WSTORM,WSTOR)
2039.   RETURN
3000.   ENTRY OFFPK2
3001.   IF (IHC.EQ.1) WRITE(13,7)
3002.   7  FORMAT(//' OFFPEAK BUYING FOR HEATING,COOLING, AND HOT WATER')
3003.   IF (IHC.NE.1) WRITE(13,8)
3004.   8  FORMAT(//' OFFPEAK BUYING FOR HEATING AND HOT WATER')
3005.   WRITE(13,9) HSTORM,TOFFPH,CSTORM,TOFFPC,WSTORM,TOFFPW
3006.   9  FORMAT(15X,'MAXIMUM',5X,'TOTAL'/15X,'STORAGE',2X,'Electricity'/'%
3007.   ' HEATING:',4X,2(1PE10.3,2X)/' COOLING: ',4X,2(1PE10.3,2X)/'%
3008.   ' HOT WATER: ',2(1PE10.3,2X))
3009.   RETURN
3010.   END

```

Chapter IV

RESULTS OF SYSTEMS ANALYSIS

Chapter IV.—RESULTS OF SYSTEMS ANALYSIS

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Results of Systems Analysis

The tables, which constitute the bulk of this chapter, provide detailed information about a number of integrated solar energy systems designed to meet the energy needs of single family houses, apartment buildings, shopping malls, communities, and industrial plants located in Albuquerque, N. Mex.; Boston, Mass.; Fort Worth, Tex.; and Omaha, Nebr. This extensive catalog was prepared to compare, on an equitable basis, the performance of the enormous variety of systems that are capable of meeting the energy requirements of these buildings and communities. The examples have been chosen to indicate the relative attractiveness of a number of different system components, which may become available during the next decade, and to indicate the facility with which different combinations of components work together as integrated systems.

This chapter is divided into two major parts:

1. A summary table giving the monthly costs for each system analyzed and the effective cost of solar energy generated by each system (this table also serves as an index to the catalog tables, which provide details about each system); and
2. A *catalog* of solar energy systems which devotes one page to each system, summarizing the assumptions made in analyzing its performance.

Chapter I of this report discusses the methods used to evaluate the economic parameters illustrated in the tables. It provides a simple technique for performing an accurate life-cycle cost analysis of energy systems that may be owned by any of several different types of owners. It also discusses the origin of the assumptions made about the financing and tax status of each type of owner. The methodology and data described in this chapter are used in a computer program that calculates the levelized monthly costs for each system; supplies information about the first costs, operating costs, and lifetimes of the system components; the fossil and electrical energy purchased; the assumed escalation rate of energy prices; and the type of owner.

Chapter II discusses the assumptions made about current and future prices of oil, gas, coal, and electricity. It provides information about the price charged for energy now on the market, the marginal cost of new energy sources, the cost of energy from sources likely to be available by the year 2000, and the time over which a transition from one source to another is likely to

occur. A simple mathematical method is presented that can translate differing estimates about future energy sources and costs into a forecast of prices that can be used in life-cycle cost analysis,

Chapter III discusses the computer programs that compute the amount of fuel and electricity that must be purchased annually to meet the energy needs of the building or community. These programs compute the amount of energy that can be provided by any solar energy system used; the purchased energy is the difference between onsite demands and available onsite solar energy.

Chapter V discusses the assumptions made about the cost and performance of each subsystem used in the analysis and provides detailed information about the buildings being analyzed and assumptions made about the energy consumed by the buildings.

An attempt was made to reduce the results of the somewhat complex analysis presented in this report to a set of simple, easily interpretable numbers—a monthly energy bill and an effective solar energy cost in ¢/kWh.

A GUIDE TO THE TABLES

Two types of numbers are provided to represent the costs of the systems examined: 1) a set of levelized monthly costs perceived by the energy consumer, with various assumptions about tax credits given and the price of nonsolar energy, and 2) a cost in ¢/kWh of solar energy (or energy conservation) obtained by comparing it with a "reference system." The reference system represents a conventional energy system operating in a building identical to the one used to analyze the performance of the solar or energy conservation system. An attempt is made to choose a reference system that most nearly resembles the system used to provide backup energy for the solar energy device.

THE SUMMARY TABLES

The summary tables provide the following information about each system examined:

- A brief descriptive title and an identifying number.
- The percentage of the energy used by the reference system that is supplied by the solar energy system. If an energy conservation device is employed that does not use solar energy, this number represents the percentage energy saving. The formula for this percentage (P_s) is as follows:

$$P_s = 100 \frac{E_r - E_t}{E_r}$$

subscript "r" refers to the reference system, subscript "t" refers to the test system, i.e., the system being compared with the reference system.

- The effective cost of solar energy with and without an investment tax credit. (When a conservation system is shown which does not use solar energy, this cost reflects the effective cost of saving

energy using the conservation device.) In some cases, the life-cycle cost of the energy conservation system (excluding the cost of energy purchased) is actually lower than the life-cycle cost of the reference system (excluding the cost of energy purchased) resulting in a situation where the effective cost of the energy conserved is negative.

The formula for effective energy cost (EC) is as follows:

$$EC = \frac{C_r + OM_r + CR_r - C_t - OM_t - CR_t}{E_r - E_t}$$

C = levelized annual capital costs (including financing charges, taxes, and insurance)

OM = levelized annual operating and maintenance costs (excluding purchases of electricity and fuels)

CR = levelized cost of replacements

- The levelized monthly energy costs for the set of owner types described below make four different assumptions about the kinds of tax credits given and the cost of conventional energy.
- A table number that indicates the number of the table in the catalog which describes the system in more detail. When a single number appears in this column, the catalog page corresponds exactly to the summary case. When two numbers appear, the first table number shown describes an identical system, but some of the costs (usually collector costs) shown in the table are not the same as those used to compute the costs shown in the summary table. The second catalog page referenced describes a slightly different system (e. g., it might have a different Collector area), but the unit costs of the components are the same as those used to compute

the costs shown on the line in the summary table, (This method was used to minimize the number of catalog pages.) When the letter "G" appears with a table number, the catalog page referenced describes an identical system which assumes oil fuel prices while the costs shown in the summary table assure that gas was the fuel used. When the letter "M" appears with a table number in the summary table the catalog page referenced describes an identical system owned by an industrial corporation, while the summary table shows the economics for municipal utility ownership. When the letter "T" appears with a table number, the catalog page referenced describes an identical system with ordinary electric rates while the costs shown in the summary table assume that marginal or "time-of-day" rates are charged.

The tables indicate the costs resulting from financing by a homeowner (for single family houses), by a real estate partnership (for apartments and shopping malls), by a municipal utility (for community systems and industries), and by an industrial corporation requiring a 20-percent return on investments (for industries).

Each of these costs is paired with a cost that would result if the additional solar or conservation equipment were owned instead by a privately owned utility. Here, it is assumed that the owner other than the private utility owns a share equal in value to the cost of the reference energy system (i. e., the backup system, in most cases).

THE CATALOG OF ENERGY SYSTEMS

Each page of the catalog is devoted to a single energy system designed to serve the building and the city indicated. The pages are divided into three parts:

- A drawing of the building giving a rough indication of the external appearance of the system.
- An energy flow-diagram indicating the way in which Collectors, storage de-

vices, engines, and energy-consuming devices are combined to meet the energy demands of the buildings.

- A set of three tables providing details about the costs and performance assumed for the system.

- Table A provides an itemized cost list of all components used in the system. It includes an estimate of the first cost, the annual operating and maintenance costs (exclusive of purchased energy) which are charged during the first year of the systems operation, and the expected lifetime of the component (rounded to 10, 15, or 30 years).

The second part of the table indicates the amount of nonsolar energy (*electricity* or fossil fuel) that was purchased to provide backup for the solar energy system. In the case of electricity the amount shown is the difference between the amount purchased from an electric utility and the amount sent from the onsite generating equipment back into the electric grid for possible purchase by the utility. The peak amount of electricity purchased during any hour of the year is also shown.

- Table B provides estimates of the levelized monthly costs for a system that begins operation in 1976, and also for a similar system that would begin operations in 1985. The only difference between the 1976 cases and the 1985 cases is that the conventional energy prices in the 1985 cases have escalated to a higher level by the startup date, as shown in chapter II. For ease of comparison with the 1976 cases, prices have not been inflated between 1976 and 1985 for the 1985 cases (i.e., all cases start in 1976 dollars, and cost inflate at 5.5 percent in each succeeding year). With the advanced solar energy systems, the 1976 costs are shown only for reference purposes; they are not meant to suggest that all technologies examined were available in 1976. The lev-

elized cost of the reference system is also shown for comparison.

The costs achieved with a 20-percent investment tax credit (ITC) could also be reached with low interest loans and other incentives. The table below shows the interest rate of a loan which would result in the same an-

nual capital costs (k,) as a 20-percent ITC.

The costs achieved with "full incentives" assumed a combination of 20-percent investment tax credit, 3-year straight-line depreciation, and exemption from property taxes. These cost reductions could also be reached with tax credits or other incentives.

| Owner | k, 20% ITC | Loan interest (baseline fraction financed) | Loan interest (95% financed) |
|------------------------------------|---------------|--|---------------------------------|
| Homeowner, new construction | 0075 | 0.033 | 0.065 |
| Homeowner, retrofit | 0.092 | 0.048 | 0.043 |
| Real estate owner | 0.067 | 0.019 | 0.070 |
| Industry (20% IRR) | 0.239 | — | 0.274 |
| Municipal utility | 0081 | 0.041 | 0.041 |
| Private utility | 0.126 | 0.066 | 0.045 |

| Owner | k, Full incentives | Equivalent ITC (%) |
|--|-----------------------|-----------------------|
| Homeowner, new construction | 0.031 | 65 |
| Homeowner, retrofit | 0,048 | 65 |
| Real estate owner | 0.022 | 43 |
| Industry (20% IRR) | 0.111 | 58 |
| Municipal utility | 0.061 | 50 |
| Private utility, | 0.071 | 53 |

– Table C provides an estimate of the effective cost of solar (or conservation) energy computed using the technique described in the description of the summary tables. The cost of conventional electricity and fuels levelized over the same time interval are provided for comparison.

SUMMARY TABLE LISTING

| Summary description of system | Table number | Percent solar | Effective cost of solar energy (¢/kWh) | | | | Levelized monthly cost of energy service | | | | | | | |
|--|--------------|---------------|--|-------|---------|-------|--|-----------------------------|--------------------------|-------------------------|--------|------|--------|------|
| | | | No credits | | 20% ITC | | Project Ion 1 No credits | Project Ion 2 No credits | Projection 2 20%A ITC | Projection 3 20% ITC | | | | |
| ALBUQUERQUE SINGLE FAMILY | | | | | | | | | | | | | | |
| <i>Reference system</i> | | | | | | | | | | | | | | |
| Conv. Gas Heat, Gas Hot Water, and Central Electric A/C (SF-1) | 1 | 0.0 | NA/ | NA | NA/ | NA | 116. / | NA | 173. / | NA | 173. / | NA | 287. / | NA |
| Systems compared to reference system | | | | | | | | | | | | | | |
| Conv. Improved Gas Heat, Hot Water, and Central Electric A/c..... | 2 | 11.9 | 71/ | 5.81 | .62/ | 5.73 | 111.1 | 123. | 160./ | 172. | 159. / | 172. | 265./ | 278. |
| Conv. Insulated House; Gas Heat and Hot Water and Central Electric A/C | 3 | 168 | .26/ | 3.98 | .02/ | 3.77 | 106. / | 119. | 153. / | 166. | 152. / | 165. | 253./ | 266. |
| Solar Hot Water; Flat-Plates (1977 Prices); SF-1 | 4 | 15.9 | 6.1 9/ | 2.61 | 5.22/ | 11.78 | 127. / | 148. | 173./ | 195. | 170. / | 192. | 273./ | 295. |
| Solar Hot Water; Flat-Plates (Future Price); SF-1 | 5 | 15.9 | 4.45/ | 0.04 | 3.75/ | 9.44 | 121. / | 140. | 167./ | 186. | 165. / | 184. | 268. / | 287. |
| Solar Heating; Flat-Plates (1977 Prices), Low-Temp. Storage; SF-1 | 6 | 41.0 | 9.47/ | 15.25 | 8.02/ | 14.01 | 172./ | 222. | 201. / | 251. | 188. / | 240. | 276.1 | 328. |
| Solar Heating; Flat-Plates (Future Price), Low-Temp. Storage; SF-1 | 7 | 41.0 | 6.12/ | 10.34 | 5.18/ | 9.53 | 143./ | 179. | 172. / | 208. | 164. / | 201. | 251. / | 289. |
| <i>Reference system</i> | | | | | | | | | | | | | | |
| Conv. Oil Heating and Central Electric A/C (SF-5) | 8 | 0.0 | NA/ | NA | NA/ | NA | 179. / | NA | 230./ | NA | 230. / | NA | 458. / | NA |
| Systems compared to reference system | | | | | | | | | | | | | | |
| Conv. Improved Oil Heating and Central Electric A/C (SF-5) | 9 | 11.5 | .63/ | 5.94 | .55/ | 5.87 | 163. / | 178. | 208./ | 223. | 208./ | 223. | 406. / | 421. |
| Conv. Insulated House; Oil Heating and Central Electric A/C (IF-5) | 10 | 18.5 | -.10/ | 3.16 | -.25/ | 3.03 | 153./ | 167. | 195./ | 209. | 194. / | 209. | 379. / | 393. |
| Solar Hot Water; Flat-Plates (1977 Prices); SF-5 | 11 | 18.0 | 4.76/ | 10.17 | 4.01/ | 9.53 | 173./ | 197. | 216./ | 239. | 212./ | 236. | 396./ | 420. |
| Solar Hot Water; Flat-plates (Future Price); SF-5 | 11/135 | 18.0 | 3.42/ | 8.19 | 2.88/ | 7.73 | 168. / | 188. | 210./ | 230. | 207./ | 228. | 392. / | 413. |
| Solar Heating; Flat-Plates (1977 Prices); Low-Temp. Storage; SF-5 | 12 | 45.4 | 7.46/ | 12.20 | 6.32/ | 11.22 | 194./ | 246. | 222./ | 274. | 209./ | 263. | 326. / | 380. |
| Solar Heating; Flat-Plates (Future Price), Low-Temp. Storage; SF-5 | 12/137 | 45.4 | 4.82/ | 8.33 | 4.08/ | 7.69 | 165./ | 204. | 193./ | 231. | 185./ | 224. | 302. / | 341, |

| Summary description of system | Table number | Percent solar | Effective cost of solar energy (¢/kWh) | | | | Levelized monthly cost of energy service | | | |
|---|--------------|---------------|--|---------------|-------------|-------------|--|-------------|----------------------|--|
| | | | No credits | | 20% ITC | | Project Ion 1 No credits | | Project Ion 2 20%ITC | |
| <i>Reference system</i> | | | | | | | | | | |
| Conv. Gas Heat, Hot Water, and Absorption A/C (IF-7) | 13 | 0.0 | NA/ NA | NA/ NA | 122./ NA | 187. / NA | 187. / NA | 295./ NA | | |
| <i>Systems compared to reference system</i> | | | | | | | | | | |
| Solar Heating and Cooling; Flat-Plates (1977 Prices); Low-Temp. Storage; SF-7 | 14 | 56.2 | 6.55/ 10.87 | 5.55/ 10.01 | 165./ 219. | 190. / 244. | 178./ 233. | 248./ 304. | | |
| Solar Heating and Cooling; Flat-Plates (Future Price), Low-Temp. Storage; SF-7 | 15 | 56.2 | 4.24/ 7.48 | 3.59/ 6.93 | 137. / 177. | 161./ 202. | 153. / 195. | 224. / 265. | | |
| <i>Reference system</i> | | | | | | | | | | |
| Conv. Insulated House; Gas Heat, Hot Water, and Absorption A/C (1 F-7) | 16 | 0.0 | NA/ NA | NA/ NA | 110. / NA | 163. / NA | 163. / NA | 260./ NA | | |
| <i>Systems compared to reference system</i> | | | | | | | | | | |
| Solar Engine Cogeneration, Insulated House; ORCS With Cooling Tower, One-Axis Tracker (Future Design), Low-Temp. Storage; IF-7 | 17 | 42.2 | 14.66/ 22.99 | 12.71 / 21.32 | 184. / 249. | 218./ 283. | 203./ 270. | 235./ 302. | | |
| Solar Engine Cogeneration, Insulated House; ORCS With Cooling Tower, One-Axis Tracker (Future Design), High-Temp. Storage, Gas Backup; IF-7 | 18 | 67.8 | 10.26/ 15.99 | 8.84/ 14.77 | 183./ 255. | 203./ 275. | 185. / 259. | 203. / 277. | | |
| Solar Engine Cogeneration, Insulated House; ORCS With Cooling Tower, One-Axis Tracker (Future Design), Battery and High-Temp. Storage, Gas Backup; IF-7 | 19 | 63.7 | 12.75/ 19.52 | 11.02/ 18.05 | 207./ 287. | 229./ 309. | 209. / 291. | 229. / 312. | | |
| Conv. Engine Cogeneration, insulated House; Stirling Engine (Low Eff.) Direct-Drive Heat Pump, Gas Hot Water; IF-9 | 20 | 45.6 | 5.45/ 8.28 | 5.23/ 8.09 | 113. / 137. | 146. / 170. | 144./ 168. | 174. / 198. | | |
| <i>Reference system</i> | | | | | | | | | | |
| Conv. System, All Electric; Heat Pump (SF-1). | 21 | 0.0 | NA/ NA | NA/ NA | 156. / NA | 203. / NA | 203./ NA | 395./ NA | | |
| <i>Systems compared to reference system</i> | | | | | | | | | | |
| Conv. System, All Electric; Improved Heat Pump (High Price) (SF-2) | 22 | 14.5 | 5.27/ 10.32 | 4.78/ 9.91 | 162. / 181. | 203./ 222. | 201./ 221. | 367./ 387. | | |
| Conv. System, All Electric; Improved Heat Pump (Low Price) (SF-2) | 23 | 14.5 | 1.34/ 4.97 | 1.22/ 4.87 | 46. / 160. | 187. / 201. | 187. / 201. | 353./ 367. | | |
| Solar Hot Water; Flat-Plates (1977 Prices); SF-2 | 24 | 28.4 | 2.67/ 5.51 | 2.25/ 5.15 | 47./ 169. | 182. / 204. | 179. / 201. | 321./ 343. | | |
| Solar Hot Water; Flat-Plates (Future Price); SF-2 | 24/150 | 28.4 | 1.91 / 4.39 | 1.61/ 4.13 | 41./ 160. | 176. / 195. | 174. / 193. | 316./ 336. | | |

Systems compared to reference system—Continued

| | | | | | | | | | |
|--|--------|-------|--------------|--------------|-------------|-------------|-------------|-------------|--|
| Solar Heating; Flat-Plates (1977 Prices), Low-Temp. Storage; SF-2 | 25 | 37.0 | 5.22/ 883 | 4.43/ 816 | 170 / 206. | 201 / 237 | 193. / 230. | 321 ./ 358 | |
| Solar Heating; Flat-Plates (1977 Prices); SF-2 | 26 | 41.4 | 5.32/ 886 | 4.51 / 817 | 172 / 212. | 202. / 241. | 193. / 234. | 313. / 354. | |
| Solar Heating; Flat-Plates (Future Price); SF-2 | 26/154 | 414 | 3.53/ 624 | 2.98/ 578 | 152. / 183 | 182 / 212 | 176. / 207 | 295 / 327 | |
| Solar Heating; Flat-Plates (1977 Prices), Low-Temp. Storage; SF-2 | 27 | 48.4 | 6.22/ 10.04 | 5.26/ 9.23 | 187 / 237. | 213 / 263 | 201. / 253. | 309. / 361 | |
| Solar Heating; Flat-Plates (Future Price), Low-Temp. Storage; SF-2 | 27/154 | 484 | 4.02/ 682 | 3.40/ 6.29 | 158 / 195. | 184 / 221 | 176 / 214 | 284. / 322. | |
| 100-Percent Solar Heating; Flat-Plates (1977 Prices), Community Seasonal Low-Temp. Storage; SF-2 | 28 | 65.4 | 7.17/ 11.20 | 5.90/ 10.12 | 214. / 286. | 234. / 305 | 211 / 286. | 290 / 364 | |
| 100-Percent Solar Heating; Flat-Plates (Future Price), Community Seasonal Storage; SF-2 | 29 | 65.4 | 4.36/ 7.00 | 3.62/ 6.37 | 165. / 211. | 184. / 231 | 171 / 219 | 249./ 298 | |
| PV System; Air-Cooled Si Arrays (\$0.50/W); SF-2 | 30 | 85.6 | 5.29/ 8.31 | 4.44/ 7.59 | 213./ 284. | 234. / 304. | 215 / 288. | 299. / 372 | |
| PV System; Air-Cooled Thin-Film Arrays (\$0.10/W); SF-2 | 31 | 59.9 | 2.05/ 3.78 | 1.72/ 3.50 | 141./ 169. | 169./ 197. | 163. / 192. | 276./ 305. | |
| PV Cogeneration; One-Axis Concentrator With Si Cells (\$15/W Cells), Multitank Low-Temp. Storage; SF-2 | 32 | 92.7 | 11.66/ 17.65 | 9.81 / 16.08 | 358. / 508. | 368. / 519. | 322. / 479. | 364 / 521. | |
| Reference system | | | | | | | | | |
| Conv. Insulated All Electric House; Heat Pump (IF-2) | 33 | 0.0 | NA/ NA | NA/ NA | 142. / NA | 183. / NA | 183. / NA | 350./ NA | |
| Systems compared to reference system | | | | | | | | | |
| PV System, Insulated House; Air-Cooled Si Arrays (\$1/W); IF-2 | 34/171 | 51.9 | 9.68/ 15.33 | 8.15/ 14.03 | 222./ 291. | 249./ 317. | 230./ 302. | 338./ 409. | |
| PV System, Insulated House; Air-Cooled Si Arrays (\$0.50/W); IF-2 | 34 | 51.9 | 5.37/ 9.00 | 4.53/ 8.28 | 170. / 214. | 197. / 241. | 187./ 232. | 294./ 340. | |
| PV System; Air-Cooled Si Arrays (\$0.50/W), Battery Storage; IF-2 | 35 | 45.2 | 8.50/ 13.49 | 7.32/ 12.49 | 190. / 243. | 215./ 267. | 202. / 257. | 303./ 357. | |
| PV System, Insulated House; Air-Cooled Si Arrays (\$0.50/W); Improved IF-2 | 36 | 61.2 | 4.78/ 7.94 | 4.04/ 7.31 | 165. / 210. | 188./ 233. | 178. / 224. | 272. / 319. | |
| PV System, Insulated House; Air-Cooled Thin-Film Arrays (\$0.30/W); IF-2 | 37 | 29.1 | 4.24/ 8.23 | 3.55/ 7.64 | 148./ 175. | 180./ 207. | 175. / 203. | 306./ 333. | |
| PV System, Insulated House; Air-Cooled Thin-Film Arrays (\$0.10/W); IF-2 | 38 | 37.5 | 2.05/ 4.58 | 1.71 / 4.29 | 132./ 154. | 162./ 184. | 159. / 181. | 281./ 303. | |
| PV System, Insulated House; Air-Cooled Thin-Film Arrays (\$0.10/W); Improved SF-2. | 39 | 46.2 | 1.99/ 4.15 | 1.69/ 3.89 | 127. / 151. | 154./ 177. | 151. / 175. | 260./ 283. | |
| PV Cogeneration, Insulated House; One-Axis Concentrator With Si Cells (\$15/W) Cells, Multitank Low-Temp. Storage; IF-2. | 40 | 76.7 | 8.95/ 13.89 | 7.55/ 12.69 | 235./ 323. | 249. / 337. | 224./ 316. | 282. / 374. | |
| PV Cogeneration, Insulated House; Plastic Dye PV Concentrator, Multitank Low-Temp. Storage; IF-2. | 41 | 100.8 | 2.63/ 4.41 | 2.21 / 4.05 | 124. / 166. | 133./ 175 | 123. / 166 | 160. / 203 | |
| PV System, Insulated House; Plastic Dye PV Concentrator With Passive Cooling; IF-2. | 42 | 90.0 | 2.36/ 4.12 | 1.98/ 3.80 | 133. / 170. | 150. / 187. | 142. / 181. | 214. / 252. | |

| Summary description of system | Table number | Percent solar | Effective cost of solar energy (¢/kWh) | | | | Levelized monthly cost of energy service | | | |
|---|--------------|---------------|--|----------------|-------------|-------------|--|----------------------------|-------------------------|-------------------------|
| | | | No credits | | 200/0 ITC | | Project Ion 1 No credits | Projection 2 No credits | Projection 2 20% ITC | Projection 3 20% ITC |
| <i>Systems compared to reference system—Continued</i> | | | | | | | | | | |
| <i>PV System, Insulated House; Air-Cooled Si Arrays (\$0.50/W), Low-Temp. Storage; Improved IF-2</i> | 43 | 73.9 | 5.75/ 8.87 | 5.02/ 8.24 | 157. / 211. | 177. / 231. | 164./ 220. | 182./ 238. | | |
| <i>Reference system</i> | | | | | | | | | | |
| <i>Conv. All Electric House; Resistance Heat and Window A/C (SF-3)</i> | 44 | 0.0 | NA/ NA | NA/ NA | 177. / NA | 238. / NA | 238./ NA | 490./ NA | | |
| <i>Systems compared to reference system</i> | | | | | | | | | | |
| <i>Conv. All Electric House; Resistance Heat and Window A/C, 65/85 Thermostat (SF-3)</i> | 45 | 4.2 | -.00/ 5.27 | -.00/ 5.27 | 171. / 179. | 230./ 238. | 230./ 238. | 472./ 480. | | |
| <i>Conv. Insulated All Electric House; Resistance Heat and Window A/C (IF-3)</i> | 48 | 21.5 | .37/ 1.63 | .251 1.53 | 149./ 159. | 198./ 208. | 197./ 207. | 399./ 409. | | |
| <i>Solar Heating; Flat-Plates (Future Price), Low-Temp. Storage; SF-4</i> | 49 | 47.0 | 3.47/ 5.54 | 2.94/ 5.09 | 169./ 205. | 204./ 240. | 195. / 232. | 337./ 374. | | |
| <i>Solar Heating; Flat-Plates (Future Price), Low-Temp. Storage; SF-4</i> | 49/192 | 47.0 | 2.31/ 3.83 | 1.95/ 3.53 | 149./ 176. | 184./ 211. | 178. / 205. | 320. / 347. | | |
| <i>Solar Heating; Flat-Plates (1977 Prices), Low-Temp. Storage; SF-4</i> | 52 | 56.2 | 3.98/ 6.23 | 3.37/ 5.70 | 179./ 224. | 208./ 254. | 196./ 243. | 317. / 364. | | |
| <i>Solar Heating; Flat-Plates (Future Price), Low-Temp. Storage; SF-4</i> | 53 | 67.2 | 2.83/ 4.48 | 2.39/ 4.11 | 151./ 191. | 174. / 215. | 163./ 205. | 259./ 301. | | |
| ALBUQUERQUE SINGLE FAMILY TIME-OF-DAY RATES | | | | | | | | | | |
| <i>Reference system</i> | | | | | | | | | | |
| <i>Conv. All Electric House (SF-3); Marginal Electric Rates</i> | T44 | 0.0 | NA/ NA | NA/ NA | 241./ - NA | 241./ NA | 241./ NA | 241./ NA | | |
| Systems compared to reference system | | | | | | | | | | |
| <i>Conv. Off-Peak Electric Heating; Window A/C, Low-Temp. Storage (SF-4)</i> | 46 | | | | | | | | | |
| <i>Conv. Off-Peak Electric Heating and Cooling System; Central Electric Chilling, Low-Temp. Thermal and Cold Storage (SF-4)</i> | 47 | -6 | -96.34/ .***** | -75.80/ .***** | 183./ 204. | 183./ 204. | 179./ 200. | 179./ 200. | | |
| <i>Solar Off-Peak Heating; Flat-Plates (1977 Prices), Low-Temp. Storage; SF-4</i> | 50 | .1 | ● .***** | ● .***** | 197./ 232. | 197./ 232. | 188./ 225. | 188./ 225. | | |
| <i>Solar Off-Peak Heating; Flat-Plates (Future Price), Low-Temp. Storage; SF-4</i> | 50/194 | 46.7 | 4.06/ 6.42 | 3.42/ 5.87 | 196./ 236. | 196./ 236. | 185./ 227. | 185./ 227. | | |
| <i>Solar Off-Peak Heating and Cooling; Flat-Plates (1977 Prices), Low-Temp. Storage; SF-4</i> | 51 | 47.2 | 2.88/ 4.70 | 2.42/ 4.31 | 176./ 207. | 176./ 207. | 168./ 200. | 168./ 200. | | |
| <i>Solar Off-Peak Heating and Cooling; Flat-Plates (Future Price), Low-Temp. Storage; SF-4</i> | 51/196 | 47.2 | 6.28/ 9.69 | 5.33/ 8.89 | 212./ 271. | 212./ 271. | 196./ 258. | 196./ 258. | | |

BOSTON SINGLE FAMILY

Reference system

| | | | | | | | | | | | | | | | | | |
|--|----|-----|-----|----|-----|----|------|---|----|------|---|----|------|---|----|-------|----|
| Conv. Gas Heat, Hot Water, and Central Electric A/C (SF-1) | 54 | 0.0 | NAI | NA | NAI | NA | 204. | / | NA | 328. | / | NA | 328. | / | NA | 549./ | NA |
|--|----|-----|-----|----|-----|----|------|---|----|------|---|----|------|---|----|-------|----|

Systems compared to reference system

| | | | | | | | | | | | | | | | | | |
|---|--------|------|--------|-------|--------|-------|-------|------|-------|-------|-------|-------|-------|-------|------|------|------|
| Conv. Improved Gas Heat, Hot Water, and Central Electric A/C (SF-1) | 55 | 12.8 | .73/ | 5.92 | .64/ | 5.84 | 188. | / | 202. | 293./ | 307. | 293. | / | 307. | 496. | / | 510. |
| Conv. Gas Heat, Hot Water, Central Electric Chilling, 65/85 Thermostat (SF-1) | 56 | 5.5 | -.00/ | 11.36 | -.00/ | 11.36 | 193. | / | 206. | 312./ | 325. | 312./ | 325. | 514./ | 527. | | |
| Solar Hot Water; Flat-Plates (1977 Prices); SF-1 | 57 | 12.0 | 9.46/ | 19.01 | 7.97/ | 17.74 | 211./ | 235. | 317.1 | 341. | 314./ | 338. | 518./ | 542. | | | |
| Solar Hot Water; Gas Heat, Central Electric A/C; SF-1 | 57/125 | 12.0 | 6.66/ | 14.88 | 5.61/ | 13.98 | 204./ | 225. | 310./ | 331. | 308./ | 329. | 512./ | 533. | | | |
| Solar Heating; Flat-Plates (1977 Prices), Low-Temp. Storage; SF-1 | 58 | 34.1 | 15.44/ | 24.47 | 13.06/ | 22.44 | 266. | / | 330. | 340./ | 404. | 323./ | 390. | 498. | / | 564. | |
| Solar Heating; Flat-Plates (Future Price), Low-Temp. Storage; SF-1 | 58/127 | 34.1 | 9.80/ | 16,19 | 8.28/ | 14.89 | 226./ | 272. | 300./ | 345. | 289./ | 336. | 464./ | 511. | | | |

Reference system

| | | | | | | | | | | | | | | | | | |
|---|----|-----|-----|----|-----|----|-------|----|-------|----|------|---|----|-------|----|--|--|
| Conv. Insulated House; Gas Heat, Hot Water, and Central Electric A/C (IF-1) | 59 | 0.0 | NA/ | NA | NAI | NA | 174./ | NA | 266./ | NA | 266. | / | NA | 456./ | NA | | |
|---|----|-----|-----|----|-----|----|-------|----|-------|----|------|---|----|-------|----|--|--|

Systems compared to reference system

| | | | | | | | | | | | | | | | | | |
|---|----|-------|---------|--------|--------|--------|-------|------|-------|------|-------|------|------|-------|------|--|--|
| Conv. Insulated House; Improved Gas Heat, Hot Water, and Central Electric A/C (IF-1) | 60 | 12.3 | .74/ | 7.97 | .65/ | 7.89 | 62./ | 176. | 240./ | 255. | 240./ | 255. | 416. | / | 431. | | |
| Conv. Insulated House; Oil Heat and Central Electric A/C (IF-5) | 61 | -12.9 | -3.74/ | -11.07 | -3.53/ | -10.89 | 96./ | 211. | 303./ | 318. | 303. | / | 318. | 506./ | 521. | | |
| Conv. Insulated House; Gas Heat, Hot Water, and Absorption Cooling (IF-7) | 62 | -3.5 | -5.61 / | -35.64 | -3.86/ | -34.15 | 76./ | 193. | 277./ | 294. | 276. | / | 293. | 455./ | 472. | | |
| Conv. Engine Cogeneration; Insulated House; Stirling Engine (Low Eff.), Heat Pump, Gas Hot Water, Low-Temp. Storage, Gas Backup; IF-9 | 63 | 42.8 | 5.23/ | 8.44 | 4.92/ | 8.17 | 134./ | 157. | 200./ | 222. | 198. | / | 221. | 259./ | 282. | | |

Reference system

| | | | | | | | | | | | | | | | | | |
|--|----|-----|-----|----|-----|----|-------|----|-------|----|-------|----|-------|----|--|--|--|
| Conv. Oil Heat and Central Electric A/C (SF-5) | 64 | 0.0 | NA/ | NA | NA/ | NA | 230./ | NA | 301./ | NA | 301./ | NA | 609./ | NA | | | |
|--|----|-----|-----|----|-----|----|-------|----|-------|----|-------|----|-------|----|--|--|--|

Systems compared to reference system

| | | | | | | | | | | | | | | | | | |
|---|--------|------|--------|-------|--------|-------|-------|------|-------|------|-------|------|-------|-------|------|------|--|
| Conv. Improved Oil Heat, Gas Hot Water, and Central Electric A/C (SF-5) | 65 | 13.9 | .57/ | 5.44 | .50/ | 5.38 | 211.1 | 227. | 274./ | 290. | 274./ | 290. | 546.1 | 563. | | | |
| Conv. Oil Heat and Central Electric A/C, 65/85 Thermostat (SF-5) | 66 | 4.7 | -.00/ | 13.48 | -.00/ | 13.48 | 219./ | 235. | 285./ | 301. | 285./ | 301. | 575./ | 590. | | | |
| Solar Hot Water; Flat-Plates (1977 Prices); SF-5 | 67 | 13.0 | 7.56/ | 15.98 | 6.37/ | 14.96 | 234./ | 260. | 298./ | 324. | 294./ | 321. | 568./ | 595. | | | |
| Solar Hot Water; Flat-Plates (Future Price); SF-5 | 67/135 | 13.0 | 5.32/ | 12.67 | 4.48/ | 11.96 | 227.1 | 250. | 291./ | 314. | 288./ | 311. | 563./ | 586. | | | |
| Solar Heating; Flat-Plates (1977 Prices), Low-Temp. Storage; SF-5 | 68 | 36.9 | 12.35/ | 19.85 | 10.45/ | 18.23 | 283./ | 350. | 334./ | 400. | 317. | / | 386. | 530./ | 599. | | |
| Solar Heating; Flat-Plates (Future Price), Low-Temp. Storage; SF-5 | 68/137 | 36.9 | 7.84/ | 13.22 | 6.62/ | 12.19 | 243./ | 291. | 294.1 | 341. | 283. | / | 332. | 496. | / | 545. | |

| Summary description of system | Table number | Percent solar | Effective cost of solar energy (¢/kWh) | | | | Levelized monthly cost of energy service | | | | | |
|--|--------------|---------------|--|--------------|------------|------------|--|------------|----------------------|--|----------------------|--|
| | | | No credits | | 200/0 ITC | | Projection 1 No credits | | Projection 2 20% ITC | | Projection 3 20% ITC | |
| <i>Reference system</i> | | | | | | | | | | | | |
| Conv. Gas Heat, Hot Water, and Absorption A/C (SF-7)..... | 69 | 0.0 | NA/ NA | NA/ NA | 208./ NA | 341./ NA | 341./ NA | 552./ NA | | | | |
| <i>Systems compared to reference system</i> | | | | | | | | | | | | |
| Solar Heating and Cooling; Flat-Plates (1977 Prices); Low-Temp. Storage; SF-7..... | 70 | 42.2 | 12.12/ 19.69 | 10.25/ 18.09 | 258./ 326. | 326./ 395. | 310./ 380. | 461./ 532. | | | | |
| Solar Heating and Cooling; Flat-Plates (Future Price); Low-Temp. Storage; SF-7..... | 70/143 | 42.2 | 7.69/ 13.19 | 6.50/ 12.17 | 218./ 267. | 287./ 336. | 276./ 327. | 427./ 479. | | | | |
| <i>Reference system</i> | | | | | | | | | | | | |
| Conv. All Electric House; Heat Pump (SF-2) . . . | 71 | 0.0 | NA/ NA | NA/ NA | 261./ NA | 349./ NA | 349./ NA | 709./ NA | | | | |
| <i>Systems compared to reference system</i> | | | | | | | | | | | | |
| Conv. All Electric House; Improved Heat Pump (SF-2)..... | 72 | 15.2 | 1.31/ 4.85 | 1.19/ 4.74 | 239./ 254. | 317./ 332. | 316./ 331. | 631./ 646. | | | | |
| Solar Hot Water; Flat-Plates (1977 Prices); SF-2..... | 73 | 20.4 | 4.08/ 8.25 | 3.44/ 7.71 | 248./ 272. | 321./ 345. | 318./ 342. | 617./ 642. | | | | |
| Solar Hot Water; Flat-Plates (Future Price); SF-2..... | 73/150 | 20.4 | 2.86/ 6.46 | 2.41/ 6.07 | 241./ 261. | 314./ 335. | 312./ 333. | 611./ 632. | | | | |
| Solar Heating; Flat-Plates (1977 Prices), Low-Temp. Storage; SF-2..... | 74 | 28.7 | 5.48/ 10.04 | 4.36/ 9.08 | 254./ 290. | 321./ 358. | 312./ 350. | 587./ 626. | | | | |
| Solar Heating; Flat-Plates (Future Price), Low-Temp. Storage; SF-2..... | 74/154 | 28.7 | 2.99/ 6.40 | 2.24/ 5.76 | 233./ 261. | 301./ 329. | 295./ 323. | 570./ 599. | | | | |
| Solar Heating; Flat-Plates (1977 Prices), Low-Temp. Storage; SF-2..... | 75 | 40.3 | 9.64/ 15.30 | 8.15/ 14.03 | 298./ 362. | 357./ 421. | 340./ 407. | 581./ 647. | | | | |
| Solar Heating; Flat-Plates (Future Price), Low-Temp. Storage; SF-2..... | 75/154 | 40.3 | 6.12/ 10.12 | 5.17/ 9.31 | 258./ 303. | 317./ 362. | 306./ 353. | 547./ 594. | | | | |
| PV System; Air-Cooled Si Arrays (\$50/W); SF-2 | 76 | 57.0 | 7.64/ 12.05 | 6.42/ 11.01 | 305./ 376. | 362./ 433. | 343./ 416. | 574./ 648. | | | | |
| PV System; Air-Cooled Thin-Film Arrays (\$10/W); SF-2..... | 77 | 40.2 | 3.53/ 6.33 | 2.95/ 5.83 | 242./ 274. | 307./ 339. | 301./ 333. | 565./ 598. | | | | |
| PV Cogeneration; One-Axis Concentrator With Si Cells (\$15/W Cells); Multitank Low-Temp. Storage; SF-2..... | 78 | 63.3 | 16.44/ 24.93 | 13.84/ 22.72 | 448./ 599. | 494./ 645. | 447./ 605. | 633./ 791. | | | | |
| <i>Reference system</i> | | | | | | | | | | | | |
| Conv. Insulated All Electric House; Heat Pump (IF-2)..... | 79 | 0.0 | NA/ NA | NA/ NA | 226./ NA | 300./ NA | 300./ NA | 601./ NA | | | | |
| <i>Systems compared to reference system</i> | | | | | | | | | | | | |
| Conv. Insulated All Electric House; Improved Heat Pump (IF-2)..... | 80 | 10.7 | 1.67/ 8.21 | 1.51/ 8.08 | 214./ 230. | 282./ 298. | 282./ 297. | 558./ 574. | | | | |
| PV System, Insulated House; Air-Cooled Si Arrays (\$0.50/W); IF-2..... | 81 | 36.8 | 7.75/ 3.11 | 6.53/ 12.07 | 247./ 292. | 304./ 348. | 293./ 340. | 524./ 570. | | | | |
| PV System, Insulated House; Air-Cooled Si Arrays (\$0.50/W), Battery Storage; IF-2..... | 82 | 32.8 | 12.09/ 9.31 | 10.42/ 17.88 | 268./ 321. | 323./ 376. | 310./ 366. | 534./ 589. | | | | |

| | | | | | | | | |
|--|--------|------|--------------|--------------|-------------|-------------|-------------|-------------|
| PV System, Insulated House; Air-Cooled Si Arrays (\$0.50/W); IF-2 | 83 | 46.3 | 6.55/ 10.96 | 5.55/ 10.11 | 238./ 284. | 289. / 335. | 278./ 326. | 487./ 534. |
| PV System, Insulated House; Air-Cooled Thin-Film Arrays (\$0.10/W); IF-2 | 84 | 35.8 | 2.70/ 5.71 | 2.29/ 5.36 | 202./ 226. | 257./ 281. | 254./ 279. | 480. / 505. |
| PV Cogeneration, Insulated House; One-Axis Concentrator With Si Cells (\$15/W Cells), Multitank Low-Temp. Storage; Improved IF-2 | 85 | 58.9 | 12.06/ 18.78 | 10.18/ 17.17 | 302./ 392. | 343.1 432. | 317./ 410. | 482./ 575 |
| PV System, Insulated House; Heat Engine, Air-Cooled Silicon Arrays (\$0.50/W), Low-Temp. Storage; IF-2 | 86 | 71.2 | 5.78/ 9.02 | 5.02/ 8.37 | 178. / 230. | 224./ 276. | 212. / 266. | 255./ 308. |
| <i>Reference system</i> | | | | | | | | |
| Conv. All Electric House; Resistance Heat and Window A/C (SF-3) | 87 | 0.0 | NA/ NA | NA/ NA | 307./ NA | 421./ NA | 421./ NA | 883./ NA |
| <i>Systems compared to reference system</i> | | | | | | | | |
| Conv. All Electric House; Resistance Heat and Window A/C, 65/85 Thermostat (SF-3) | 88 | 2.5 | -.00/ 9.38 | -.00/ 9.38 | 301./ 310. | 412. / 421. | 412. / 421. | 865./ 874. |
| Solar Heating; Flat-Plates (1977 Prices), Low-Temp. Storage; SF-4 | 89 | 43.9 | 6.54/ 10.12 | 5.53/ 9.26 | 309./ 369. | 380./ 440. | 363./ 425. | 651./ 713. |
| Solar Heating; Flat-Plates (Future Price), Low-Temp. Storage; SF-4 | 89/198 | 43.9 | 4.14/ 6.60 | 3.50/ 6.05 | 269./ 310. | 340./ 381. | 329. / 372. | 617.1 659. |
| <i>Reference system</i> | | | | | | | | |
| Conv. Insulated All Electric House; Resistance Heat and Window A/C (IF-3) | 90 | 0.0 | NA/ NA | NA/ NA | 240./ NA | 326./ NA | 326./ NA | 676./ NA |
| <i>Systems compared to reference system</i> | | | | | | | | |
| Conv. Insulated House; Resistance Heat and Window A/C, 65/85 Thermostat (IF-3) | 91 | 3.5 | -.00/ 11.10 | -.00/ 11.10 | 234./ 245. | 318./ 328. | 318./ 328. | 658./ 668 |
| FORT WORTH SINGLE FAMILY | | | | | | | | |
| <i>Reference system</i> | | | | | | | | |
| Conv. Gas Heat, Hot Water, and Central Electric A/C (SF-7) | 92 | 0.0 | NA/ NA | NA/ NA | 132./ NA | 188./ NA | 188./ NA | 326./ NA |
| <i>Systems compared to reference system</i> | | | | | | | | |
| Conv. Improved Gas Heat, Hot Water, and Central Electric A/C (SF-1) | 93 | 9.2 | .87/ 7.70 | .76/ 7.60 | 127./ 141. | 177. / 191. | 176. / 190. | 309./ 323. |
| Conv. Insulated House; Gas Heat, Hot Water, and Central Electric A/C (IF-1) | 94 | 20.2 | -.21/ 2.81 | -.35/ 2.69 | 115./ 129. | 158./ 172. | 158./ 171. | 277./ 291. |
| Solar Hot Water Flat-plates (1977 Prices); SF-1 | 95 | 12.1 | 8.20/ 16.89 | 6.91/ 15.79 | 146./ 169. | 193. / 216. | 189. / 213. | 320./ 344. |
| Solar Hot Water; Flat-plates (Future price); SF-1 | 95/5 | 12.1 | 5.83/ 13.39 | 4.91 / 12.60 | 139./ 160. | 186./ 207. | 184. / 205. | 315./ 335 |
| Solar Heating; Flat-plates (1977 Prices), Low-Temp. Storage; SF-1 | 96 | 25.3 | 13.17/ 21.60 | 11.16/ 19.88 | 189. / 236. | 227. / 274. | 215. / 264. | 337./ 386 |
| Solar Heating; Flat-plates (Future Price), Low-Temp. Storage; SF-1 | 96/127 | 25.3 | 8.57/ 14.87 | 7.25/ 13.74 | 163./ 198, | 201. / 236. | 193. / 230. | 315./ 351. |

| Summary description of system | Table number | Percent solar | Effective cost of solar energy (¢/kWh) | | | | Levelized monthly cost of energy service | | | | | | | |
|--|--------------|---------------|--|--------------|-------------|------------|--|------------|-------------------------|--------|---------------------|--------|---------------------|--------|
| | | | No credits | | 200/0 ITC | | Projection 1 No credits | | Projection 2 No credits | | Projection 2 20%ITC | | Projection 3 20%ITC | |
| <i>Reference system</i> | | | | | | | | | | | | | | |
| Conv. Gas Heat, Hot Water, and Absorption A/C (SF-7) | 97 | 0.0 | NA/ NA | NA/ NA | NA/ NA | NA/ NA | 134./ NA | NA/ NA | 206./ NA | NA/ NA | 206./ NA | NA/ NA | 321./ NA | NA/ NA |
| <i>Systems compared to reference system</i> | | | | | | | | | | | | | | |
| Conv. Insulated House; Gas Heat, Hot Water, and Absorption A/C (IF-7) | 98 | 19.4 | -.63/ 3.02 | -.68/ 2.98 | 116./ 133. | 173./ 190. | 173./ 190. | 273./ 290. | | | | | | |
| Solar Heating and Cooling; Flat-Plates (1977 Prices); Low-Temp. Storage; SF-7 | 99 | 47.7 | 9.45/ 15.43 | 7.99/ 14.19 | 208./ 277. | 242./ 311. | 225./ 297. | 306./ 378. | | | | | | |
| Solar Heating and Cooling; Flat-Plates (Future Price); Low-Temp. Storage; SF-7 | 99/143 | 47.7 | 6.00/ 10.37 | 5.07/ 9.57 | 168./ 219. | 202./ 253. | 191./ 244. | 272./ 324. | | | | | | |
| <i>Reference system</i> | | | | | | | | | | | | | | |
| Conv. All Electric House; Heat Pump (SF-2) | 100 | 0.0 | NA/ NA | NA/ NA | NA/ NA | NA/ NA | 179./ NA | NA/ NA | 233./ NA | NA/ NA | 233./ NA | NA/ NA | 451./ NA | NA/ NA |
| <i>Systems compared to reference system</i> | | | | | | | | | | | | | | |
| Conv. All Electric House; Improved Heat Pump (High Cost) (SF-2) | 101/125 | 15.0 | 6.16/ 11.89 | 5.59/ 11.41 | 186./ 210. | 232./ 256. | 229./ 254. | 417./ 441. | | | | | | |
| Conv. All Electric House; Improved Heat Pump (SF-2) | 101 | 15.0 | 1.55/ 5.61 | 1.41/ 5.49 | 166./ 183. | 213./ 229. | 212./ 229. | 399./ 416. | | | | | | |
| Solar Hot Water; Flat-Plates (1977 Prices); SF-2 | 102 | 22.3 | 3.54/ 7.53 | 2.98/ 7.06 | 173./ 198. | 215./ 240. | 212./ 237. | 384./ 409. | | | | | | |
| Solar Hot Water; Flat-Plates (Future Price); SF-2 | 102/150 | 22.3 | 2.50/ 6.01 | 2.11/ 5.67 | 166./ 188. | 209./ 230. | 206./ 228. | 379./ 401. | | | | | | |
| Solar Heating; Flat-Plates (1977 Prices), Low-Temp. Storage; SF-2 | 103 | 26.5 | 6.26/ 11.09 | 5.31/ 10.28 | 192./ 227. | 232./ 268. | 225./ 262. | 388./ 425. | | | | | | |
| Solar Heating; Flat-Plates (Future Price), Low-Temp. Storage; SF-2 | 103/152 | 26.5 | 4.16/ 8.03 | 3.53/ 7.49 | 176./ 205. | 216./ 245. | 212./ 241. | 375./ 405. | | | | | | |
| Solar Heating; Flat-Plates (1977 Prices), Low-Temp. Storage; SF-2 | 104 | 34.9 | 7.65/ 12.70 | 6.48/ 11.70 | 209./ 258. | 245./ 294. | 234./ 285. | 380./ 431. | | | | | | |
| Solar Heating; Flat-Plates (Future Price), Low-Temp. Storage; SF-2 | 104/154 | 34.9 | 4.98/ 8.79 | 4.21/ 8.13 | 183./ 220. | 219./ 256. | 212./ 250. | 358./ 396. | | | | | | |
| PV System; Air-Cooled Si Arrays (\$0.50/W); SF-2 | 105 | 64.9 | 6.78/ 10.79 | 5.70/ 9.86 | 238./ 311./ | 266./ 339. | 247./ 322. | 362./ 437. | | | | | | |
| PV System; Air-Cooled Thin-Film Arrays (\$0.10/W); SF-2 | 106 | 45.5 | 2.63/ 5.03 | 2.20/ 4.66 | 165./ 195. | 199./ 230. | 194./ 225. | 335./ 366. | | | | | | |
| PV Cogeneration; One-Axis Concentrator With Si Cells (\$15/W Cells), Multitank Low-Temp. Storage; SF-2 | 107 | 58.4 | 17.96/ 27.33 | 15.12/ 24.91 | 401./ 553. | 427./ 579. | 380./ 540. | 484./ 643. | | | | | | |

Reference system

| | | | | | | | | | | | | | | |
|--|-----|-----|-----|----|-----|----|-------|----|-------|----|-------|----|-------|----|
| Conv. Insulated All Electric House; Heat Pump (IF-2) | 108 | 0.0 | NA/ | NA | NA/ | NA | 157./ | NA | 203./ | NA | 203./ | NA | 387./ | NA |
|--|-----|-----|-----|----|-----|----|-------|----|-------|----|-------|----|-------|----|

Systems compared to reference system

| | | | | | | | | | | | | | | |
|--|----------|------|--------|-------|-------|-------|-------|------|-------|------|-------|------|-------|------|
| Conv. Insulated All Electric House; Improved Heat Pump (IF-2) | 109 | 11.4 | 1.79/ | 8.31 | 1.63/ | 8.17 | 150./ | 167. | 191./ | 208. | 190./ | 207. | 355./ | 372. |
| PV System, Insulated House; Air-Cooled Si Arrays (\$ I/W); Improved IF-2 | 11 2/172 | 50.3 | 10.38/ | 16.54 | 8.76/ | 15.16 | 234./ | 306. | 261./ | 333. | 242.1 | 317. | 352./ | 427. |
| PV System, Insulated House; Air-Cooled Thin-Film Arrays (\$0.50/W); IF-2 | 110 | 40.2 | 6.89/ | 11.79 | 5.81/ | 10.86 | 186./ | 232. | 217./ | 263. | 207./ | 254. | 333./ | 380. |
| PV System, Insulated House; Air-Cooled Thin-Film Arrays (\$0.50/w), Battery Storage; IF-2 | 111 | 36.6 | 10.54/ | 16.97 | 9.08/ | 15.72 | 208./ | 263. | 238.1 | 293. | 226./ | 282. | 347./ | 403. |
| PV System, Insulated House; Air-Cooled Si Arrays (\$0.50/W); Improved IF-2 | 112 | 50.3 | 5.92/ | 9.98 | 5.01/ | 9.21 | 181./ | 229. | 208./ | 256. | 198./ | 247. | 308./ | 357. |
| PV System, Insulated House; Air-cooled Thin-Film Arrays (\$0.10/W); IF-2 | 113 | 38.6 | 2.51/ | 5.37 | 2.13/ | 5.05 | 143./ | 169. | 173./ | 199. | 170./ | 196. | 294./ | 320. |
| PV System, Insulated House; One-Axis Concentrator With Si Cells (\$0.15/W Cells); Multitank Low-Temp. Storage; Improved IF-2 | 114 | 58.9 | 11.77/ | 18.40 | 9.93/ | 16.83 | 258./ | 348. | 278./ | 369. | 253./ | 348. | 337./ | 432. |
| Conv. Engine Cogeneration, Insulated House; Stirling Engine (Low Eff.), Direct Drive Heat Pump, Gas Hot Water, Low-Temp. Storage, No Grid Connect Ion (IF-9) | 115 | 51.4 | 2.96/ | 4.89 | 2.80/ | 4.75 | 115./ | 138. | 152./ | 175. | 150./ | 173. | 183./ | 207. |
| PV Heat Engine System, Insulated House; Air-Cooled Thin-Film Arrays (\$0.50/W), Low-Temp. Storage; IF-2 | 116 | 70.5 | 5.82/ | 9.10 | 5.07/ | 8.46 | 161./ | 215. | 184./ | 237. | 171./ | 227. | 192./ | 247. |

Reference system

| | | | | | | | | | | | | | | |
|---|-----|-----|-----|----|-----|----|-------|----|-------|----|-------|----|-------|----|
| Conv. All Electric House; Resistance Heat and Window A/C (SF-3) | 117 | 0.0 | NA/ | NA | NA/ | NA | 182./ | NA | 245./ | NA | 245./ | NA | 502./ | NA |
|---|-----|-----|-----|----|-----|----|-------|----|-------|----|-------|----|-------|----|

Systems compared to reference system

| | | | | | | | | | | | | | | |
|---|-----|------|-------|------|-------|------|-------|------|-------|------|-------|------|-------|------|
| Conv. All Electric House; Resistance Heat and Window A/C, 65/85 Thermostat (SF-3) | 118 | 8.6 | -.00/ | 3.17 | -.00/ | 3.17 | 169./ | 178. | 227./ | 236. | 227./ | 236. | 462./ | 471. |
| Conv. Insulated All Electric House; Resistance Heat and Window A/C (IF-3) | 119 | 27.0 | .15/ | 1.28 | .08/ | 1.22 | 143./ | 153. | 190./ | 200. | 189./ | 199. | 379./ | 389. |
| Conv. Insulated All Electric House; Resistance Heat and Window A/C, 65/85 Thermostat (IF-3) | 120 | 34.4 | .12/ | 1.00 | .06/ | .96 | 132./ | 142. | 174./ | 184. | 174./ | 184. | 346./ | 356. |

OMAHA SINGLE FAMILY

Reference system

| | | | | | | | | | | | | | | |
|--|-----|-----|-----|----|-----|----|-------|----|-------|----|-------|----|-------|----|
| Conv. Gas Heat, Hot Water, and Central Electric A/C (SF-1) | 121 | 0.0 | NA/ | NA | NA/ | NA | 125./ | NA | 180./ | NA | 180./ | NA | 302./ | NA |
|--|-----|-----|-----|----|-----|----|-------|----|-------|----|-------|----|-------|----|

| Summary description of system | Table number | Percent solar | Effective cost of solar energy (¢/kWh) | | | | Levelized monthly cost of energy service | | | | | |
|---|--------------|---------------|--|--------------|------------|-------------|--|------------|-------------------------|--|-------------------------|--|
| | | | No credits | | 20% ITC | | Projection 1 No credits | | Projection 2 20% ITC | | Projection 3 20% ITC | |
| <i>Systems compared to reference system</i> | | | | | | | | | | | | |
| Conv. Improved Furnace, Gas Hot Water, and Central Electric A/C (SF-1) | 122 | 11.9 | .77/ 6.21 | .67/ 6.12 | 121./ 136. | 169. / 185. | 169. / 184. | 284./ 299. | | | | |
| Conv. Gas Heat, Hot Water, and Central Electric A/C, 65/85 Thermostat (SF-1) | 123 | 10.0 | -.00/ 6.08 | -.00/ 6.08 | 115./ 129. | 167. / 181. | 167. / 181. | 272./ 286. | | | | |
| Solar Hot Water; Flat-Plates (1977 Prices); SF-1 | 124 | 10.4 | 9.04/ 19.03 | 7.62/ 17.81 | 142./ 166. | 191. / 215. | 188. / 213. | 303./ 328. | | | | |
| Solar Hot Water; Flat-Plates (Future Price); SF-1 | 125 | 10.4 | 6.42/ 15.16 | 5.41/ 14.30 | 135./ 157. | 185./ 206. | 182./ 204. | 298./ 320. | | | | |
| Solar Heating; Flat-Plates (1977 Prices), Low-Temp. Storage; SF-1 | 126 | 24.0 | 14.00/ 22.72 | 11.98/ 21.00 | 191./ 240. | 233./ 282. | 221./ 272. | 330./ 381. | | | | |
| Solar Heating; Flat-Plates (Future Price), Low-Temp. Storage; SF-1 | 127 | 24.0 | 9.40/ 15.98 | 8.07/ 14.85 | 165./ 202. | 207./ 244. | 199./ 237. | 308./ 346. | | | | |
| <i>Reference system</i> | | | | | | | | | | | | |
| Conv. Insulated House; Gas Heat, Hot Water, and Central Electric A/C (IF-1) | 128 | 0.0 | NA/ NA | NA/ NA | 111./ NA | 154./ NA | 154./ NA | 261./ NA | | | | |
| <i>Systems compared to reference system</i> | | | | | | | | | | | | |
| Conv. Insulated House; Improved Gas Heat, Hot Water, and Central Electric A/C (IF-1) | 129 | 11.3 | .80/ 8.40 | .70/ 8.31 | 108./ 124. | 146./ 161. | 146./ 161. | 248./ 264. | | | | |
| Conv. Insulated House; Gas Heat, Hot Water, and Central Electric A/C, 65/85 Thermostat (IF-1) | 130 | 11.4 | -.00/ 7.16 | -.00/ 7.16 | 103./ 117. | 142./ 156. | 142./ 156. | 234./ 249. | | | | |
| <i>Reference system</i> | | | | | | | | | | | | |
| Conv. Oil Heat and Central Electric A/C (SF-5) | 131 | 0.0 | NA/ NA | NA/ NA | 204./ NA | 263./ NA | 263./ NA | 522./ NA | | | | |
| <i>Systems compared to reference system</i> | | | | | | | | | | | | |
| Conv. Improved Oil Heating, Gas Hot Water, and Central Electric A/C (SF-5) | 132 | 13.0 | .61/ 5.79 | .53/ 5.72 | 186./ 204. | 237./ 255. | 237./ 255. | 461./ 479. | | | | |
| Conv. Oil Heat and Central Electric A/C, 65/85 Thermostat (SF-5) | 133 | 8.7 | -.00/ 7.30 | -.00/ 7.30 | 195./ 212. | 249./ 267. | 249./ 267. | 492./ 509. | | | | |
| Solar Hot Water; Flat-Plates (1977 Prices); SF-5 | 134 | 11.4 | 7.23/ 16.16 | 6.09/ 15.19 | 209./ 236. | 261./ 288. | 257./ 285. | 486./ 513. | | | | |
| Solar Hot Water; Flat-Plates (Future Price); SF-5 | 135 | 11.4 | 5.14/ 13.07 | 4.33/ 12.38 | 202./ 227. | 254./ 279. | 252./ 276. | 480./ 505. | | | | |
| Solar Heating; Flat-Plates (1977 Prices); SF-5 | 136 | 26.2 | 11.55/ 18.97 | 9.94/ 17.60 | 244./ 297. | 288./ 340. | 277./ 331. | 466./ 520. | | | | |
| Solar Heating; Flat-Plates (Future Price); Low-Temp. Storage; SF-5 | 137 | 26.2 | 7.87/ 13.58 | 6.81/ 12.68 | 219./ 259. | 262./ 302. | 255./ 296. | 444./ 485. | | | | |

Reference system

| | | | | | | | | | | | | | | |
|---|-----|-----|-----|----|-----|----|-------|----|-------|----|-------|----|-------|----|
| Conv. Insulated House; Oil Heat and Central Electric A/C (IF-5) | 138 | 0.0 | NA/ | NA | NA/ | NA | 125./ | NA | 173./ | NA | 173./ | NA | 285./ | NA |
|---|-----|-----|-----|----|-----|----|-------|----|-------|----|-------|----|-------|----|

Systems compared to reference system

| | | | | | | | | | | | | | | |
|---|-----|------|-------|------|-------|------|-------|------|-------|------|-------|------|-------|------|
| Conv. Insulated House; Improved Oil Heating, Hot Water, and Central Electric A/C (IF-5) | 139 | 12.6 | .64/ | 7.44 | .56/ | 7.37 | 121./ | 138. | 162./ | 180. | 162./ | 179. | 268./ | 286. |
| Conv. Insulated House; Oil Heat and Central Electric A/C, 65/85 Thermostat (IF-5) | 140 | 10.2 | -.00/ | 8.06 | -.00/ | 8.06 | 116./ | 133. | 160./ | 177. | 160./ | 177. | 258./ | 274. |

Reference system

| | | | | | | | | | | | | | | |
|--|-----|-----|-----|----|-----|----|-------|----|-------|----|-------|----|-------|----|
| Conv. Gas Heat, Hot Water, and Absorption A/C (SF-7) | 141 | 0.0 | NA/ | NA | NA/ | NA | 127./ | NA | 188./ | NA | 188./ | NA | 297./ | NA |
|--|-----|-----|-----|----|-----|----|-------|----|-------|----|-------|----|-------|----|

Systems compared to reference system

| | | | | | | | | | | | | | | |
|--|-----|------|-------|-------|-------|-------|-------|------|-------|------|-------|------|-------|------|
| Solar Heating and Cooling; Flat-Plates (1977 Prices), Low-Temp. Storage; SF-7 | 142 | 44.4 | 9.97/ | 16.35 | 8.43/ | 15.04 | 211./ | 281 | 245./ | 315. | 228./ | 301. | 313./ | 385 |
| Solar Heating and Cooling; Flat-Plates (Future Price); Low-Temp. Storage; SF-7 | 143 | 44.4 | 6.33/ | 11.00 | 5.351 | 10.17 | 171./ | 223. | 205./ | 256. | 194./ | 247. | 279./ | 332. |

Reference system

| | | | | | | | | | | | | | | |
|---|-----|-----|-----|----|-----|----|-------|----|-------|----|-------|----|-------|----|
| Conv. Insulated House; Gas Heat, Hot Water, and Absorption A/C (IF-7) | 144 | 0.0 | NA/ | NA | NA/ | NA | 111./ | NA | 158./ | NA | 158./ | NA | 254./ | NA |
|---|-----|-----|-----|----|-----|----|-------|----|-------|----|-------|----|-------|----|

Systems compared to reference system

| | | | | | | | | | | | | | | |
|---|-----|------|--------|-------|--------|-------|-------|------|------|------|-------|------|-------|------|
| Solar Engine System, Insulated House; ORCS and One-Axis Tracker (Future Design), High-Temp. Oil Storage; IF-7 | 145 | 33.0 | 27.39/ | 41.58 | 23.57/ | 38.32 | 244./ | 334. | 276/ | 365. | 251./ | 345. | 280./ | 374. |
|---|-----|------|--------|-------|--------|-------|-------|------|------|------|-------|------|-------|------|

Reference system

| | | | | | | | | | | | | | | |
|--|-----|-----|-----|----|-----|----|-------|----|-------|----|-------|----|-------|----|
| Conv. All-Electric House; Heat Pump (SF-2) | 146 | 0.0 | NA/ | NA | NA/ | NA | 190./ | NA | 249./ | NA | 249./ | NA | 490./ | NA |
|--|-----|-----|-----|----|-----|----|-------|----|-------|----|-------|----|-------|----|

Systems compared to reference system

| | | | | | | | | | | | | | | |
|---|-----|------|--------|-------|--------|-------|-------|------|-------|------|-----------|------|-------|------|
| Conv. Improved Heat pump (SF-2) | 147 | 18.1 | .98/ | 3.65 | .89/ | 3.57 | 173./ | 189. | 223./ | 239. | 222./ | 238. | 424./ | 440. |
| Conv. All Electric House; Heat Pump, 65/85 Thermostat (SF-2) | 148 | 7.0 | -.00/ | 5.96 | -.00/ | 5.96 | 181./ | 195. | 237./ | 251. | 237./ | 251. | 462./ | 476. |
| Solar Hot Water; Flat-Plates (1977 prices); SF-2 | 149 | 16.8 | 3.90/ | 8.18 | 3.29/ | 7.65 | 191./ | 215. | 241./ | 265. | 237./ | 262. | 442./ | 467. |
| Solar Hot Water; Flat-plates (Future price); SF-2 | 150 | 16.8 | 2.76/ | 6.50 | 2.33/ | 6.12 | 184./ | 205. | 234./ | 255. | 232./ | 253. | 437./ | 458. |
| Solar Heating; Using Flat-plates (1977 Prices), Low-Temp. Storage; SF-2 | 151 | 20.5 | 6.56/ | 11.57 | 5.58/ | 10.73 | 209./ | 243. | 257./ | 292. | 250.1286. | | 447./ | 483. |
| Solar Heating; Flat-Plates (Future Price), Low-Temp. Storage; SF-2 | 152 | 20.5 | 4.48/ | 8.54 | 3.80/ | 7.96 | 195./ | 222. | 243./ | 271. | 238./ | 267. | 435./ | 464. |
| Solar Heating; Flat-Plates (1977 Prices), Low-Temp. Storage; SF-2 | 153 | 29.1 | 7.63/ | 12.60 | 6.47/ | 11.60 | 227./ | 275. | 271./ | 319. | 260./ | 310. | 438./ | 488. |
| Solar Heating; Flat-Plates (Future Price); Low-Temp. Storage; SF-2 | 154 | 29.1 | 4.97/ | 8.69 | 4.20/ | 8.04 | 201./ | 237. | 245./ | 281. | 237./ | 275. | 416./ | 453. |
| PV System; Air-Cooled Si Arrays (\$1/W); SF-2 | 155 | 53.6 | 12.61/ | 19.33 | 10.60/ | 17.61 | 363./ | 484. | 401./ | 521, | 365./ | 490. | 517./ | 643. |
| PV Cogeneration; Air-Cooled Si Arrays (\$0.50/W); SF-2 | 156 | 53.6 | 6.83/ | 10.83 | 5.74/ | 9.90 | 259./ | 331. | 297./ | 369. | 277./ | 352. | 430./ | 505. |

| Summary description of system | Table number | Percent solar | Effective cost of solar energy (¢/kWh) | | | | Levelized monthly cost of energy service | | | | | |
|--|--------------|---------------|--|---------------|------------|------------|--|------------|-------------------------|--|----------------------|--|
| | | | No credits | | 20% ITC | | Projection 1 No credits | | Projection 2 No credits | | Projection 2 20% ITC | |
| Systems compared to reference system—Continued | | | | | | | | | | | | |
| PV Cogeneration; Water-Cooled Si Arrays (\$1/w), Multitank Low-Temp. Storage; SF-2. | 157 | 63.2 | 15.18/ 23.00 | 12.78/ 20.94 | 441./ 607. | 472./ 638. | 421./ 594. | 547./ 720. | | | | |
| PV Cogeneration; Water-Cooled Si Arrays (\$0.50/w), Multitank Low-Temp. Storage; SF-2 | 158 | 63.2 | 8.64/ 13.36 | 7.27/ 12.19 | 303./ 403. | 334./ 434. | 305./ 409. | 431./ 535. | | | | |
| PV System; Air-Cooled Thin-Film Arrays (\$0.30/W); SF-2 | 159 | 29.2 | 5.54/ 9.56 | 4.64/ 8.80 | 212./ 252. | 259./ 298. | 250./ 291. | 438./ 478. | | | | |
| PV System; Air-Cooled Thin-Film Arrays (\$0.10/W); SF-2 | 160 | 37.9 | 2.61/ 4.94 | 2.18/ 4.58 | 183./ 213. | 226./ 256. | 221./ 251. | 395./ 426. | | | | |
| PV System; Air-Cooled Thin-Film Arrays (\$0.10/W), Battery Storage; SF-2 | 161 | 35.2 | 3.45/ 6.18 | 2.93/ 5.74 | 189./ 221. | 231./ 263. | 225./ 258. | 397./ 430. | | | | |
| PV Cogeneration; One-Axis Concentrator With Si Cells (\$15/W Cells); Multitank Low-Temp. Storage; SF-2 | 162 | 59.4 | 14.73/ 22.39 | 12.41 / 20.40 | 411./ 563. | 441./ 593. | 395./ 553. | 517./ 675. | | | | |
| PV Cogeneration; One-Axis Concentrator With Si Cells (\$15/W Cells), Multitank Low-Temp. and Battery Storage; SF-2 | 163 | 57.5 | 15.83/ 23.96 | 13.37/ 21.86 | 423./ 579. | 452./ 609. | 405./ 568. | 526./ 690. | | | | |
| PV Cogeneration; One-Axis Concentrator With Si Cells (\$1/W Cells), Multitank Low-Temp. Storage; SF-2 | 164 | 69.3 | 3.93/ 6.35 | 3.30/ 5.82 | 200./ 256. | 226./ 282. | 211./ 270. | 317./ 376. | | | | |
| Reference system | | | | | | | | | | | | |
| Conv. Insulated All Electric House, Heat Pump (IF-2) | 165 | 0.0 | NA/ NA | NA/ NA | 161./ NA | 208./ NA | 208./ NA | 399./ NA | | | | |
| Systems compared to reference system | | | | | | | | | | | | |
| Conv. Insulated All Electric House; Heat Pump, 65/85 Thermostat (IF-2) | 166 | 8.0 | -.00/ 7.36 | -.00/ 7.36 | 153./ 168. | 197./ 212. | 197./ 212. | 375./ 390. | | | | |
| Conv. Insulated All Electric House; Improved Heat Pump (IF-2) | 167 | 13.5 | 1.31 / 6.15 | 1.19/ 6.04 | 152./ 169. | 193./ 210. | 193./ 210. | 362./ 379. | | | | |
| Solar Hot Water, Insulated House; Flat-Plates (Future Price), Low-Temp. Storage, IF-2 | 168 | 22.0 | 2.74/ 6.67 | 2.31/ 6.30 | 154./ 177. | 193./ 215. | 190./ 213. | 346./ 368. | | | | |
| Solar Heating, Insulated House Using Flat-Plates (Future Price), Low-Temp. Storage, IF-2 | 169 | 33.9 | 4.54/ 8.36 | 3.84/ 7.76 | 167./ 200. | 200./ 233. | 194./ 228. | 330./ 364. | | | | |
| Solar Heating, Insulated House; Flat-Plates (Future Price); Low-Temp. Storage; IF-2 | 170 | 38.6 | 4.86/ 8.63 | 4.11/ 7.99 | 171./ 208. | 202./ 240. | 195./ 233. | 323./ 362. | | | | |
| PV System, Insulated House; Air-Cooled Si Arrays (\$1/W); IF-2 | 171 | 36.1 | 12.55/ 20.08 | 10.54/ 18.36 | 248./ 318. | 284./ 353. | 265./ 338. | 409./ 481. | | | | |
| PV System, Insulated House; Air-Cooled Si Arrays (\$1/W); Improved IF-2 | 172 | 47.9 | 9.71/ 15.47 | 8.18/ 14.16 | 240./ 311. | 270./ 341. | 252./ 325. | 376./ 450. | | | | |
| PV System, Insulated House; Air-Cooled Si Arrays (\$0.50/W); IF-2 | 173 | 36.1 | 6.88/ 11.75 | 5.77/ 10.81 | 196./ 241. | 231./ 276. | 221./ 267. | 364./ 411. | | | | |
| PV System, Insulated House; Air-Cooled Si Arrays (\$0.50/W), Battery Storage; IF-2 | 174 | 32.1 | 10.67/ 17.17 | 9.17/ 15.89 | 217./ 271. | 251./ 305. | 239./ 294. | 378./ 433. | | | | |

Systems compared to reference system—Continued

| | | | | | | | | |
|---|-----|------|--------------|--------------|-------------|-------------|-------------|-------------|
| PV System, Insulated House; Air-Cooled Si Arrays (\$0.50/W), Improved IF-2 | 175 | 47.9 | 5.48/ 9.25 | 4.62/ 8.52 | 188./ 234. | 218./ 265. | 208. / 256. | 332./ 381. |
| PV System, Insulated House; Air-Cooled Thin-Film Arrays (\$030/W); Improved IF-2 | 176 | 32.2 | 3.91/ 7.51 | 3.31/ 7.00 | 163. / 193. | 199./ 228. | 194./ 224. | 336./ 367. |
| PV System, Insulated House; Air-Cooled Thin-Film Arrays (\$ 0. 10/W); Improved IF-2 | 177 | 37.3 | 2.32/ 4.95 | 1.97/ 4.65 | 150. / 175. | 183./ 209. | 180. / 206. | 317. / 343. |
| PV Cogeneration, Insulated House; One-Axis Concentrator With Si Cells (\$15/W Cells), With Multitank Low-Temp. Storage; improved IF-2 | 178 | 57.4 | 10.89/ 17.00 | 9.19/ 15.55 | 266./ 356. | 291./ 381. | 266. / 359. | 366./ 460. |
| PV Cogeneration, Insulated House; One-Axis Concentrator With Si Cells (\$15/W Cells), Multitank Low-Temp. Storage; Improved IF-2 | 179 | 80.5 | 14.34/ 21.81 | 12.09/ 19.89 | 381./ 536. | 397./ 552. | 351./ 512. | 416. / 578. |
| PV Cogeneration, Insulated House; One-Axis Concentrator With Si Cells (\$1/W Cells), Multitank Low-Temp. Storage; Improved IF-2 | 180 | 43.4 | 5.27/ 9.07 | 4.43/ 8.35 | 178./ 220. | 208./ 250. | 198. / 242. | 321./ 365. |
| PV Cogeneration, Insulated House; One-Axis Concentrator With Si Cells (\$1/W Cells), Multitank Low-Temp. Storage; IF-2 | 181 | 52.1 | 5.38/ 9.01 | 4.52/ 8.28 | 183./ 232. | 210./ 259. | 198. / 249. | 308./ 358. |
| PV Cogeneration, Insulated House; One-Axis Concentrator With Si Cells (\$1/W Cells), Multitank Low-Temp. Storage; Improved IF-2 | 182 | 63.0 | 4.99/ 8.21 | 4.23/ 7.56 | 182. / 234. | 205./ 257. | 192. / 246. | 285./ 340. |
| PV Cogeneration, Insulated House; Air-Cooled Si Arrays (\$0.50/w), Diesel Backup, Low-Temp. Storage; IF-2 | 183 | 72.0 | 5.39/ 8.38 | 4.70/ 7.79 | 161. / 216. | 178./ 234. | 165. / 223. | 182. / 239. |
| PV Cogeneration, Insulated House; Plastic Dye Concentrator, Multitank Low-Temp. Storage; IF-2 | 184 | 79.7 | 3.42/ 5.75 | 2.87/ 5.28 | 165. / 212. | 185./ 233. | 174. / 223. | 256./ 306. |
| PV System, Insulated House; Plastic Dye Concentrator; IF-2 | 185 | 74.8 | 3.02/ 5.24 | 2.53/ 4.82 | 165./ 208. | 191./ 234. | 181. / 225. | 285. / 329. |
| Conv. Engine Cogeneration, Insulated House; Stirling Engine (Low Eff), Direct Drive Heat Pump, Gas Hot Water, Low-Temp. Storage (IF-9) | 186 | 56.3 | 2.49/ 4.07 | 2.35/ 3.95 | 106. / 129. | 133. / 156, | 131/ 155. | 157./ 180. |

Reference system

| | | | | | | | | |
|---|-----|-----|--------|--------|----------|----------|----------|----------|
| Conv. All Electric House; Resistance Heat and window A/C (SF-3) | 187 | 0.0 | NA/ NA | NA/ NA | 206./ NA | 277./ NA | 277./ NA | 570./ NA |
|---|-----|-----|--------|--------|----------|----------|----------|----------|

Systems compared to reference system

| | | | | | | | | |
|---|-----|------|------------|------------|------------|------------|------------|------------|
| Conv. All Electric House; Resistance Heat and Window A/C, 65/85 Thermostat (SF-3) | 188 | 4.7 | -.00/ 5.17 | -.00/ 5.17 | 198./ 208. | 267./ 277. | 267./ 277 | 547/ 557 |
| Solar Heating: Flat-plates (1977 Prices), Low-Temp. Storage; SF-4 | 191 | 32.7 | 5.37/ 8.59 | 4.55/ 7.89 | 226./ 270 | 277./ 320 | 265./ 311 | 471./ 517 |
| Solar Heating, Flat-Plates (Future Price), Low-Temp. Storage; SF-4 | 192 | 32.7 | 3.46/ 5.79 | 2.93/ 5.34 | 200./ 232. | 251./ 282. | 243. / 276 | 449 / 482. |

| Summary description of system | Table number | Percent solar | Effective cost of solar energy (¢/kWh) | | Levelized monthly cost of energy service | | | |
|---|--------------|---------------|--|------------|--|----------------------------|-------------------------|-------------------------|
| | | | No credits | 20% ITC | Projection 1 No credits | Projection 2 No credits | Projection 2 20% ITC | Projection 3 20% ITC |
| Systems compared to reference system—Continued | | | | | | | | |
| Solar Heating; Flat-Plates (1977 Prices), Low-Temp. Storage; SF-3 | 197 | 38.3 | 6.23/ 9.76 | 5.27/ 8.94 | 243./ 300. | 290./ 347. | 275./ 334. | 466. / 525. |
| Solar Heating; Flat-Plates (Future Price), Low-Temp. Storage; SF-3 | 198 | 38.3 | 3.95/ 6.41 | 3.34/ 5.89 | 207./ 246. | 254./ 293. | 244./ 285. | 435. / 476. |
| 100-Percent Solar Heating; Insulated House; Flat-Plates (1977 Prices), Community Seasonal Low-Temp. Storage; SF-2 | 199 | 76.4 | 6.79/ 10.21 | 5.66/ 9.25 | 299./ 408. | 321. / 430. | 285. / 399. | 375. / 490 |
| 100-Percent Solar Heating; Flat-Plates (Future Price), Central Electric A/C, Community Seasonal Aquifer Storage; SF-2 | 200 | 76.4 | 4.15/ 6.27 | 3.52/ 5.72 | 215./ 282. | 237./ 304. | 217. / 287. | 307./ 377 |
| Reference system | | | | | | | | |
| Conv. Insulated All Electric House; Resistance Heat and Window A/C (IF-3). | 201 | 0.0 | NA/ NA | NA/ NA | 159./ NA | 211./ NA | 211./ NA | 423./ NA |
| Systems compared to reference system | | | | | | | | |
| Conv. Insulated All Electric House; Resistance Heat and Window A/C, 65/85 Thermostat (IF-3) | 202 | 5.9 | -.00/ 6.54 | -.00/ 6.54 | 152./ 163. | 201. / 213. | 201./ 213, | 403. / 414. |

**OMAHA SINGLE FAMILY
TIME-OF-DAY RATES**

Reference system

| | | | | | | | | |
|---|------|------------|--------|--------|----------|----------|----------|----------|
| Conv. All Electric House (SF-3); Marginal Electric Rates. | T187 | 0.0 | NA/ NA | NA/ NA | 278./ NA | 278./ NA | 278./ NA | 278./ NA |
|---|------|------------|--------|--------|----------|----------|----------|----------|

Systems compared to reference system

| | | | | | | | | |
|---|-----|------|---------------|----------------|------------|------------|-------------|------------|
| Conv. Off-Peak Electric Heating; Window A/C, Low-Temp. Storage (SF-4). | 189 | -.7 | -79.79/ .**** | -62.11 / .**** | 218./ 241. | 218./ 241. | 213./ 237. | 213./ 237. |
| Conv. Off-Peak Electric Heating and Chilling; Low-Temp. Thermal and Cold Storage (SF-4). | 190 | -.3 | • .** , ***** | • ****, ****, | 236./ 278. | 236./ 278. | 226./ 270. | 226./ 270. |
| Solar Off-Peak Heating; Flat-Plates (1977 Prices), Low-Temp. Storage; SF-4 | 193 | 32.3 | 6.32/ 10.04 | 5.31/ 9.18 | 246./ 296. | 246./ 296. | 232. / 284. | 232./ 284. |
| Solar Off-Peak Heating; Flat-Plates (Future Price), Low-Temp. Storage; SF-4 | 194 | 32.3 | 4.39/ 7.22 | 3.67/ 6.60 | 220./ 258. | 220./ 258. | 210./ 250. | 210./ 250. |
| Solar Heating and Cooling; Flat-Plates (1977 Prices), Low-Temp. Thermal and Cold Storage; Off-Peak Electric Backup Heating and Chilling | 195 | 32.7 | 9.71/ 15.03 | 8.24/ 13.77 | 268./ 341. | 268./ 341. | 248./ 324. | 248.1 324. |
| Solar Off-Peak Heating and Cooling; Flat-Plates (1977 Prices), Low-Temp. Storage; SF-4 | 196 | 32.7 | 7.80/ 12.24 | 6.62/ 11.23 | 242./ 303. | 242./ 303. | 226./ 289. | 226./ 289. |

ALBUQUERQUE HIGH RISE (196 UNITS)

Reference system

| | | | | | | | | | | | | | | |
|---|---------|------|--------|-------|--------|-------|-------|------|-------|------|-------|-----|-------|------|
| Conv. Central Electric Chilled-Water System With Fan Coil Units and a Central Gas Boiler (HR-1) | 203 | 0.0 | NA/ | NA | NA/ | NA | 51./ | NA | 71./ | NA | 71./ | NA | 129/ | NA |
| Systems compared to reference system | | | | | | | | | | | | | | |
| Solar Hot Water; Flat-Plates (1977 Prices); HR-1 | 204 | 8.1 | 12.20/ | 18.90 | 9.05/ | 17.55 | 58.1 | 63. | 76./ | 81. | 74./ | 80 | 129./ | 136 |
| Solar Hot Water; Flat-Plates (Future Prices); HR-1 | 204/278 | 8.1 | 7.61/ | 13.28 | 5.66/ | 12.45 | 54./ | 59. | 72./ | 77. | 71./ | 76 | 126./ | 132 |
| Solar Heating; I-Cover Pond, Seasonal Aquifer Storage; HR-1 | 205 | 26.4 | 8.45/ | 11.17 | 6.61/ | 10.38 | 65./ | 72. | 77.1 | 84. | 72./ | 82 | 122./ | 132 |
| PV System; Air-Cooled Si Arrays (\$1/W), Bat- tery Storage; HR-1 | 206 | 45.7 | 21.56/ | 26.53 | 16.38/ | 24.32 | 136./ | 158. | 152./ | 174. | 129./ | 165 | 170./ | 205 |
| PV System; Air-Cooled Si Arrays (\$0.50/W); HR-1 | 207 | 51.1 | 8.47/ | 11.05 | 6.23/ | 10.09 | 84.1 | 96. | 100.1 | 113. | 89.1 | 108 | 132./ | 151 |
| PV System; Air-Cooled Si Arrays (\$ I/W); HR-1 | 207/281 | 51.1 | 15.28/ | 19.38 | 11.26/ | 17.67 | 117./ | 138. | 134./ | 154. | 114./ | 146 | 157.1 | 189. |
| PV System; Air-Cooled Si Arrays (\$0.50/W), Battery Storage; HR-1 | 208 | 45.7 | 12.55/ | 15.69 | 9.57/ | 14.42 | 96./ | 110. | 112.1 | 126. | 99./ | 21 | 140./ | 161 |
| PV System; Air-Cooled Thin-Film Arrays (\$0.30/W); HR-1 | 209 | 11.7 | 26.18/ | 34.42 | 19.68/ | 31.65 | 78./ | 88. | 98.1 | 107. | 90./ | 04 | 144./ | 157 |

Reference system

| | | | | | | | | | | | | | | |
|--|-----|-------|--------|-------|-------|-------|-------|------|-------|------|-------|------|-------|------|
| Conv. Central Gas Boiler and Absorption Chilling, Two-Pipe System to Fan-Coil Units (HR-7) | 210 | 0.0 | NA/ | NA | NA/ | NA | 49./ | NA | 73./ | NA | 73./ | NA | 121./ | NA |
| Systems compared to reference system | | | | | | | | | | | | | | |
| PV System; Two-Axis Concentrator With GaAs Cells (Low Price), Battery and Multi- tank Low-Temp. Storage; HR-8 | 211 | 74.9 | 4.31/ | 5.68 | 3.26/ | 5.23 | 85./ | 95 | 100./ | 110. | 92./ | 107 | 153./ | 168. |
| PV System; Two-Axis Concentrator With GaAs Cells (Low Price), Battery and Multi- tank Low-Temp. Storage; HR-7 | 212 | 97.1 | 5.37/ | 6.76 | 4.14/ | 6.24 | 101./ | 115. | 114./ | 128. | 102./ | 123. | 155./ | 176. |
| PV System; Two-Axis Concentrator With GaAs Cells (Low Price), iron-REDOX Battery and Multitank Low-Temp. Storage; HR-7 | 213 | 106.8 | 6.66/ | 8.27 | 5.16/ | 7.62 | 87./ | 105. | 87.1 | 105. | 71./ | 98 | 71./ | 98. |
| PV System; Two-Axis Concentrator With GaAs Cells (Low Price), iron-REDOX Battery and Multitank Low-Temp. Storage; HR-7 | 214 | 06.6 | 8.35/ | 10.19 | 6.53/ | 9.41 | 106./ | 126. | 106./ | 126. | 86./ | 118 | 86./ | 118 |
| 100-Percent Solar PV System; Two-Axis Con- centrator With GaAs Cells (Low Price), Iron- REDOX Battery and Multitank Low-Temp. Storage; HR-7 | 215 | 00.0 | 9.67/ | 11.75 | 7.58/ | 10.86 | 114./ | 135. | 114./ | 135. | 92./ | 126. | 92./ | 126. |
| PV System; Two-Axis Concentrator With GaAs Cells (Low Price), Battery and Multi- tank Low-Temp. Storage; HR-7 | 216 | 21.4 | 6.62/ | 8.13 | 5.15/ | 7.50 | 97./ | 116. | 97./ | 116 | 79./ | 108 | 79./ | 108 |
| Conv. Engine Cogeneration; Gas-Fired Diesel/ORCS Engine/Generator and Low- Temp. Storage; HR-8 | 217 | 37.7 | 11.51/ | 14.44 | 8.97/ | 13.35 | 78./ | 90. | 99.1 | 111 | 89./ | 106 | 109./ | 126 |
| PV System; Two-Axis Concentrator With GaAs Cells (Low Price), Multitank Low- Temp. Storage; HR-7 | 218 | 73.5 | 5.03/ | 6.52 | 3.85/ | 6.02 | 61./ | 72 | 69./ | 81. | 60./ | 77. | 69./ | 85 |

| Summary description of system | Table number | Percent solar | Effective cost of solar energy (¢/kWh) | | | | Levelized monthly cost of energy service | | | | | | | |
|---|--------------|---------------|--|-------|---------|-------|--|------|--------------------------|------|----------------------|------|----------------------|------|
| | | | No credits | | 20% ITC | | Project Ion 1 No credits | | Project Ion 2 No credits | | Projection 2 20% ITC | | Projection 3 20% ITC | |
| <i>Systems compared to reference system—Continued</i> | | | | | | | | | | | | | | |
| Solar Engine; LT ORCS and 2-Cover Pond, Seasonal Aquifer Storage, HR-7 | 219 | 100.0 | 15.95/ | 9.25 | 12.35/ | 7.72 | 179./ | 213. | 179./ | 213. | 141./ | 197. | 141./ | 197. |
| Solar Engine; LT ORCS and 2-Cover Pond, Seasonal Aquifer Storage, HR-7 | 220 | 100.0 | 11.19/ | 3.75 | 8.49/ | 2.60 | 130./ | 156. | 130./ | 156. | 102./ | 144. | 102./ | 144. |
| Solar Engine Cogeneration; Two-Axis Dish With High Eff. Stirling Engine/Generator, Gas Backup, and Low-Temp. Storage; HR-8 | 221 | 66.9 | 4.51/ | 5.56 | 3.78/ | 5.25 | 56./ | 63. | 67./ | 74. | 62./ | 72. | 72./ | 82. |
| Solar Engine Cogeneration; Two-Axis Dish With Low Eff. Stirling Engine/Generator, Gas Backup, and Multitank High- and Low-Temp. Storage; HR-8 | 222 | 71.5 | 6.01/ | 7.49 | 4.77/ | 6.97 | 67./ | 78. | 77./ | 88. | 68./ | 84. | 77./ | 93 |
| Solar Engine Cogeneration; Two-Axis Dish With Low Eff. Stirling Engine/Generator, Gas Backup, and Multitank High- and Low-Temp. Storage; HR-7 | 223 | 76.4 | 7.31/ | 9.00 | 5.81/ | 8.36 | 79./ | 92. | 87./ | 100. | 75./ | 95. | 82./ | 103 |
| Solar Engine Cogeneration; Two-Axis Dish With High Eff. Stirling Engine/Generator, Gas Backup, and Multitank Low-Temp. Storage; HR-8 | 224 | 81.4 | 6.53/ | 8.02 | 5.23/ | 7.46 | 75./ | 87. | 81./ | 93. | 70./ | 89. | 76./ | 95 |
| Solar Engine Cogeneration; Two-Axis Dish, Stirling Engines (High Eff.), Battery and High- and Low-Temp. Storage; Gas Backup; HR-7 | 225 | 98.4 | 11.39/ | 14.54 | 8.26/ | 13.20 | 130./ | 162. | 131./ | 163. | 99./ | 149. | 99./ | 150. |
| 100-Percent Solar Engine Cogeneration; Two-Axis Dish, Stirling Engine (High Eff.) Battery and High- and Low-Temp. Storage; HR-7 | 226 | 100.0 | 12.25/ | 15.51 | 8.96/ | 14.11 | 140./ | 174. | 140./ | 174. | 107./ | 160. | 107./ | 160. |
| <i>Reference system</i> | | | | | | | | | | | | | | |
| Conv. All Electric System; Central Electric Chilled-Water System and Fan Coil Units With Resistance Heaters (HR.2) | 227 | 0.0 | NA/ | NA | NA/ | NA | 84./ | NA | 113./ | NA | 113./ | NA | 232./ | NA |
| Systems compared to reference system | | | | | | | | | | | | | | |
| Solar Hot Water; Flat-Plates (1977 Prices); HR-2 | 228 | 19.3 | 3.35/ | 5.07 | 2.48/ | 4.71 | 87./ | 92. | 114./ | 119. | 112./ | 118. | 220./ | 227. |
| Solar Heating; Flat-Plates (Future Price); HR-2 | 228/322 | 19.3 | 2.09/ | 3.53 | 1.55/ | 3.30 | 84./ | 88. | 110./ | 115. | 109./ | 114. | 218./ | 223. |
| Solar Heating; Flat-Plates (1977 Prices), Low-Temp. Storage; HR-2 | 229 | 31.4 | 4.45/ | 6.05 | 3.29/ | 5.55 | 95./ | 102. | 120./ | 128. | 115./ | 125. | 218./ | 228. |
| Solar Heating; Flat-Plates (Future Price), Low-Temp. Storage; HR-2 | 229/324 | 31.4 | 2.80/ | 4.03 | 2.07/ | 3.72 | 87./ | 93. | 113./ | 118. | 109./ | 117. | 212./ | 220. |
| Solar Heating; Flat-Plates (1977 Prices), Seasonal Low-Temp. Storage; HR-2 | 230 | 52.6 | 5.55/ | 7.42 | 3.87/ | 6.70 | 85./ | 99. | 97./ | 112. | 84./ | 106. | 134./ | 156. |
| Solar Heating; Flat-Plates (Future Price), Seasonal Low-Temp. Storage; HR-2 | 230/328 | 52.6 | 4.30/ | 5.89 | 2.95/ | 5.32 | 75./ | 88. | 87./ | 100. | 77./ | 95. | 126./ | 145. |

| | | | | | | | | |
|--|-----|-------|--------------|---------------|------------|------------|------------|------------|
| Solar Heating; Flat-Plates (1977 Prices), Cheap Seasonal Low-Temp. Storage; HR-2 | 231 | 52.6 | 4.11/ 5.43 | 3.00/ 4.96 | 74./ 84. | 86 / 96 | 77./ 92 | 127./ 142 |
| Solar Heating; Flat-Plates (Future Price), Seasonal Aquifer Storage; HR-2 | 232 | 52.6 | 2.70/ 3.70 | 1.96/ 3.39 | 63./ 71. | 75./ 83. | 69./ 80 | 119./ 130 |
| Solar Heating; I-Cover Pond, Seasonal Aquifer Low-Temp. Storage; HR-1 | 233 | 51.6 | 1.91/ 2.60 | 1.52/ 2.43 | 57./ 62. | 69./ 74. | 66./ 73. | 116./ 123, |
| Solar Heating; Two-Axis Concentrator (Med. Price), Multitank Low-Temp. Storage; HR-2 | 234 | 307 | 3.69/ 5.08 | 2.79/ 4.70 | 91./ 98. | 117./ 123. | 113./ 121 | 216./ 224 |
| PV Cogeneration; Two-Axis Concentrator With Si Cells (Med. Price), Multitank Low-Temp. Storage; HR-2 | 235 | 37.1 | 4.13/ 5.54 | 3.10/ 5.10 | 95./ 103. | 120./ 128 | 114./ 125 | 214./ 225 |
| PV Cogeneration; Two-Axis Concentrator With Si Cells (Med. Price) Replaced Every 10 Years, Multitank Low-Temp. Storage; HR-2 | 236 | 37.1 | 6.85/ 7.96 | 5.81/ 7.52 | 110./ 116. | 135./ 141 | 129./ 138 | 229./ 239 |
| PV System; Two-Axis Concentrator With Si Cells (Med. Price); HR-2 | 237 | 6.2 | 22.59/ 30.53 | 16.99/ 28.14 | 102./ 109. | 130./ 138 | 125./ 135. | 240./ 250. |
| PV System; Two-Axis Concentrator With St Cells (Med. Price) Replaced Every 10 Years; HR-2 | 238 | 6.2 | 38.15/ 44.34 | 32.58/ 41.96 | 116./ 122. | 145./ 150. | 139./ 148. | 254./ 263 |
| PV Cogeneration; Two-Axis Concentrator With Si Cells (Med. Price), Multitank Low-Temp. Storage; HR-2 | 239 | 54.3 | 5.28/ 6.77 | 3.97/ 6.2 | 110./ 122. | 133./ 145. | 122./ 140 | 214./ 232. |
| PV Cogeneration; One-Axis Concentrator With Si Cells (\$15/W Cells), Multitank Low-Temp. Storage; HR-2 | 240 | 63.4 | 10.02/ 12.47 | 7.55/ 11.4 | 164./ 187. | 188./ 210. | 164./ 201. | 261./ 297 |
| PV Cogeneration; one-Axis Concentrator With Si Cells (\$15/W Cells), Battery and Multitank Low-Temp. Storage; HR-2 | 241 | 62.9 | 10.29/ 12.77 | 7.77/ 11.69 | 166./ 189. | 189./ 212 | 166./ 202 | 262./ 298. |
| PV Cogeneration; Two-Axis Concentrator With High Eff. Cells, Multitank Low-Temp. Storage; HR-2 | 242 | 101.1 | 2.90/ 3.69 | 2.20/ 3.39 | 103./ 115. | 123./ 135, | 113./ 130. | 192./ 210 |
| PV System; Two-Axis Concentrator With High Eff. Cells, iron.REDOX Battery and Multitank Low-Temp. Storage; HR-2 | 243 | 96.3 | 3.08/ 3.92 | 2.35/ 3.60 | 104./ 116. | 124./ 136. | 113./ 131. | 194./ 211. |
| PV Cogeneration; Two-Axis Concentrator With High Eff. Cells, Multitank Low-Temp. Storage; Diesel Backup; HR-2 | 244 | 78.7 | 5.18/ 6.40 | 4.03/ 5.91 | 81./ 96. | 92./ 106. | 78./ 100. | 88./ 109. |
| Reference system | | | | | | | | |
| Conv. All-Electric System; Resistance Heat, Window A/C and Individual Electric Water Heaters (HR-4) | 245 | 0.0 | NA/ NA | NA/ NA | 83.1 NA | 112./ NA | 112./ NA | 229./ NA |
| Systems compared to reference system | | | | | | | | |
| PV System; Air-Cooled Si Arrays (\$ I/W); HR-4 | 246 | 36.0 | 14.95/ 18.68 | 11 .00/ 17.00 | 149./ 168. | 173./ 192. | 153./ 184. | 254./ 284. |
| PV System; Air-Cooled Si Arrays (\$0.50/W); HR-4 | 246 | 36.0 | 8.32/ 10.55 | 6.12/ 9.61 | 115./ 127. | 140./ 151. | 129./ 146 | 229./ 247 |
| PV System; Air-Cooled Thin-Film Arrays (\$0.10/W); HR-4 | 247 | 25.2 | 5.37/ 7.07 | 3.94/ 6.46 | 95./ 101. | 120./ 126 | 115./ 124 | 219./ 228. |
| PV System; Air-Cooled Thin-Film Arrays, Vertical on Wall (\$0.10/W); HR-4 | 248 | 6.3 | 3.63/ 6.37 | 2.60/ 5.94 | 84./ 86. | 112./ 114 | 111./ 114 | 223./ 226 |

| Summary description of system | Table number | Percent solar | Effective cost of solar energy (¢/kWh) | | | | Levelized monthly cost of energy service | | | | | | | |
|---|--------------|---------------|--|-------|---------|-------|--|------|-------------------------|----|----------------------|------|-------|------|
| | | | No credits | | 20% ITC | | Projection 1 No credits | | Projection 2 No credits | | Projection 3 20% ITC | | | |
| <i>BOSTON HIGH RISE (196 UNITS)</i> | | | | | | | | | | | | | | |
| <i>Reference system</i> | | | | | | | | | | | | | | |
| <i>Conv. Electric Chilled-Water System With Fan Coil Units and Central Gas Boiler (HR-1) . . .</i> | 249 | 0.0 | NA/ | NA | NA/ | NA | 105./ | NA | 155./ | NA | 155./ | NA | 283./ | NA |
| <i>Systems compared to reference system</i> | | | | | | | | | | | | | | |
| <i>Solar Hot Water; Flat-Plates (1977 Prices);</i> | | | | | | | | | | | | | | |
| <i>HR-1</i> | 250 | 6.7 | 16.86/ | 27.36 | 12.50/ | 25.50 | 111./ | 118. | 157./ | | 155./ | 163. | 279./ | 287. |
| <i>Solar Hot Water; Flat-Plates (Future Price);</i> | | | | | | | | | | | | | | |
| <i>HR-1</i> | 250/278 | 6.7 | 10.55/ | 19.63 | 7.83/ | 18.47 | 107./ | 113 | 153 / | | 152. / | 158. | 276./ | 282. |
| <i>Conv. Engine Cogeneration; Diesel/ORCS, Absorption and Electric Chillers, Low-Temp. Storage; HR-8.</i> | | | | | | | | | | | | | | |
| | 251 | 33.5 | 13.64/ | 16.43 | 11.44/ | 15.49 | 102./ | 111. | | | 140./ | 153 | 181./ | 194. |

235./

Reference system

| | | | | | | | | | | | | | | |
|--|-----|-----|-----|----|-----|----|-------|----|-------|----|-------|----|-------|----|
| Conv. All Electric System; Resistance Heat, Individual Window A/C, and Electric Water Heaters (HR-4) | 260 | 0 0 | NA/ | NA | NA/ | NA | 169./ | NA | 231./ | NA | 231./ | NA | 483./ | NA |
|--|-----|-----|-----|----|-----|----|-------|----|-------|----|-------|----|-------|----|

Systems compared to reference system

| | | | | | | | | | | | | | | |
|---|---------|------|--------|-------|--------|-------|-------|------|-------|------|-------|-----|-------|------|
| PV System; Air-Cooled Si Arrays (\$0.50/W); HR-4 | 261 | 22.5 | 12.04/ | 15.32 | 8.85/ | 13.96 | 181./ | 192. | 231./ | 242 | 220./ | 238 | 423/ | 441. |
| PV System; Air-Cooled Si Arrays (\$1/W); HR-4 | 261/349 | 22.5 | 21.62/ | 27.08 | 15.91/ | 24.65 | 214./ | 233. | 264./ | 283 | 244./ | 275 | 448./ | 478. |
| PV System; Air-Cooled Thin-Film Arrays (\$0.10/W); HR-4 | 262 | 159 | 5.69/ | 8.38 | 3.64/ | 7.51 | 160./ | 167. | 213./ | 220. | 208./ | 217 | 423./ | 433. |

FORT WORTH HIGH RISE (196 UNITS)

Reference system

| | | | | | | | | | | | | | | |
|--|-----|-----|-----|----|-----|----|------|----|-------|----|-------|----|-------|----|
| Conv. Central Electric Chilled-Water System With Fan Coil Units and Central Gas Boiler for Heat (HR-1) | 263 | 0 0 | NA/ | NA | NA/ | NA | 76./ | NA | 102./ | NA | 102./ | NA | 186./ | NA |
|--|-----|-----|-----|----|-----|----|------|----|-------|----|-------|----|-------|----|

Systems compared to reference system

| | | | | | | | | | | | | | | |
|--|---------|------|--------|-------|--------|-------|-------|------|-------|------|-------|------|-------|------|
| Solar Hot Water; Flat-Plates (1977 Prices), HR-1 | 264 | 6.5 | 15.48/ | 26.32 | 11.47/ | 24.61 | 85./ | 93. | 108./ | 117. | 105./ | 115 | 187./ | 197 |
| Solar Hot Water; Flat-Plates (Future Price), HR-2 | 264/278 | 6.5 | 9.62/ | 19.15 | 7.14/ | 18.09 | 81./ | 88. | 104./ | 111 | 102./ | 110 | 184 / | 192 |
| Conv. Engine Cogeneration, Diesel/ORCS, Absorption and Electric Chillers, Low-Temp Storage; HR-8 | 265 | 36.2 | 6.67/ | 9.12 | 5.29/ | 8.54 | 72./ | 83. | 96./ | 106. | 90./ | 104 | 112./ | 126. |
| Solar Engine Cogeneration; Two-Axis Dish, Stirling Engine (Low Eff.) High-Temp. Storage, Gas Backup, HR-8 | 266 | 560 | 11.51/ | 14.67 | 8.86/ | 13.54 | 112./ | 132. | 128./ | 149 | 111./ | 141. | 126./ | 156 |
| Solar Engine Cogeneration; Two-Axis Dish, Stirling Engine (Low Eff.), High-Temp. and Multitank Low-Temp. Storage, Gas Backup; HR-8 | 267 | 63.2 | 9.74/ | 12.08 | 7.83/ | 11.27 | 106./ | 123. | 120./ | 137. | 106./ | 31. | 118./ | 143. |
| Solar Engine Cogeneration; Two-Axis Dish, Stirling Engine (High Eff.), Multitank Low-Temp. Storage, Gas Backup; HR-8 | 268 | 707 | 8.12/ | 10.08 | 6.53/ | 9.41 | 99./ | 115. | 109./ | 125. | 97./ | 20 | 107./ | 130. |

Reference system

| | | | | | | | | | | | | | | |
|--|-----|-----|-----|----|-----|----|-------|----|-------|----|-------|----|-------|----|
| Conv. All Electric; Central Chilled-water System and Fan Coil Units With Resistance Heaters (HR-2) | 269 | 0.0 | NA/ | NA | NA/ | NA | 101./ | NA | 133./ | NA | 133./ | NA | 265./ | NA |
|--|-----|-----|-----|----|-----|----|-------|----|-------|----|-------|----|-------|----|

Systems compared to reference system

| | | | | | | | | | | | | | | |
|---|---------|------|-------|------|-------|------|-------|------|-------|------|-------|------|-------|------|
| Solar Hot Water; Flat-Plates (1977 Prices), HR-2 | 270 | 15.8 | 4.87/ | 7.97 | 3.63/ | 7.44 | 108./ | 115. | 138./ | 146. | 135./ | 144. | 259./ | 268. |
| Solar Hot Water; Flat-Plates (Future Price); HR-2 | 270/322 | 15.8 | 4.18/ | 6.76 | 3.42/ | 6.43 | 106./ | 112. | 136./ | 143. | 135/ | 142. | 258/ | 266. |
| Solar Heating; Flat-Plates (1977 Prices), Low-Temp. Storage; HR-2 | 271 | 224 | 5.97/ | 8.74 | 4.42/ | 8.08 | 115./ | 124. | 144./ | 154. | 139/ | 151. | 260/ | 272. |

| Summary description of system | Table number | Percent solar | Effective cost of solar energy (¢/kWh) | | | | Levelized monthly cost of energy service | | | | | | | |
|---|--------------|---------------|--|--------------|------------|------------|--|------------|-------------------------|--|----------------------|--|-----------------------|--|
| | | | No credits | | 20% ITC | | Projection 1 No credits | | Projection 2 No credits | | Projection 2 20% ITC | | Project ion 3 20% ITC | |
| Systems compared to reference system—continue | | | | | | | | | | | | | | |
| Solar Heating; Flat-Plates (Future Price), Low-Temp. Storage; HR-2 | 271/324 | 22.4 | 3.76/ 6.03 | 2.78/ 5.61 | 107./ 115. | 137./ 144. | 133./ 143. | 254./ 264. | | | | | | |
| Solar Heating; Flat-Plates (1977 Prices), Seasonal Low-Temp. Storage; HR-2 | 272 | 38.6 | 7.15/ 9.89 | 5.02/ 8.98 | 110./ 127. | 129./ 146. | 117./ 140. | 195./ 218. | | | | | | |
| Solar Heating; Flat-Plates (Future Price), Seasonal Low-Temp. Storage; HR-2 | 272/328 | 38.6 | 5.43/ 7.79 | 3.75/ 7.07 | 100./ 114. | 119./ 133. | 109./ 129. | 187./ 207. | | | | | | |
| Solar Heating; Flat-Plates (1977 Prices), Seasonal Aquifer Storage; HR-2 | 273 | 38.6 | 5.57/ 7.69 | 4.08/ 7.05 | 101./ 114. | 120./ 133. | 111./ 129. | 189./ 207. | | | | | | |
| Solar Heating; Flat-Plates (Future Price), Aquifer Thermal Storage; HR-2 | 273/232 | 38.6 | 3.57/ 5.24 | 2.61/ 4.83 | 89./ 99. | 108./ 118. | 103./ 116. | 180./ 194. | | | | | | |
| Reference system | | | | | | | | | | | | | | |
| Conv. All Electric System; Resistance Heat, Individual Window A/C and Electric Water Heaters (HR-4) | 274 | 0.0 | NA/ NA | NA/ NA | 96./ NA | 127./ NA | 127./ NA | 256./ NA | | | | | | |
| Systems compared to reference system | | | | | | | | | | | | | | |
| PV System; Air-Cooled Thin-Film Arrays (\$0.10/W); HR-4 | 275 | 19.5 | 4.90/ 7.28 | 3.07/ 6.50 | 101./ 107. | 129./ 135. | 124./ 133. | 239./ 248. | | | | | | |
| OMAHA HIGH RISE (196 UNITS) | | | | | | | | | | | | | | |
| Reference system | | | | | | | | | | | | | | |
| Conv. Central Electric Chilled-Water System With Fan Coil Units and Central Gas Boiler (HR-1) | 276 | 0.0 | NA/ NA | NA/ NA | 57./ NA | 76./ NA | 76./ NA | 129./ NA | | | | | | |
| Systems compared to reference system | | | | | | | | | | | | | | |
| Solar Hot Water; Flat-Plates (1977 Prices); HR-1 | 277 | 5.2 | 20.05/ 34.32 | 14.86/ 32.11 | 66./ 74. | 84./ 92. | 82./ 91. | 133./ 142. | | | | | | |
| Solar Hot Water; Flat-Plates (Future Price); HR-1 | 278 | 5.2 | 12.54/ 25.13 | 9.31/ 23.75 | 62./ 69. | 80./ 87. | 79./ 86. | 130./ 138. | | | | | | |
| Solar Heating; I-Cover Pond, Seasonal Aquifer Storage; HR-1 | 279 | 34.0 | 12.80/ 16.48 | 10.07/ 15.32 | 94./ 107. | 105./ 118. | 95./ 113. | 140./ 158. | | | | | | |
| Solar Heating; I-Cover Pond, Seasonal Aquifer Storage; HR-1 | 280 | 34.0 | 8.30/ 11.06 | 6.67/ 10.36 | 78./ 87. | 89./ 98. | 83./ 96. | 128./ 141. | | | | | | |
| PV System; Air-cooled Si Arrays (\$1/W); HR-1 | 281 | 31.3 | 23.43/ 30.38 | 17.26/ 27.75 | 122./ 144. | 137./ 160. | 117./ 151. | 153./ 187. | | | | | | |
| PV System; Air-Cooled Si Arrays (\$1/W), Battery Storage; HR-1 | 282 | 34.3 | 22.66/ 28.93 | 16.97/ 26.50 | 124./ 146. | 139./ 161. | 118./ 152. | 150./ 184. | | | | | | |
| PV System; Air-Cooled Si Arrays (\$1/W), Seasonal iron-REDOX Battery Storage; HR-1 | 283 | 66.0 | 33.33/ 41.07 | 25.06/ 37.54 | 257./ 309. | 265./ 318. | 209./ 294. | 217./ 302. | | | | | | |
| PV System; Air-Cooled Si Arrays (\$0.50/W); HR-1 | 284 | 31.3 | 13.07/ 17.68 | 9.64/ 16.21 | 88./ 103. | 104./ 119. | 93./ 114. | 128./ 150. | | | | | | |
| PV System; Air-Cooled Si Arrays (\$0.50/W), Battery Storage; HR-1 | 285 | 34.3 | 13.71/ 18.06 | 10.31/ 16.61 | 92./ 108. | 107./ 122. | 95./ 117. | 127./ 149. | | | | | | |

| | | | | | | | | |
|---|---------|-------|--------------|--------------|------------|------------|------------|------------|
| PV System, Air-Cooled Si Arrays (\$0.50/W), Seasonal Iron-Redox Battery Storage; HR-1 | 286 | 66.0 | 16.85/ 21.04 | 12.74/ 19.29 | 144./ 173. | 153/ 181. | 125./ 170. | 133./ 177. |
| PV System; Air-Cooled Thin-Film Arrays (\$0.30/W); HR-1 | 287 | 18.8 | 12.21/ 17.69 | 9.01/ 16.32 | 73./ 84. | 90./ 101. | 84./ 98. | 125./ 139. |
| PV System; Air-Cooled Thin-Film Arrays (\$0.10/W), HR-1 | 288 | 18.8 | 7.75/ 12.21 | 5.73/ 11.34 | 65./ 73. | 81./ 90. | 78./ 88 | 119./ 130. |
| PV System; Air-Cooled Thin-Film Arrays (\$0.10/W) Vertical on Wall, HR-1 | 289 | 9.2 | 3.71/ 10.09 | 2.75/ 9.68 | 57./ 63. | 75./ 81. | 74./ 80. | 120./ 127. |
| PV Cogeneration; Two-Axis Concentrator With Si Cells, Multitank Low-Temp Storage; HR-1 | 290 | 35.4 | 9.01/ 12.32 | 6.86/ 11.40 | 78./ 90. | 91./ 103. | 83./ 99. | 119./ 136. |
| PV Cogeneration; Diesel Backup, Two-Axis Concentrator With High Eff. Cells, Multitank Low-Temp. Storage, HR-2 | 291 | 53.7 | 7.81/ 10.71 | 5.62/ 9.78 | 76./ 92. | 87./ 103. | 75./ 98. | 86./ 109. |
| Solar Engine Cogeneration; One-Axis Tracker, ORCS Engines, High-Temp. Storage; HR-7 | 292 | 13.9 | 45.74/ 57.69 | 35.95/ 53.51 | 108./ 125. | 129./ 147 | 115./ 141. | 135./ 161. |
| <i>Reference system</i> | | | | | | | | |
| Conv. Gas Heat, Hot Water, and Absorption Chilling (HR-7) | 293 | 0.0 | NA/ NA | NA/ NA | 57./ NA | 79./ NA | 79./ NA | 125./ NA |
| <i>Systems compared to reference system</i> | | | | | | | | |
| Solar Heating and Cooling, One-Axis Tracker (Future Design), Low-Temp. Storage; HR-7 | 294 | 35.7 | 8.20/ 11.67 | 5.94/ 10.71 | 80./ 94. | 93./ 107. | 84./ 103. | 121./ 140. |
| Solar Heating and Cooling; One-Axis Tracker (Future Design), Low-Temp. Storage; HR-7 | 295 | 28.1 | 17.73/ 22.87 | 13.91/ 21.23 | 105./ 121. | 120./ 135. | 108./ 130. | 147./ 169. |
| Solar Engine; LT ORCS, 2-Cover Pond, Seasonal Aquifer and Low-Temp. Storage; HR-7 | 296 | 100.0 | 17.85/ 21.51 | 13.98/ 19.85 | 220./ 260. | 220./ 260. | 177./ 242. | 177./ 242. |
| PV Cogeneration; Two-Axis Concentrator With Si Cells (Low Price), Multitank Low- Temp. Storage; HR-7 | 297 | 46.4 | 6.41/ 8.87 | 4.89/ 8.22 | 77./ 90. | 90./ 102. | 82./ 99. | 111./ 128. |
| PV Cogeneration; Two-Axis Concentrator With Si Cells (Low Price) Multitank Low- Temp. Storage; HR-7 | 298 | 54.4 | 6.61/ 8.96 | 5.04/ 8.29 | 82./ 96. | 93./ 107. | 84./ 103. | 111./ 130. |
| PV Cogeneration; Two-Axis Concentrator With GaAs Cells (Low Price), Seasonal Low- Temp. Storage; HR-8 | 299/300 | 82.3 | 7.04/ 9.27 | 5.25/ 8.57 | 99./ 120. | 104./ 124. | 88./ 118. | 108./ 137. |
| PV Cogeneration; Two-Axis Concentrator With GaAs Cells (Low Price), Battery and Multitank Low-Temp. Storage; HR-7 | 301 | 100.0 | 17.66/ 21.27 | 13.88/ 19.66 | 218./ 258. | 218./ 258. | 176./ 240. | 176./ 240. |
| PV Cogeneration; One-Axis Tracker With Si Cells (\$15/W Cells), and Multitank Low- Temp. Storage; HR-7 | 302 | 30.1 | 20.06/ 26.12 | 15.10/ 24.01 | 115./ 135. | 131./ 151. | 114./ 144. | 151./ 180. |
| PV System; One-Axis Tracker With Si Cells (\$1/W cells), Multitank Low-Temp. Storage; | 303 | 35.9 | 9.20/ 12.57 | 7.03/ 11.65 | 84./ 97. | 98./ 111. | 89./ 108. | 123./ 142. |
| PV Cogeneration; Two-Axis Concentrator With High Eff. Cells, Multitank Low-Temp. Storage; HR-7 | 304 | 68.9 | 5.86/ 7.87 | 4.45/ 7.26 | 84./ 100. | 95./ 110. | 84./ 106. | 107./ 128. |

| Summary description of system | Table number | Percent solar | Effective cost of solar energy (¢/kWh) | | | | Levelized monthly cost of energy service | | | |
|--|--------------|---------------|--|--------------|------------|------------|--|------------|----------------------|--|
| | | | No credits | | 20% ITC | | Projection 1 No credits | | Projection 2 20% ITC | |
| Systems compared to reference system—Continued | | | | | | | | | | |
| Solar Engine; LT ORCS, 2-Cover Pond, Seasonal Aquifer and Low-Temp. Storage; HR-7 | 305 | 100.0 | 16.46/ 21.81 | 11.39/ 19.64 | 205./ 264. | 205./ 264. | 149./ 240. | 149./ 240. | | |
| Conv. Engine Cogeneration; Diesel/ORCS Engines, Absorption and Electric Chillers, Low-Temp. Storage (HR-8) | 306 | 35.6 | 9.52/ 11.86 | 8.13/ 11.27 | 77./ 87. | 95./ 104. | 89./ 101. | 105./ 117. | | |
| Solar Engine Cogeneration; Two-Axis Dish, Stirling Engine (Low Eff.), Multitank Low-Temp. Storage; HR-8 | 307 | 50.9 | 7.23/ 9.26 | 5.96/ 8.72 | 77./ 88. | 90./ 101. | 83./ 98. | 95./ 110. | | |
| Solar Engine Cogeneration; Two-Axis Dish, Stirling Engine (Low Eff.), Multitank Low-Temp. Storage; HR-8 | 308 | 62.5 | 9.21/ 11.56 | 7.39/ 10.78 | 97./ 113. | 107./ 123. | 94./ 117. | 103./ 127. | | |
| Solar Engine Cogeneration; Two-Axis Dish, Stirling Engine (Low Eff.), High-Temp. and Multitank Low-Temp. Storage; HR-8 | 309 | 65.3 | 9.23/ 11.60 | 7.35/ 10.80 | 99./ 116. | 108./ 125. | 95./ 119. | 103./ 128. | | |
| Solar Engine Cogeneration; Two-Axis Dish, Stirling Engine (High Eff.), Multitank Low-Temp. Storage; HR-8 | 310 | 67.3 | 6.95/ 9.02 | 5.43/ 8.37 | 83./ 99. | 92./ 108. | 81./ 103. | 89./ 111. | | |
| Solar Engine Cogeneration; Two-Axis Dish, Stirling Engine (High Eff.), Battery Storage, High- and Low-Temp. Storage; HR-8 | 311 | 80.4 | 11.22/ 14.15 | 8.59/ 13.03 | 128./ 154. | 133./ 159. | 110./ 149. | 115./ 154. | | |
| Solar Engine Cogeneration; Two-Axis Dish, Stirling Engine (Low Eff.), High-Temp. and Multitank Low-Temp. Storage; HR-8 | 312 | 82.0 | 12.11/ 15.06 | 9.41/ 13.90 | 138./ 164. | 142./ 169. | 118./ 159. | 122./ 163. | | |
| Solar Engine Cogeneration; Two-Axis Dish, Stirling Engine (High Eff.), Battery, High-, and Low-Temp. Storage; HR-8 | 313 | 86.5 | 14.28/ 17.81 | 10.90/ 16.37 | 163./ 197. | 167./ 200. | 135./ 187. | 138./ 190. | | |
| Solar Engine Cogeneration; Two-Axis Dish, Stirling Engine (High Eff.), Battery Storage; HR-8 | 314 | 98.9 | 16.75/ 21.21 | 12.33/ 19.33 | 206./ 255. | 206./ 255. | 158./ 234. | 159./ 235. | | |
| Solar Engine Cogeneration; Two-Axis Dish, Stirling Engine (High Eff.), Battery, High-, and Low-Temp. Storage; HR-8 | 315 | 96.2 | 5.66/ 19.54 | 11.83/ 17.91 | 190./ 231. | 191./ 232. | 151./ 215. | 152./ 216. | | |
| 100-Percent Solar Engine Cogeneration; Two-Axis Dish, Stirling Engine (High Eff.), Battery, High-, and Low-Temp. Storage; HR-8 | 316 | 100.0 | 7.53/ 22.14 | 12.93/ 20.18 | 217./ 267. | 217./ 267. | 166./ 246. | 166./ 246. | | |
| Solar Engine Cogeneration; Two-Axis Dish, Stirling Engine (High Eff.), Battery, High-, and Low-Temp. Storage; HR-7 | 317 | 98.7 | 7.09/ 21.47 | 12.73/ 19.61 | 210./ 257. | 210./ 257. | 163./ 237. | 163./ 238. | | |
| Solar Engine Cogeneration; Two-Axis Dish, Stirling Engine (High Eff.), Battery, High-, and Low-Temp. Storage; HR-7 | 318 | 98.1 | 17.10/ 21.42 | 12.79/ 19.58 | 209./ 255. | 209./ 256. | 163./ 236. | 163./ 236. | | |
| Conv. Engine Cogeneration; Stirling Engine (Low Eff.), Absorption and Electric Chillers, Low-Temp. Storage (HR-8) | 319 | 38.0 | 4.72/ 6.27 | 4.35/ 6.12 | 59./ 66. | 76./ 82. | 74./ 82. | 90./ 97. | | |

Reference system

| | | | | | | | | | | | | | | |
|---|-----|------|--------|-------|---------|-------|--------|-------|--------|------|--------|------|---------|------|
| Conv. All Electric System; Central Chilled-Water System and Fan Coil Units With Resistance Heaters (HR-2) | 320 | 0.0 | NAI | NA | NA/ | NA | 87./ | NA | 11 3./ | NA | 113./ | NA | 2 2 3./ | NA |
| Systems compared to reference system | | | | | | | | | | | | | | |
| Solar Hot Water; Flat-Plates (1977 Prices); HR-2 | 321 | 12.5 | 5.07/ | 8.41 | 3.76/ | 7.05 | 89./ | 96. | 13./ | 20. | 110./ | 119. | 206./ | 215. |
| Solar Hot Water; Flat-Plates (Future Price); HR-2 | 322 | 12.5 | 3.17/ | 6.09 | 2.35/ | 5.74 | 85./ | 91. | 09./ | 15. | 107./ | 114. | 203./ | 210 |
| Solar Heating; Flat-Plates (1977 Prices), Low-Temp. Storage; HR-2 | 323 | 19.5 | 6.18/ | 8.98 | 4.57/ | 8.29 | 94./ | 104 | 16./ | 25 | 111./ | 123. | 199./ | 212. |
| Solar Heating; Flat-Plates (Future Price), Low-Temp. Storage; HR-2 | 324 | 19.5 | 3.90/ | 6.18 | 2.88/ | 5.75 | 87./ | 94. | 08./ | 16. | 105./ | 115. | 194./ | 203. |
| Solar Heating; Flat-Plates (1977 Prices), Low-Temp. Storage; HR-2 | 325 | 26.3 | 7.66/ | 10.43 | 5.65/ | 9.57 | 104./ | 116, | 123./ | 136. | 114./ | 132. | 196./ | 213. |
| Solar Heating; Flat-Plates (Future Price), Low-Temp. Storage; HR-2 | 326 | 26.3 | 4.83/ | 6.96 | 3.56/ | 6.42 | 91./ | 100. | 111./ | 120, | 105./ | 118. | 186./ | 199. |
| 100% Solar Heating; Flat-Plates (1977 Prices), Seas. Low-Temp. Storage; HR-2 | 327 | 61.1 | 7.73/ | 10.20 | 5.46/ | 9.24 | 127./ | 152. | 1 37./ | 163. | 114./ | 153. | 157./ | 197. |
| 1000% Solar Heating; Flat-Plates (Future Price), Seas. Low-Temp. Storage; HR-2 | 328 | 61.1 | 5.72/ | 7.75 | 3.98/ | 7.00 | 106./ | 127. | 116./ | 138. | 98./ | 130. | 142./ | 173. |
| 100% Solar Heating; Flat-Plates (1977 Prices), Seas. Aquifer Storage; HR-2 | 329 | 61.1 | 6.76/ | 8.78 | 4.94/ | 8.01 | 11 7./ | 138. | 127./ | 148. | 108./ | 140. | 152./ | 184. |
| 1000% Solar Heating; Flat-Plates (Future Price), Seas. Aquifer Storage; HR-2 | 330 | 61.1 | 4.39/ | 5.88 | 3.19/ | 5.37 | 92./ | 107. | 103./ | 118. | 90./ | 113. | 134./ | 156. |
| PV System, Two-Axis Concentrator With Si Cells (Med. Price), Multitank Low-Temp. Storage; HR-2 | 331 | 42.3 | 6.90/ | 9.03 | 5.20/ | 8.30 | 109./ | 124. | 125./ | 140. | 1 13./ | 135. | 178./ | 200. |
| PV Cogeneration; Two-Axis Concentrator With si Cells (Med. Price), Multitank Low-Temp. Storage; HR-2 | 332 | 43.0 | 4.23/ | 5.80 | 3.16/ | 5.35 | 90./ | 102. | 106./ | 118, | 98./ | 114. | 163./ | 179. |
| PV Cogeneration; Two-Axis Concentrator With Si Cells, Multitank Low-Temp. Storage; HR-6 | 333 | 46.4 | 4.86/ | 6.52 | 3.66/ | 6.00 | 96./ | 109. | 11 1./ | 124. | 101./ | 120. | 163./ | 181. |
| PV Cogeneration; Two-Axis Concentrator With GaAs Cells, Multitank Low-Temp. Storage; HR-2 | 334 | 42.6 | 6.60/ | 8.64 | 4.98/ | 7.95 | 107./ | 122. | 123./ | 138. | 111./ | 133. | 176 / | 197. |
| PV Cogeneration; Two-Axis Concentrator With GaAs Cells (Low Price), Multitank Low-Temp. Storage; HR-2 | 335 | 43.9 | 4.27/ | 5.78 | 3.26/ | 5.35 | 91./ | 102. | 106./ | 118. | 99./ | 114. | 163./ | 179. |
| PV Cogeneration; Two-Axis Concentrator With GaAs Cells (Low Price), Seasonal Low-Temp. Storage; HR-2 | 336 | 73.3 | 4.53/ | 6.08 | 3.24/ | 5.53 | 96./ | 115. | 104./ | 123. | 88./ | 116. | 120./ | 149. |
| PV System; Two-Axis Concentrator With GaAs Cells (Low Price), Seasonal Multitank Low-Temp. Storage; HR-2 | 337 | 74.1 | 5.52/ | 7.40 | 3.87/ | 6.70 | 109./ | 133. | 1 17./ | 140. | 96./ | 132. | 128./ | 164. |
| PV Cogeneration; One-Axis Concentrator With Si Cells (\$15/W Cells), Multitank Low-Temp. Storage; HR-2 | 338 | 28.4 | 9.80/ | 13.17 | 6.97/ | 11.96 | 115./ | 132. | 135./ | 151. | 121./ | 145. | 200./ | 224. |
| PV Cogeneration; One-Axis Concentrator With Si Cells (\$15/W Cells), Multitank Low-Temp. Storage; HR-2 | 339 | 40.7 | 13.53/ | 17.10 | 10.1 9/ | 15.67 | 154./ | 179. | 170./ | 195. | 147./ | 185. | 213./ | 251. |
| PV Cogeneration; One-Axis Concentrator With Si Cells (\$1/W Cells), Multitank Low-Temp. Storage; HR-2 | 340 | 31.9 | 5.30/ | 7.32 | 3.98/ | 6.76 | 94./ | 105.. | 113./ | 124. | 106./ | 121. | 181./ | 196. |

| Summary description of system | Table number | Percent solar | Effective cost of solar energy (¢/kWh) | | | | Levelized monthly cost of energy service | | | | | | | |
|--|--------------|---------------|--|--------------|------------|------------|--|------------|-------------------------|--|----------------------|--|----------------------|--|
| | | | No credits | | 20% ITC | | Projection 1 No credits | | Projection 2 No credits | | Projection 2 20% ITC | | Projection 3 20% ITC | |
| | | | | | | | | | | | | | | |
| Systems compared to reference system—Continued | | | | | | | | | | | | | | |
| PV Cogeneration; One-Axis Concentrator With Si Cells (\$1/w Cells), Multitank Low-Temp. Storage; HR-2 | 341 | 46.1 | 6.51/ 8.43 | 4.98/ 7.78 | 108./ 123. | 123./ 138. | 111./ 133. | 173./ 195. | | | | | | |
| PV Cogeneration; Two-Axis Concentrator With High Eff. Cells, Multitank Low-Temp. Storage; HR-2 | 342 | 49.1 | 4.431 5.92 | 3.36/ 5.46 | 95.1 107. | 110./ 122. | 101./ 118. | 163./ 181. | | | | | | |
| PV Cogeneration; Two-Axis Concentrator With High Eff. Cells, Seasonal Low-Temp. Storage; HR-2 | 343 | 85.7 | 4.90/ 6.49 | 3.49/ 5.89 | 106./ 129. | 112./ 136. | 92./ 127. | 117./ 152. | | | | | | |
| PV Cogeneration; Two-Axis Concentrator With High Eff. Cells, Seasonal Multitank Low-Temp. Storage; HR-2 | 344 | 98.1 | 3.35/ 4.45 | 2.44/ 4.07 | 87./ 105. | 91./ 110. | 76./ 103. | 95./ 122. | | | | | | |
| Solar Engine Cogeneration; Two-Axis Dish, Stirling Engine (Low Eff.), High-Temp. and Multitank Low-Temp. Storage; HR-6 | 345 | 87.4 | 7.93/ 9.71 | 6.20/ 8.97 | 153./ 180. | 160./ 186. | 134./ 175. | 159./ 201. | | | | | | |
| Solar Engine Cogeneration; Two-Axis Dish, Stirling Engine (Low Eff.), High Temp. and Multitank Low-Temp. Storage; HR-6 | 346 | 90.7 | 8.35/ 10.12 | 6.59/ 9.37 | 165./ 192. | 171./ 198. | 144./ 186. | 169./ 212. | | | | | | |
| Reference system | | | | | | | | | | | | | | |
| Conv All Electric System, Resistance Heat, Individual Window A/C, and Electric Water Heaters (HR-4) | 347 | 0.0 | NA/ NA | NA/ NA | 83./ NA | 09./ NA | 109./ NA | 215./ NA | | | | | | |
| Systems compared to reference system | | | | | | | | | | | | | | |
| PV System; Air-Cooled Si Arrays (\$ 1/W), HR-4 | 348 | 9.2 | 18.94/ 23.93 | 3.94/ 21.80 | 31./ 147. | 53./ 69. | 137./ 162. | 225./ 250. | | | | | | |
| PV System; Air-Cooled Si Arrays (\$ 1/W), HR-4 | 349 | 23.5 | 1 9.19/ 24.13 | 4.11/ 21.96 | 44./ 163. | 65./ 84. | 145./ 175. | 230./ 260. | | | | | | |
| PV System, Air-Cooled Si Arrays (\$ 1/W), Battery Storage; HR-4 | 350 | 22.7 | 21 .37/ 26.63 | 5.87/ 24.28 | 49./ 169. | 69./ 89. | 149./ 180. | 233./ 264. | | | | | | |
| PV System, Air-Cooled Si Arrays (\$0.50/W), HR-4 | 351 | 19.2 | 10.66/ 13.78 | 7.84/ 12.57 | 05./ 115. | 27./ 37. | 118./ 133. | 206./ 221. | | | | | | |
| PV System, Air-Cooled Si Arrays (\$0 501 W), HR - 4 | 352 | 18.4 | 16.33/ 19.97 | 2.64/ 18.39 | 20./ 131. | 42./ 53. | 131./ 148. | 218./ 235. | | | | | | |
| PV System: Air-Cooled Si Arrays (\$0.50/W). HR-4 | 353 | 23.5 | 10.79/ 13.80 | 7.93/ 12.58 | 111./ 123. | 132./ 144. | 121./ 139. | 206./ 224. | | | | | | |
| PV System, Air-Cooled Si Arrays (\$0 501 W), Battery Storage, HR-4 | 354 | 41.3 | 1 7.49/ 21.33 | 13.23/ 19.51 | 176./ 202. | 191./ 218. | 162./ 205. | 226./ 269. | | | | | | |
| PV System; Air-Cooled Si Arrays (\$050/W): HR-4 | 355 | 46.7 | 12.64/ 15.80 | 9.31/ 14.38 | 158./ 182. | 175./ 199. | 149./ 188 | 219./ 258. | | | | | | |
| PV System, Air-Cooled Thin-Film Arrays (\$0.30/W), HR-4 | 356 | 11.5 | 11.22/ 14.93 | 8.23/ 13.65 | 97./ 104. | 120./ 127. | 114./ 25. | 209./ 220. | | | | | | |
| PV System; Air-Cooled Thin-Film Arrays* (\$0.30/W); HR-4 | 357 | 12.9 | 11.01/ 14.53 | 8.09/ 13.29 | 98./ 106, | 121./ 129. | 115./ 26. | 208./ 220. | | | | | | |
| PV System; Air-Cooled Thin-Film Arrays Vertical (\$0.10/W); HR-4 | 358 | 5.2 | 3.441 6.77 | 2.461 6.35 | 82./ 85. | 107./ 110. | 106./ 10. | 207./ 211. | | | | | | |

| | | | | | | | | |
|---|---------|------|--------------|--------------|------------|------------|------------|------------|
| PV System; Air-Cooled Thin-Film Arrays Vertical (\$0.10/W); HR-4 | 359 | 4.9 | 3.95/ 7.53 | 2.83/ 7.05 | 83./ 86. | 108./ 110. | 107./ 110. | 208./ 211. |
| PV System, Air-Cooled Thin-Film Arrays (\$0.10/W) HR4 | 360 | 129 | 6.96/ 9.56 | 5.10/ 8.77 | 89./ 95. | 112./ 118. | 108./ 116. | 202./ 210. |
| PV System; Air-Cooled Thin-Film Arrays (\$0.10/W, HR-4 | 361 | 14.8 | 6.92/ 9.38 | 5.08/ 8.60 | 91./ 97. | 113./ 119. | 109./ 117. | 201./ 209. |
| PV System, Air-Cooled Thin-Film Arrays (\$0.10/W), Battery Storage: HR-4 | 362 | 162 | 7.39/ 9.83 | 5.46/ 9.01 | 92./ 99. | 114./ 121. | 109./ 119. | 199./ 209. |
| PV System, Air-Cooled Thin-Film Arrays (\$0.10/w) HR-4 | 363 | 16.5 | 6.93/ 9.30 | 5.08/ 8.51 | 92./ 98. | 114./ 120. | 109./ 118. | 199./ 208. |
| ALBUQUERQUE SHOPPING CENTER | | | | | | | | |
| <i>Reference system</i> | | | | | | | | |
| Conv. Gas Heat, Hot Water, and Central Electric A/C (SC-1) | 364 | 0.0 | NA/ NA | NA/ NA | 8.5/ NA | 114./ NA | 114./ NA | 219./ NA |
| Systems compared to reference system | | | | | | | | |
| Solar Hot Water; Flat-Plates (1977 Prices); SC-1 | 365 | 3.0 | 8.99/ 22.44 | 6.64/ 21.44 | 88./ 95. | 115./ 122. | 114./ 121. | 217./ 225. |
| Solar Hot Water; Flat-Plates (Future price), SC-1 | 365/401 | 3.0 | 5.53/ 18.20 | 4.08/ 17.59 | 86./ 92. | 113./ 120. | 112./ 119. | 216./ 223. |
| <i>Reference system</i> | | | | | | | | |
| Conv. Gas Heat, Hot Water, and Absorption Chilling (SC-7) | 366 | 0.0 | NA/ NA | NA/ NA | 79./ NA | 115./ NA | 115./ NA | 202./ NA |
| Systems Compared to reference system | | | | | | | | |
| Conv. Gas Heat, Hot Water, and Double-Effect Absorption Chilling (SC-7) | 367 | 9.7 | .91/ 4.60 | .58/ 4.46 | 76./ 82. | 105./ 112. | 104./ 111. | 186./ 193. |
| Solar Heating; Flat-Plates (1977 Prices), Low-Temp. Storage, sC-7 | 368 | 19.8 | 13.81/ 18.30 | 10.53/ 16.90 | 119./ 135. | 142./ 158. | 130./ 53. | 206./ 229. |
| Solar Heating; Flat-plates (Future price), Low-Temp. Storage; SC-7 | 368/405 | 19.8 | 7.76/ 11.20 | 5.70/ 10.32 | 96./ 109. | 120./ 132. | 112./ 129. | 189./ 205. |
| 100% Solar Heating and Cooling; Flat-Plates (1977 prices), Seas. Low-Temp. Storage; SC-7 | 369 | 30.1 | 13.20/ 17.37 | 9.67/ 15.87 | 136./ 159. | 153./ 176. | 133./ 168. | 204./ 238. |
| Solar Heating; Flat-Plates (Future Prices), Low-Temp. Storage; SC-7 | 69/407 | 30.1 | 8.25/ 11.25 | 6.05/ 10.32 | 108./ 125. | 125./ 142. | 113./ 137. | 184./ 207. |
| Solar Heating and Cooling; One-Axis Tracker (1977 Design), Low-Temp. Storage; SC-7 | 370 | 19.6 | 12.97/ 17.31 | 9.88/ 15.99 | 115./ 131. | 139./ 154. | 128./ 150. | 204./ 226. |
| Solar Heating and Cooling; One-Axis Tracker (Future Design), Low-Temp. Storage; SC-7 | 371 | 24.1 | 4.42/ 6.73 | 3.33/ 6.26 | 85./ 96. | 106./ 117. | 101./ 114. | 175./ 188. |
| Solar Heating and Cooling; One-Axis Tracker (Future Design), Low-Temp. Storage; SC-7 | 372 | -848 | -1.44/ -2.12 | -1.10/ -1.97 | 149./ 160. | 235./ 246. | 230./ 244. | 364./ 378. |
| Solar Heating and Cooling; One-Axis Tracker (Future Design), Seasonal Low-Temp. Storage; SC-7 | 373 | 30.1 | 6.72/ 9.16 | 5.17/ 8.50 | 100./ 113. | 117./ 130. | 108./ 127. | 179./ 197. |
| Solar Heating; One-Axis Tracker (Future Design), Cheap Seasonal Storage; SC-7 | 374 | 30.1 | 5.71/ 8.02 | 4.31/ 7.43 | 94./ 107. | 111./ 124. | 104./ 121. | 174./ 191. |
| Solar Engine Cogeneration; ORCS, One-Axis Tracker (Future Design), Multitank High-Temp. Storage, Absorption Chillers; SC-7 | 375 | 15.2 | 44.88/ 55.56 | 34.91/ 51.30 | 193./ 223. | 244./ 273. | 216./ 262. | 262./ 308. |

| Summary description of system | Table number | Percent solar | Effective cost of solar energy (¢/kWh) | | | | Levelized monthly cost of energy service | | | | | |
|---|--------------|---------------|--|--------------|------------|------------|--|------------|----------------------|--|----------------------|--|
| | | | No credits | | 20% ITC | | Projection 1 No credits | | Projection 2 20% ITC | | Projection 3 20% ITC | |
| <i>Systems compared to reference system—Continued</i> | | | | | | | | | | | | |
| <i>Solar Engine Cogeneration; ORCS, One-Axis Tracker (Future Design), Multitank High-Temp. Storage, Absorption Chillers; SC-7</i> | | | | | | | | | | | | |
| | 376 | 36.5 | 19.97/ 24.85 | 15.35/ 22.88 | 189./ 222. | 227./ 260. | 196./ 247. | 231./ 282. | | | | |
| <i>Reference system</i> | | | | | | | | | | | | |
| <i>Conv. All-Electric Shopping Center (SC-2)</i> | | | | | | | | | | | | |
| | 377 | 0.0 | NA/ NA | NA/ NA | 90./ NA | 120./ NA | 120./ NA | 239./ NA | | | | |
| <i>Systems compared to reference system</i> | | | | | | | | | | | | |
| <i>Solar Hot Water; Flat-Plates (1977 Prices); SC-2</i> | | | | | | | | | | | | |
| | 378 | 8.5 | 2.78/ 6.64 | 2.05/ 6.33 | 89./ 96. | 116./ 123. | 115./ 122. | 225./ 233. | | | | |
| <i>Solar Hot Water; Flat-Plates (Future Price); "SC-2</i> | | | | | | | | | | | | |
| | 378/416 | 8.5 | 1.71/ 5.33 | 1.26/ 5.14 | 88./ 94. | 115./ 121. | 114./ 120. | 224./ 231. | | | | |
| <i>Solar Heating; Flat-Plates (1977 Price), Low-Temp. Storage; SC-2</i> | | | | | | | | | | | | |
| | 379 | 12.7 | 3.59/ 6.58 | 2.65/ 6.18 | 92./ 100. | 118./ 126. | 116./ 125. | 224.1 233. | | | | |
| <i>Solar Heating; Flat-Plates (Future Design), Low-Temp. Storage; SC-2</i> | | | | | | | | | | | | |
| | 379/418 | 12.7 | 2.20/ 4.87 | 1.62/ 4.62 | 89./ 95. | 115./ 122. | 114./ 121. | 221./ 229. | | | | |
| <i>Solar Heating; Flat-Plates (1977 Price), Seasonal Low-Temp. Storage; SC-2</i> | | | | | | | | | | | | |
| | 380 | 18.1 | 4.41 / 7.06 | 3.14/ 6.52 | 95./ 105. | 120./ 130. | 116./ 128. | 217./ 229. | | | | |
| <i>Solar Heating; Flat-Plates (Future Price), Seasonal Low-Temp. Storage; SC-2</i> | | | | | | | | | | | | |
| | 380/422 | 18.1 | 3.12/ 5.49 | 2.19/ 5.09 | 91./ 99. | 116./ 124. | 112./ 123. | 214./ 224. | | | | |
| <i>PV System; Air-Cooled si Arrays (\$0.50/W); SC-2</i> | | | | | | | | | | | | |
| | 381 | 60.4 | 7.76/ 9.98 | 5.72/ 9.11 | 160./ 187. | 181./ 207. | 156./ 197. | 239./ 279. | | | | |
| <i>PV System; Air-Cooled Si Arrays (\$1/W); SC-2</i> | | | | | | | | | | | | |
| | 381/423 | 60.4 | 14.27/ 17.96 | 10.52/ 16.36 | 238./ 282. | 258./ 302. | 214./ 283. | 296./ 366. | | | | |
| <i>PV System; Air-Cooled Thin-Film Arrays (\$0.10/W); SC-2</i> | | | | | | | | | | | | |
| | 382 | 42.1 | 4.86/ 6.62 | 3.57/ 6.08 | 113./ 128. | 136./ 150. | 125./ 146. | 216./ 237. | | | | |
| <i>PV Cogeneration; Two-Axis Concentrator With High Eff. Cells, Multitank Low-Temp. Storage; SC-2</i> | | | | | | | | | | | | |
| | 383 | 86.8 | 3.96/ 5.10 | 3.02/ 4.70 | 125./ 145. | 141./ 161. | 125./ 154. | 191./ 219. | | | | |
| <i>PV Cogeneration; Two-Axis Concentrator With High Eff. Cells, Battery and Multitank Low-Temp. Storage; SC-2</i> | | | | | | | | | | | | |
| | 384 | 80.6 | 4.36/ 5.58 | 3.33/ 5.14 | 127./ 147. | 144./ 163. | 127./ 156. | 194./ 222. | | | | |
| FORT WORTH SHOPPING CENTER | | | | | | | | | | | | |
| <i>Reference system</i> | | | | | | | | | | | | |
| <i>Conv. Gas Heat, Hot Water, and Central Electric A/C (SC-1).</i> | | | | | | | | | | | | |
| | 385 | 0.0 | NA/ NA | NA/ NA | 103./ NA | 137./ NA | 137./ NA | 264./ NA | | | | |

| | | | | | | | | | | | | |
|---|---------|------|--------------|--------------|------------|------------|------------|------------|--|--|--|--|
| <i>Systems compared to reference system</i> | | | | | | | | | | | | |
| <i>Solar Hot Water; Flat-plates (1977 Prices);</i> | | | | | | | | | | | | |
| SC-1 | 386 | 2.5 | 12.07/ 32.09 | 8.92/ 30.75 | 107./ 116/ | 140./ 149 | 138./ 148 | 264./ 273. | | | | |
| <i>Solar Hot Water; Flat-plates (Future Price);</i> | | | | | | | | | | | | |
| SC-1 | 386/401 | 2.5 | 7.36/ 26.34 | 5.44/ 25.52 | 105./ 114. | 137./ 146 | 137./ 146. | 262./ 271. | | | | |
| <i>Solar Heating and Cooling; Absorption A/C, One-Axis Tracker (Future Design Low-Temp. Storage; SC-7)</i> | | | | | | | | | | | | |
| | 387 | 229 | 8.62/ 12.63 | 6.22/ 11.60 | 110./ 127 | 133./ 150. | 123./ 145 | 202./ 225 | | | | |
| <i>Solar Heating and Cooling; Absorption A/C, One-Axis Tracker (Future Design), Low-Temp. Storage; SC-7</i> | | | | | | | | | | | | |
| | 388 | 18.4 | 13.69/ 19.19 | 10.06/ 17.64 | 123./ 141. | 148./ 166 | 136./ 161 | 218./ 243 | | | | |
| <i>Solar Heating and Cooling; Absorption A/C, One-Axis Tracker (Future Design), Low-Temp. Storage; SC-7</i> | | | | | | | | | | | | |
| | 389 | 18.7 | 26.52/ 34.87 | 19.54/ 31.89 | 166./ 194. | 192./ 220. | 168./ 210. | 249./ 291 | | | | |
| <i>Solar Heating and cooling; Absorption A/C, One-Axis Tracker (Future Design), Seasonal Low-Temp. Storage; sc-7</i> | | | | | | | | | | | | |
| | 390 | 30.6 | 10.54/ 14.68 | 7.48/ 13.37 | 129./ 151. | 147./ 170. | 130./ 163. | 205./ 238. | | | | |
| <i>Solar Heating and Cooling; Absorption A/C, One-Axis Tracker (Future Design), Seasonal Low-Temp. Storage; SC-7</i> | | | | | | | | | | | | |
| | 391 | 30.6 | 13.08/ 17.68 | 9.46/ 16.13 | 143./ 168. | 161./ 186. | 141./ 178. | 216./ 253 | | | | |
| <i>Solar Heating and Cooling; Absorption A/C, One-Axis Tracker (1977 Design), Seasonal Low-Temp. Storage; SC-7</i> | | | | | | | | | | | | |
| | 391/407 | 30.6 | 25.28/ 32.57 | 18.50/ 29.68 | 210./ 250. | 228./ 269. | 191./ 253. | 266./ 327. | | | | |
| <i>Solar Engine Cogeneration; ORCS and One-Axis Tracker (Future Design), 011 Backup, Multitank High-Temp. 011 Storage; SC-7</i> | | | | | | | | | | | | |
| | 392 | -2.5 | •••••/••••• | •••••••••• | 209./ 242. | 269./ 301. | 241./ 289. | 296./ 345. | | | | |
| <i>Reference system</i> | | | | | | | | | | | | |
| Conv. All-Electric Shopping Center (SC-2) | 393 | 0.0 | NA/ NA | NA/ NA | 111./ NA | 146./ NA | 146./ NA | 290./ NA | | | | |
| <i>Systems compared to reference system</i> | | | | | | | | | | | | |
| <i>Solar Hot Water; Flat-Plates (1977 Prices);</i> | | | | | | | | | | | | |
| SC-2 | 394 | 7.3 | 3.73/ 9.48 | 2.76/ 9.06 | 113./ 122. | 148./ 156. | 46./ 155. | 286./ 295. | | | | |
| <i>Solar Hot Water; Flat-Plates (Future Price);</i> | | | | | | | | | | | | |
| SC-2 | 394/416 | 7.3 | 2.27/ 7.70 | 1.68/ 7.44 | 111./ 119. | 146./ 153. | 45./ 153. | 284./ 293. | | | | |
| <i>Solar Heating; Flat-Plates (1977 Prices), Low-Temp. Storage; SC-2</i> | | | | | | | | | | | | |
| | 395 | 11.3 | 4.571 8.77 | 3.371 8.26 | 110./ 120. | 141./ 150. | 38./ 149. | 264./ 275. | | | | |
| <i>Solar Heating; Flat-Plates (Future Price), Low-Temp. Storage; SC-2</i> | | | | | | | | | | | | |
| | 395/420 | 11.3 | 2.80/ 6.60 | 2.06/ 6.29 | 106./ 115. | 137./ 146. | 35./ 145. | 261./ 271. | | | | |
| <i>Solar Heating; Flat-Plates (1977 Prices), Seasonal Low-Temp. Storage; SC-2</i> | | | | | | | | | | | | |
| | 396 | 15.1 | 4.99/ 8.55 | 3.62/ 7.96 | 113./ 124. | 144./ 155. | 140./ 153. | 263./ 276. | | | | |
| <i>Solar Heating; Flat-Plates (Future Price) Seasonal Low-Temp. Storage; SC-2</i> | | | | | | | | | | | | |
| | 396/422 | 15.1 | 3.27/ 6.44 | 2.35/ 6.05 | 108./ 118. | 139./ 148. | 136./ 147. | 259./ 271. | | | | |
| <i>PV System; Air-Cooled Si Arrays (\$0.50/W);</i> | | | | | | | | | | | | |
| SC-2 | 397 | 46.4 | 9.98/ 13.02 | 7.35/ 11.90 | 183./ 211. | 211./ 239. | 186./ 228 | 297./ 339. | | | | |
| <i>PV System; Air-Cooled Si Arrays (\$ I/W); SC-2.</i> | | | | | | | | | | | | |
| | 397/423 | 46.4 | 18.33/ 23.26 | 13.52/ 21.20 | 261./ 307. | 288./ 334. | 243./ 315. | 354./ 426. | | | | |
| <i>PV System; Air-Cooled Thin-Film Arrays (\$0.10/W); Building Equipped SC-2</i> | | | | | | | | | | | | |
| | 398 | 32.3 | 6.25/ 8.79 | 4.60/ 8.08 | 136./ 152, | 165./ 181. | 154./ 176 | 272./ 295 | | | | |

| Summary description of system | Table number | Percent solar | Effective cost of solar energy (¢/kWh) | | | | Levelized monthly cost of energy service | | | | | | | |
|--|--------------|---------------|--|-------|-----------|-------|--|------|-------------------------|------|----------------------|------|----------------------|------|
| | | | No credits | | 200/0 ITC | | Projection 1 No credits | | Projection 2 No credits | | Projection 2 20% ITC | | Projection 3 20% ITC | |
| OMAHA SHOPPING CENTER | | | | | | | | | | | | | | |
| Reference System | | | | | | | | | | | | | | |
| Conv. Gas Heat, Hot Water, and Central Electric A/C (SC-1)..... | 399 | 0.0 | NA/ | NA | NA/ | NA | 85./ | NA | 112./ | NA | 112./ | NA | 210./ | NA |
| Systems compared to reference system | | | | | | | | | | | | | | |
| Solar Hot Water; Flat-Plates (1977 Prices); SC-1..... | 400 | 2.4 | 13.54/ | 35.32 | 10.01/ | 33.82 | 90./ | 98. | 116./ | 124. | 114./ | 124. | 211./ | 221. |
| Solar Hot Water; Flat-Plates (Future Price); Se-1..... | 401 | 2.4 | 8.26/ | 28.87 | 6.10/ | 27.95 | 87./ | 96. | 114./ | 122. | 113./ | 121. | 209./ | 218. |
| Reference system | | | | | | | | | | | | | | |
| Conv. Gas Heat, Gas Hot Water, and Absorption Chillers (SC-7)..... | 402 | 0.0 | NA/ | NA | NA/ | NA | 79./ | NA | 108./ | NA | 108./ | NA | 189./ | NA |
| Systems compared to reference system | | | | | | | | | | | | | | |
| Conv. Gas Heat, Hot Water, and Double-Ef. feet Absorption Chilling (SC-7)..... | 403 | 7.6 | 1.60/ | 7.92 | 1.02/ | 7.67 | 78./ | 86. | 104./ | 112. | 103./ | 112. | 181./ | 190. |
| Solar Heating; Flat-Plates (1977 Prices), Low-Temp. Storage; SC-7..... | 404 | 16.8 | 20.25/ | 27.48 | 14.90/ | 25.20 | 31./ | 152. | 153./ | 174. | 137./ | 167. | 212./ | 242. |
| Solar Heating; Flat-Plates (Future Price); SC-7..... | 405 | 16.8 | 12.73/ | 18.27 | 9.33/ | 16.83 | 09./ | 125. | 131./ | 147. | 121./ | 143. | 196./ | 218. |
| 100-Percent Solar Heating; Flat-Plates (1977 Prices), Seasonal Low-Temp. Storage; SC-7..... | 406 | 27.8 | 19.43/ | 25.41 | 14.33/ | 23.23 | 61./ | 190. | 179./ | 208. | 154./ | 197. | 224./ | 267. |
| Solar Heating; Flat-Plates (Future Price), Seasonal Low-Temp. Storage; SC-7..... | 407 | 27.8 | 12.21/ | 16.57 | 8.99/ | 15.20 | 26./ | 148. | 144./ | 165. | 128./ | 158. | 199./ | 229. |
| Solar Heating; One-Axis Tracker (1977 Designs), Low-Temp. Storage; SC-7..... | 408 | 15.3 | 23.69/ | 31.46 | 18.02/ | 29.04 | 136./ | 156. | 158./ | 179. | 143./ | 172. | 218./ | 248. |
| Solar Heating; One-Axis Tracker (Future Design), Low-Temp. Storage; SC-7..... | 409 | 11.3 | 11.73/ | 18.00 | 8.97/ | 16.82 | 97./ | 109. | 121.1 | 134. | 116./ | 131. | 193./ | 208. |
| Solar Heating and Cooling; One-Axis Tracker (Future Design) and Low-Temp. Storage; SC-7..... | 410 | 26.3 | 13.27/ | 17.73 | 10.07/ | 16.36 | 129./ | 149. | 147./ | 167. | 132./ | 161. | 203./ | 232. |
| Solar Heating; One-Axis Tracker (Future Design), Low-Temp. Storage; SC-7..... | 411 | 92.8 | 3.64/ | 4.86 | 2.78/ | 4.49 | 88./ | 108. | 90./ | 110. | 77./ | 104. | 85./ | 113. |
| Solar Heating and Cooling; One-Axis Tracker (Future Design), Seasonal Low-Temp. Storage; SC-7..... | 412 | 27.8 | 10.41/ | 14.21 | 7.89/ | 13.13 | 118./ | 136. | 135./ | 153. | 123./ | 148. | 193./ | 219. |
| Solar Engine Cogeneration; ORCS, One-Axis Tracker (Future Design), High-Temp. Storage; SC-7..... | 413 | -1.8 | • *****, | ••••• | •••••/• | ••••• | 196./ | 229. | 239./ | 272. | 210./ | 260. | 250./ | 300. |
| Reference system | | | | | | | | | | | | | | |
| Conv. All-Electric (SC-2)..... | 414 | 0.0 | NA/ | NA | NA/ | NA | 96./ | NA | 126./ | NA | 126./ | NA | 247./ | NA |

Systems compared to reference system

| | | | | | | | | |
|--|-----|------|---------------|--------------|-------------|-------------|------------|-------------|
| Solar Hot Water; Flat-Plates (1977 Prices); SC-2 | 415 | 6.6 | 4.18/ 10.42 | 3.09/ 9.95 | 97. / 105, | 125./ 133. | 123./ 132. | 237./ 246. |
| Solar Hot Water; Flat-Plates (Future Price); SC-2 | 416 | 6.6 | 33961 46.86 | 25.11/ 43.08 | 135. / 152. | 163./ 180. | 152./ 175. | 265./ 289. |
| Solar Heating; Flat-Plates (1977 Prices) and Low-Temp. Storage; SC-2 | 417 | 101 | 5 1 3 1 9 7 3 | 3.79/ 9.16 | 100./ 109. | 27./ 136. | 124./ 135 | 235./ 245. |
| Solar Heating; Flat-Plates (Future Prices) and Low-Temp. Storage; SC-2 | 418 | 10.1 | 4.46/ 9.01 | 3.15/ 8.51 | 98. / 108. | 26./ 135, | 123./ 134. | 233./ 244. |
| Solar Heating; Flat-Plates (1977 Prices) and Low-Temp. Storage; SC-2 | 419 | 12.6 | 6.82/ 11.09 | 5.06/ 10.34 | 105./ 116 | 32./ 142 | 127./ 141. | 236./ 249. |
| Solar Heating; Flat-Plates (Future Prices) and Low-Temp. Storage; SC-2 | 420 | 126 | 4.42/ 8.14 | 3.29/ 7.66 | 99. / 108. | 26./ 135 | 123./ 134. | 231./ 242. |
| 100-Percent Solar Heating; Flat-Plates (1977 Prices) and Seasonal Low-Temp. Storage; SC-2 | 421 | 24.2 | 11.31/ 14.58 | 9.25/ 13.69 | 133. / 149. | 156./ 172. | 147./ 168. | 240./ 262. |
| 100-Percent Solar Heating; Flat-Plates (Future Prices) and Seasonal Low-Temp. Storage; SC-2 | 422 | 24.2 | 8.92/ 11.64 | 7.47/ 11.3 | 122./ 135. | 145. / 158. | 138./ 155. | 232./ 249. |
| PV System; Air-Cooled Si Arrays (\$1/W) SC-2. | 423 | 46.5 | 8.53/ 23.47 | 13.66/ 21.40 | 237. / 283 | 255./ 301. | 211./ 282. | 284./ 355. |
| PV System; Air-Cooled Si Arrays (\$1/W), Battery Storage; SC-2 | 424 | 45.4 | 9.79/ 24.92 | 14.68/ 22.74 | 244./ 290. | 261./ 307. | 215./ 288. | 287./ 360 |
| PV System; Air-Cooled Si Array (\$0.50/W); SC-2 | 425 | 46.5 | 0.08/ 13.12 | 7.43/ 11.99 | 160./ 188. | 178./ 206. | 153./ 195. | 227./ 269 |
| PV System; Air-Cooled Thin-Film Arrays (\$0.30/W); SC-2 | 426 | 25.2 | 3.53/ 17.97 | 9.97/ 16.46 | 148./ 170. | 171./ 193. | 153./ 186. | 249./ 281. |
| PV System; Air-Cooled Thin-Film Arrays (\$0.10/W); SC-2 | 427 | 32.5 | 6.28/ 8.78 | 4.62/ 8.07 | 116./ 132. | 137. / 153. | 126./ 149. | 213./ 236. |
| PV System; Air-Cooled Thin-Film Arrays (\$0.10/W) Battery Storage; SC-2 | 428 | 32.3 | 6.47/ 9.01 | 4.77/ 8.29 | 116./ 132. | 138./ 154. | 127./ 149. | 213./ 236. |
| PV Cogeneration; Two-Axis Concentrator With High Eff. Cells, Battery and Multitank Low-Temp. Storage, SC-2 | 429 | 63.1 | 6.09/ 7.82 | 4.68/ 7.23 | 127./ 149. | 139. / 161. | 122./ 154. | 170. / 202. |
| PV Cogeneration; Two-Axis Concentrator With High Eff. cells, Multitank Low-Temp. Storage, SC-2 | 430 | 66.9 | 5 12/ 6.70 | 3.89/ 6.18 | 120. / 141. | 132./ 153, | 116./ 147. | 166. / 196. |

ALBUQUERQUE COMMUNITY

Conventional systems

| | | | | | | | | |
|--|-----|-----|--------|--------|----------|-----------|----------|----------|
| Conv. Heating and Cooling Systems in Each Building: Mixture of Gas/Electric Hot Water, Gas/Heat-pump/Resistance Heating, and Electric Chilling | 431 | 0.0 | NA/ NA | NA/ NA | 90./ NA | 126./ NA | 126./ NA | 225./ NA |
| Conv. Heating and Cooling Systems in Each Building, All Use Electric Hot Water, Resistance Heating, Electric Cooling, and Utility Electricity | 432 | 0.0 | NA/ NA | NA/ NA | 129./ NA | 174. / NA | 174/ NA | 357./ NA |

| Summary description of system | Table number | Percent solar | Effective cost of solar energy (¢/kWh) | | | | Levelized monthly cost of energy Service | | | |
|--|--------------|---------------|--|-------------|------------|------------|--|-------------------------|----------------------|----------------------|
| | | | No credits | | 20% ITC | | Projection 1 No credits | projection 2 No credits | Projection 2 20% ITC | Projection 3 20% ITC |
| Reference system | | | | | | | | | | |
| <i>Conv. Heating and Cooling Systems in Each Building; All Use Electric Hot Water and Cooling; the High Rises and Shopping Center Use Resistance Heating, Other Buildings Use Heat Pumps</i> | 433 | 0.0 | NA/ NA | NA/ NA | 125./ NA | 164./ NA | 164./ NA | 325./ NA | | |
| Systems compared to reference system | | | | | | | | | | |
| <i>Conv. Engine Cogeneration; Oil-Burning Diesel/ORCS, Absorption and Electric Chillers</i> | 434 | 54.0 | 5.33/ 8.08 | 4.68/ 7.31 | 122./ 152 | 135./ 166. | 128./ 157. | 189./ 218. | | |
| <i>Conv. Engine Cogeneration; Gas-Burning Diesel/ORCS, Absorption and Electric Chillers</i> | G434 | 54.0 | 5.33/ 8.08 | 4.68/ 7.31 | 101./ 131. | 118./ 148. | 111./ 139. | 126./ 155. | | |
| <i>Conv. Engine Cogeneration; Coal Steam Turbines and Absorption and Electric Chillers. 100-Percent Solar Heating; I-Cover Pond, Seasonal Aquifer Storage, Electric Chillers, and Utility Electricity.</i> | 435 | 41.7 | 9.18/ 13.85 | 8.02/ 12.45 | 125./ 165. | 136./ 175. | 126./ 164. | 157./ 195. | | |
| <i>100-Percent Solar Heating; I-Cover Pond, Seasonal Aquifer Storage, Electric Chillers, and Utility Electricity.</i> | 436 | 54.7 | 6.67/ 9.86 | 5.90/ 8.94 | 140./ 175. | 155./ 191. | 147./ 181. | 210./ 244. | | |
| <i>100-Percent Solar Heating; I-Cover Pond, Seasonal Aquifer Storage, Electric Chillers, and Utility Electricity.</i> | 437 | 54.7 | 5.52/ 8.28 | 4.88/ 7.50 | 127./ 158. | 143./ 173. | 135./ 165. | 199./ 228. | | |
| <i>100-Percent Solar Heating; Flat-Plates (1977 Prices), Seasonal Low-Temp. Storage, Absorption Chillers, and Utility Electricity</i> | 438 | 67.0 | 7.82/ 11.90 | 6.81/ 10.68 | 157./ 213. | 66./ 222. | 153./ 205. | 191./ 244. | | |
| <i>100. Percent Solar Heating; Flat-Plates (Future Price), Absorption Chillers, Low-Temp. Storage, and Utility Electricity.</i> | 439 | 66.9 | 5.71/ 8.90 | 4.93/ 7.96 | 128./ 172. | 38./ 181. | 127./ 168. | 165./ 207. | | |
| <i>Solar Engine Cogeneration; Steam Turbines, Heliostats, High- and Low-Temp. Storage, Absorption and Electric Chillers and Coal Backup</i> | 440 | 70.1 | 7.91/ 11.56 | 6.98/ 10.44 | 150./ 203. | 56./ 208. | 143./ 192. | 158./ 208. | | |
| <i>Solar Engine Cogeneration; Heliostats, Steam Turbines With Coal Superheat, High- and Low-Temp. Storage, Absorption and Electric Chillers, and Coal Backup.</i> | 441 | 66.4 | 7.75/ 11.37 | 6.83/ 10.26 | 144./ 193. | 150./ 199. | 137./ 184. | 155./ 202. | | |
| <i>Solar Engine Cogeneration; Two-Axis Dish, High Eff. Stirling Engines, High- and Low-Temp. Storage, Absorption and Electric Chillers, and Oil Backup.</i> | 442 | 91.4 | 6.05/ 8.71 | 5.38/ 7.92 | 146./ 96. | 149./ 198. | 137./ 184. | 148./ 195. | | |
| <i>Solar Engine Cogeneration; Two-Axis Dish, High Eff. Stirling Engines, High- and Low-Temp. Storage, Absorption and Electric Chillers, and Gas Backup.</i> | G442 | 91.4 | 6.05/ 8.71 | 5.38/ 7.92 | 143./ 92. | 146./ 195. | 133./ 180. | 136./ 183. | | |

| | | | | | | | | |
|---|------|-------|---------------|-------------|------------|------------|-------------|-------------|
| Solar Engine Cogeneration; Two-Axis Dish, Low Eff. Stirling Engines, High- and Low-Temp. Storage, Absorption and Electric Chillers, and 011 Backup. | 443 | 90.4 | 6.63/ 9.36 | 5.95/ 8.54 | 157./ 207. | 159./ 210. | 147. / 195. | 160. / 207. |
| Solar Engine Cogeneration; Two-Axis Dish, Low Eff. Stirling Engines, High- and Low-Temp. Storage, Absorption and Electric Chillers, and Gas Backup. | G443 | 90.4 | 6.63/ 9.36 | 5.95/ 8.54 | 152./ 203. | 156./ 206. | 43. / 191. | 47. / 194. |
| 100-Percent Solar Engine; Low-Temp. ORCS With River-Water Condenser, 2-Cover Pond, Seasonal Aquifer Storage, and Absorption Chillers | 444 | 100.0 | 8.85/ 12.33 | 7.95/ 11.25 | 207./ 278. | 207./ 278. | 89./ 256. | 89. / 256. |
| 100-Percent Solar Engine; Low-Temp. ORCS With Cooling Tower, 2-Cover Pond, Seasonal Aquifer Storage, and Absorption Chillers | 445 | 100.0 | 11 .07/ 15.28 | 9.96/ 13.95 | 252./ 338. | 252./ 338 | 230./ 311 | 230. / 311. |
| 100-Percent Solar PV Cogeneration; Two-Axis Concentrator With Si Cells (Med. Price), Seasonal iron-REDOX Electrical and Multitank Low-Temp. Storage, and Absorption Chillers (Minimum Collector Area) | 446 | 100.0 | 9.34/ 13.15 | 8.38/ 12.00 | 217./ 295. | 217./ 295. | 198./ 271. | 98./ 271 |
| 100-Percent Solar PV Cogeneration; Two-Axis Concentrator With Si Cells (Med. Price), Seasonal iron-REDOX Electrical and Multitank Low-Temp. Storage, and Absorption Chillers (Optimized Collector Area). | 447 | 1000 | 7.88/ 11.20 | 7.05/ 10.19 | 188./ 255, | 188./ 255. | 171./ 235. | 71. / 235. |
| FORT WORTH COMMUNITY | | | | | | | | |
| <i>Conventional systems</i> | | | | | | | | |
| Conv. Heating and Cooling Systems in Each Building; Mixture of Gas/Electric Hot Water, Gas/Heat-Pump/Resistance Heating, and Electric Chilling | 448 | 0.0 | NA/ NA | NA/ NA | 117./ NA | 158./ NA | 158./ NA | 294./ NA |
| Conv. Heating and Cooling Systems in Each Building; All Use Electric Hot Water, Resistance Heating, Electric Cooling, and Utility Electricity | 449 | 0.0 | NA/ NA | NA/ NA | 145./ NA | 193./ NA | 193./ NA | 392./ NA |
| <i>Reference system</i> | | | | | | | | |
| Conv. Heating and Cooling Systems in Each Building; All Use Electric Hot Water and Electric Cooling; High Rises and Shopping Center Use Resistance Heating, Other Buildings Use Heat Pumps | 450 | 0.0 | NA/ NA | NA/ NA | 148./ NA | 194./ NA | 194./ NA | 381./ NA |
| <i>Systems compared to reference system</i> | | | | | | | | |
| Conv. Engine Cogeneration; 011-Burning Diesel/ORCS, and Absorption and Electric Chillers | 451 | 53.1 | 5.28/ 8.24 | 4.61/ 7.43 | 132./ 166. | 145./ 179. | 138./ 170. | 200./ 232. |
| Conv Engine Cogeneration; Gas-Burning Diesel/ORCS, and Absorption and Electric Chillers | G451 | 53.1 | 5.28/ 8.24 | 4.61/ 7.43 | 113./ 147. | 133./ 166. | 125./ 157. | 143./ 175. |

| Summary description of system | Table number | Percent solar | Effective cost of solar energy (¢/kWh) | | | | Levelized monthly cost of energy service | | | | | | | |
|---|--------------|---------------|--|-------|---------|-------|--|------|-------------------------|------|----------------------|------|----------------------|------|
| | | | No credits | | 20% ITC | | Projection 1 No credits | | Projection 2 No credits | | Projection 2 20% ITC | | Projection 3 20% ITC | |
| Systems compared to reference system—Continued | | | | | | | | | | | | | | |
| Conv. Engine Cogeneration; Coal Steam Turbines, and Absorption and Electric Chillers | 452 | 37.6 | 1 0.37/ | 15.92 | 9.01/ | 14.29 | 141/ | 186, | 153./ | 198. | 142./ | 185. | 1 77./ | 220. |
| Solar Engine Cogeneration; Steam Turbines, Heliostats, High- and Low-Temp. Storage, Absorption and Electric Chillers, and Coal Backup | 453 | 65.8 | 9.89/ | 14.46 | 8.73/ | 13.07 | 187./ | 251. | 1 93./ | 258. | 177. / | 238. | 196. / | 257. |
| Solar Engine Cogeneration; Steam Turbines With Coal Superheat, Heliostats, High- and Low-Temp. Absorption and Electric-Chillers, and Coal Superheat | 454 | 62.5 | 9.62/ | 14.16 | 8.47/ | 12.79 | 177./ | 238. | 184. / | 245. | 169./ | 227 | 190./ | 248. |
| OMAHA COMMUNITY | | | | | | | | | | | | | | |
| Conventional systems | | | | | | | | | | | | | | |
| Conv. Heating and Cooling Systems in Each Building; Mixture of Gas/Electric Hot Water, Gas/Heat-Pump/Resistance Heating, and Electric Chilling | | | | | | | | | | | | | | |
| Conv. Heating and Cooling Systems" in Each Building; All Use Electric Hot Water, Resistance Heating, Electric Cooling, and Utility Electricity | 455 | 0.0 | NA/ | NA | NA/ | NA | 98. / | NA | 1 33. / | NA | 1 33./ | NA | 235./ | NA |
| Reference system | 456 | 0.0 | NA/ | NA | NA/ | NA | 131./ | NA | 1 74. / | NA | 174./ | NA | 351./ | NA |
| Conv. Heating and Cooling System in Each Building; All Use Electric Hot Water and Electric Cooling; High Rises and Shopping Center Use Resistance Heating, Other Buildings Use Heat Pumps | 457 | 0.0 | NA/ | NA | NA/ | NA | 1 30. / | NA | 168./ | NA | 168./ | NA | 326./ | NA |
| Systems compared to reference system | | | | | | | | | | | | | | |
| Conv. District Heating; Central Oil Heat and Electric Chilling, and Utility Electricity | 458 | 34.9 | 4,49/ | 7.49 | 3.87/ | 6.73 | 127. / | 152. | 149./ | 174. | 144./ | 168. | 237./ | 261. |
| Conv. District Heating; Central Oil Heat and Electric Chilling, and Utility Electricity | G458 | 34.9 | 4.49/ | 7.49 | 3.87/ | 6.73 | 11 6./ | 140, | 140./ | 164. | 134./ | 158. | 203./ | 226. |
| Conv. Engine Cogeneration, Oil-Burning Diesel/ORCS, Absorption and Electric Chillers | 459 | 558 | 4.98/ | 770 | 4,34/ | 6.93 | 134. / | 170. | 147./ | 183. | 138./ | 173 | 197./ | 232. |
| Conv. Engine Cogeneration; Gas-Burning Diesel/ORCS, Absorption and Electric Chillers | G459 | 558 | 4.98/ | 770 | 4.34/ | 6.93 | 114/ | 150. | 1 30./ | 166, | 122./ | 156. | 137./ | 171. |
| Conv. Engine Cogeneration; Coal Steam Turbines, Absorption and Electric Chillers | 460 | 455 | 7.72/ | 11 85 | 6.71/ | 10.63 | 139. / | 183. | 150./ | 194 | 139./ | 181 | 173./ | 215 |
| 100-Percent Solar Heating; I-Cover Pond, Seasonal Aquifer Storage, Electric Chillers, and Utility Electricity | 461 | 60.1 | 7.29/ | 1063 | 6.48/ | 9.66 | 174. / | 221. | 188./ | 236. | 177. / | 222 | 237. / | 282. |
| 100-Percent Solar Heating; Coal Steam Turbines, Absorption and Electric Chillers | 461/437 | 601 | 7 01/ | 1003 | 6.28/ | 9.16 | 170. / | 212. | 184./ | 227. | 174./ | 215 | 234. / | 275 |

| | | | | | | | | |
|--|------|------------|--------------|--------------|--------------|--------------|------------|-------------|
| Solar Engine Cogeneration, Heliostats, Steam Turbines, High- and Low-Temp Storage, Absorption and Electric Chillers, and Coal Backup | 462 | 677 | 8.83/ 12.89 | 7.80/ 11.65 | 188./ 253. | 195./ 260. | 178./ 240. | 198./ 260. |
| Solar Engine Cogeneration; Heliostats, Steam Turbines With Coal Superheat, High- and Low-Temp. Storage, Absorption and Electric Chillers, and Coal Backup | 463 | 651 | 8.41/ 12.37 | 7.41/ 11.17 | 177./ 238. | 184./ 245. | 169./ 227. | 191./ 248. |
| Solar Engine Cogeneration; Two-Axis Dish, High Eff. Stirling Engine, High- and Low-Temp Storage, Absorption and Electric Chillers, and Gas Backup | 464 | 875 | 7.42/ 10.68 | 6.60/ 9.70 | 197./ 264. | 200./ 268. | 184./ 248. | 200./ 264. |
| Solar Engine Cogeneration; Two-Axis Dish, High Eff. Stirling Engines, High- and Low-Temp. Storage, Absorption and Electric Chillers, and Gas Backup | G464 | 875 | 7.42/ 10.68 | 6.60/ 9.70 | 191./ 258. | 196./ 263. | 179./ 243. | 183./ 247. |
| Solar Engine Cogeneration; Two-Axis Dish, Low Eff. Stirling Engines, High- and Low-Temp. Storage, Absorption and Electric Chillers, Oil Backup | 465 | 858 | 8.05/ 11.39 | 7.22/ 10.39 | 208./ 276. | 212./ 280. | 195./ 260. | 214./ 278. |
| Solar Engine Cogeneration; Two-Axis Dish, Low Eff. Stirling Engines, High- and Low-Temp. Storage, Absorption and Electric Chillers, Gas Backup | G465 | 858 | 8.05/ 11.39 | 7.22/ 10.39 | 202./ 269. | 207./ 274. | 190./ 254. | 195./ 259. |
| 100-Percent Heat Engine, LOW-Temp, ORCS With River Water Condenser, 2-Cover Pond, Seasonal Aquifer Storage, and Absorption Chillers | 466 | 100.0 | 10.45/ 14.29 | 9.47/ 13.11 | 280./ 371. | 280./ 371. | 257./ 343. | 257./ 343. |
| 100-Percent Solar Engine, Low-Temp. ORCS With Cooling Tower, 2-Cover Pond, Seasonal Aquifer Storage, Absorption Chillers | 467 | 100.0 | 14.30/ 19.54 | 12.91/ 17.88 | 371./ 495. | 371./ 495. | 339./ 456. | 339./ 456. |
| 100-Percent solar PV Cogeneration; Two-Axis Concentrator With Si Cells (Med. Price), Seasonal Iron-REDOX Electrical and Multitank Low-Temp. Storage, Absorption Chillers (Minimum Collector Area) | 468 | 1000 | 12.93/ 18.06 | 11.63/ 16.50 | 339./ 460. | 339./ 460. | 308./ 423. | 308./ 423. |
| 100-Percent Solar PV Cogeneration; Two-Axis Concentrator With Si Cells (Med. Price), Seasonal Iron-REDOX Electrical and Multitank, Low-Temp. Storage, Absorption Chillers (Optimized Collector Area) | 469 | 100.0 | 11.09/ 15.62 | 9.93/ 14.23 | 296./ 403. | 296./ 403. | 268./ 370. | 268./ 370. |
| ALBUQUERQUE INDUSTRIAL | | | | | | | | |
| Reference system | | | | | | | | |
| Conv. Coal Boiler and Utility Electricity (Industrial Owner) | 470 | 0.0 | NA/ NA | NA/ NA | 1744./ NA | 2332./ NA | 2332./ NA | 4352./ NA |
| Systems compared to reference system | | | | | | | | |
| Solar Process Heat (180° F), 2-Cover Pond, Low-Temp Storage, Coal Backup Boiler, and Utility Electricity (Industrial Owner) | 471 | 17.9 | 11.06/ 5.22 | 9.93/ 4.67 | 2776./ 2131. | 3266./ 2622. | 3142./2561 | 4871./ 4290 |

| Summary description of system | Table number | Percent solar | Effective cost of solar energy (¢/kWh) | | | | Levelized monthly cost of energy service | | | |
|---|--------------|---------------|--|--------------|---------------|---------------|--|-----------------------------|--------------------------|--------------------------|
| | | | No credits | | 200/0 ITC | | Project ion 1 No credits | Project ion 2 No credits | Project ion 2 20% ITC | Project ion 3 20% ITC |
| Systems compared to reference system—Continued | | | | | | | | | | |
| Solar Process Preheat (180° F max), 2-Cover Pond, Low-Temp Storage, Coal Backup Boiler, and Utility Electricity (Industrial Owner) | 472 | 35.2 | 5.63/ 2.66 | 5.06/ 2.38 | 2593./ 1949. | 2991./ 2346. | 2866./2285 | 4316./ 3735. | | |
| Solar Process Heat (180° F), 2-Cover Pond, (Future Price), Low-Temp Storage, Coal Backup Boiler, and Utility Electricity (Industrial Owner) | 471/494 | 17.9 | 8.12/ 3.37 | 7.30/ 2.97 | 2451 ./ 1927. | 2942./ 2417. | 2852./2373. | 4581. / 4103. | | |
| Solar Process Preheat (180° F max.); 2-Cover Pond, (Future Price), Low-Temp Storage, Coal Backup Boiler, and Utility Electricity (Industrial Owner) | 472/495 | 35.2 | 4.14/ 1.72 | 3.72/ 1.51 | 2269./ 1744. | 2666./ 2142. | 2576./2097. | 4026. / 3547. | | |
| Solar Process Heat (180° F), Flat-Plates (1977 Prices), Low-Temp Storage, Coal Backup Boiler, and Utility Electricity (Industrial Owner) | 473 | 35.6 | 17.66/ 9.46 | 15.63/ 8.45 | 5241 ./ 3441. | 5636./ 3836. | 5190./3617, | 6633./ 5060. | | |
| Solar Process Heat (180 °F); Flat-Plate's (Future Price), Low-Temp Storage, Coal Backup | 473/497 | 35.6 | 11.37/ 5.72 | 10.06/ 5.07 | 3862./ 2622. | 4257./ 3017. | 3969./2876. | 5413./ 4319. | | |
| Solar Process Heat (180° F), One-Axis Tracker (1977 Design), High-Temp Storage, Coal Backup Boiler, and Utility Electricity (Industrial Owner) | 474 | 26.9 | 26.74/ 14.98 | 23.80/ 13.54 | 5885./ 3940. | 6328./ 4382. | 5842./4143. | 7427. / 5728. | | |
| Solar Process Heat (350 °F), One-Axis Tracker (Future Design), High-Temp Storage, Coal Backup Boiler, and Utility Electricity (Industrial Owner) | 475 | 25.3 | 13.10/ 6.70 | 11.69/ 6.00 | 3517./ 2520. | 3968. / 2971. | 3748./2862. | 5359. / 4473. | | |
| Solar PV Cogeneration, Two-Axis Concentrators With GaAs Cells (Med. Price), Low-Temp. Storage, Coal Backup Boiler, and Utility Electric Backup (Industrial Owner) | 476 | 0.0 | NA/ NA | NA/ NA | 1468. / NA | 2056./ NA | 2056. / NA | 4076./ NA | | |
| Solar PV Cogeneration; Two-Axis Concentrators With GaAs Cells (Low Price), Low-Temp. Storage, Coal Backup Boiler, and Utility Electric Backup (Industrial Owner) | 477 | 17.9 | 5.36/ 7.72 | 4.90/ 7.16 | 1871 ./ 2131. | 2362. / 2622. | 231 1./2561. | 4041. / 4290. | | |
| Reference system | | | | | | | | | | |
| Conv. Coal Boiler and Utility Electricity (Municipal Utility Owner) | M470 | 44.7 | 10.51/ 5.59 | 9.34/ 5.02 | 4145. / 2790. | 4499. / 3144. | 4178./2986. | 5417. / 4226. | | |
| Systems compared to reference system | | | | | | | | | | |
| Solar Process Heat (180° F); 2-Cover Pond, Low-Temp. Storage, Coal Backup Boiler, and Utility Electricity (Municipal Utility Owner) | M471 | 47.0 | 6.77/ 3.40 | 6.04/ 3.04 | 3181./ 2204. | 3525./ 2548. | 331 1./2443. | 4501. / 3632, | | |

| | | | | | | | | | | | | | | |
|--|----------|------|--------|-------|--------|-------|---------|-------|---------|-------|-------------|---------|---------|------|
| Solar Process Preheat (180° F max.); 2-Cover, Low-Temp. Storage, Coal Backup Boiler, and Utility Electricity (Municipal Utility Owner). | M472 | 35.2 | 2.73/ | 393 | 2.50/ | 3.65 | 1689. / | 1949. | 2086. / | 2346. | 2035 / | 2285 | 3485 / | 3735 |
| Solar Process Heat (180 °F), 2-Cover Pond, " " (Future Price), LowTemp Storage, Coal Backup Boiler, and Utility Electricity (Municipal Utility Owner) | M471/494 | 17.9 | 3.98/ | 5.87 | 3.65/ | 5.46 | 1718.1 | 1927 | 2209 / | 2417. | 2172.12373 | 3902 / | 4103 | |
| Solar Process Preheat (180° F max.); 2-Cover Pond (Future Price), Low-Temp. Storage, Coal Backup Boiler, and Utility Electricity (Municipal Utility owner) | M472/495 | 35.2 | 2.031 | 2.99 | 1.86/ | 2.78 | 1536./ | 1744. | 1934. / | 2142 | 1897./2097 | 3347 / | 3547 | |
| Solar Process Heat (180° F); Flat-Plates (1977 Prices), Low-Temp. Storage, Coal Backup Boiler, and Utility Electricity (Municipal Utility Owner) | M473 | 35.6 | 730/ | 10.71 | 6.47/ | 9.71 | 2693.1 | 3441. | 3088.1 | 3836. | 290613617 | 4349 / | 5060 | |
| Solar Process Heat (180° F); Flat-Plates (Future Price), Low-Temp. Storage, Coal Backup Boiler, and Utility Electricity (Municipal Utility Owner) | M473/497 | 35.6 | 4.67/ | 6.98 | 4.13/ | 6.33 | 2115.1 | 2622. | 2511 / | 3017 | 2393.12876. | 3836.1 | 4319. | |
| Solar Process Heat (350 °F); One-Axis Tracker (Future Design), High-Temp. Storage, Coal Backup Boiler, and Utility Electricity (Municipal Utility Owner) | M474 | 26.9 | 11.77/ | 16.65 | 10.57/ | 15.21 | 3132.1 | 3940. | 3575. / | 4382 | 3376 /4143. | 4961 / | 5728 | |
| Solar Process Heat (350°); One-Axis Tracker (1977 Design), High-Temp. Storage, Coal Backup Boiler, and Utility Electricity (Industrial Owner). | M475 | 25.3 | 5.87/ | 8.47 | 5.301 | 7.77 | 2116. / | 2520. | 2567. / | 2971. | 2477./2862. | 4087 / | 4473. | |
| Solar PV Cogeneration; Two-Axis Concentrators With GaAs Cells (Medium Price), Low-Temp. Storage, Coal Backup Boiler, and Utility Electric Backup (Municipal Utility Owner) | M476 | 44.7 | 4.57/ | 6.59 | 4.10/ | 6.02 | 2233./ | 2790 | 2587. / | 3144. | 2456./2986. | 3695. / | 4226. | |
| Solar PV Cogeneration; Two-Axis Concentrators With GaAs Cells (Low Price), Low-Temp. Storage, Coal Backup Boiler, and Utility Electric Backup (Municipal Utility Owner) | M477 | 47.0 | 3.00/ | 4.35 | 2.70/ | 3.99 | 1812./ | 2204 | 2155. / | 2548. | 2068./2443. | 3257. / | 3632. | |
| Reference system | | | | | | | | | | | | | | |
| Conv. Engine Cogeneration; Coal-Burning Steam Turbine (Industrial Owner) | 478 | 0.0 | NA/ | NA | NA/ | NA | 1786. / | NA | 2269./ | NA | 2269./ | NA | 3719. / | NA |
| Systems compared to reference system | | | | | | | | | | | | | | |
| Solar Engine Cogeneration; Heliostat, Steam Turbines, High-and Low-Temp. Storage, and Coal Backup (Industrial Owner) | 479 | 47.4 | 1.109/ | 5.40 | 9.89/ | 4.81 | 4237. / | 2748. | 4491 / | 3002. | 4177./2848. | 4940. / | 3610. | |
| Reference system | | | | | | | | | | | | | | |
| Conv. Engine Cogeneration; Coal-Burning Steam Turbine (Municipal Utility Owner) | M478 | 0.0 | NA/ | NA | NA/ | NA | 1315. / | NA | 1799. / | NA | 1799. / | NA | 3249, / | NA |
| Systems compared to reference system | | | | | | | | | | | | | | |
| Solar Engine Cogeneration; Heliostats, Steam Turbines, High- and Low-Temp. Storage, and Coal Backup (Municipal Utility Owner) | M479 | 47.4 | 4.93/ | 7.19 | 4.44/ | 6.60 | 2155. / | 2748. | 2409./ | 3002. | 2281./2848. | 3043. / | 3610. | |

| Summary description of system | Table number | Percent solar | Effective cost of solar energy (¢/kWh) | | | | Levelized monthly cost of energy service | | | |
|--|--------------|---------------|--|--------------|---------------|---------------|--|---------------|----------------------|--|
| | | | No credits | | 200/0 ITC | | Project Ion 1 No credits | | Projection 2 20% ITC | |
| Reference system | | | | | | | | | | |
| Conv. Oil Boiler and Utility Electricity (Industrial Owner) | 480 | 0.0 | NA/ NA | NA/ NA | 2 2 2 8./ NA | 3 0 2 8./ NA | 3 0 2 8./ NA | 6 5 9 4./ NA | | |
| Systems compared to reference system | | | | | | | | | | |
| Solar Process Heat (180° F); 2-Cover Pond, Low-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Industrial Owner) | 481 | 17.9 | 11 .04/ 6.80 | 9.91/ 6.25 | 3018./ 2550. | 3662. / 3195. | 3538./3133. | 6383./ 5979. | | |
| Solar Process Preheat (180° F max.); 2-Cover Pond Collector, Low-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Industrial Owner) | 482 | 35.2 | 5.62/ 3.47 | 5.05/ 3.18 | 2605. / 2137. | 3100./ 2632. | 2975./2571. | 5127./ 4722. | | |
| Solar Process Heat (180° F); 2-Cover Pond (Future Price), Low-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Industrial Owner) | 481/507 | 17.9 | 8.10/ 4.95 | 7.28/ 4.55 | 2693./ 2345. | 3338./ 2990. | 3248./2946. | 6093. / 5791. | | |
| Solar Process Preheat (180° F max.); 2-Cover Pond (Future Price), Low-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Industrial Owner) | 482/508 | 35.2 | 4.13/ 2.52 | 3.71/ 2.32 | 2281./ 1933. | 2775./ 2427. | 2685./2383. | 4837./ 4535. | | |
| Solar Process Heat (180° F); Flat-Plates (1977 Prices), Low-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Industrial Owner) | 483 | 35.6 | 17.66/ 10.26 | 15.63/ 9.26 | 5249. / 3625. | 5740. / 4116. | 5294./3897. | 7429. / 6032. | | |
| Solar Process Heat (180° F); Flat-Plates (Future Price), Low-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Industrial Owner) | 483/510 | 35.6 | 11 .36/ 6.51 | 10.05/ 5.87 | 3868./ 2805. | 4359./ 3296. | 4072./3154. | 6207./ 5289. | | |
| Solar Process Heat (350° F); One-Axis Tracker (1977 Design), High-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Industrial Owner) | 484 | 26.9 | 26.74/ 16.05 | 23.80/ 14.60 | 601 1./ 4241. | 6577. / 4807. | 6091./4568. | 8577. / 7054. | | |
| Solar Process Heat (350° F); One-Axis Tracker (Future Design), High-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Industrial Owner) | 485 | 25.3 | 13.1 0/ 7.83 | 11 .69/ 7.13 | 3663./ 2842. | 4244. / 3422. | 4024./3314. | 6574. / 5864. | | |
| Solar PV Cogeneration: Two-Axis Concentrators With GaAs Cells (Med. Price), Low-Temp. Storage, Oil Backup Boiler, and Utility Electric Backup (Industrial Owner) | 486 | 44.7 | 10.51 / 6.23 | 9.34/ 5.66 | 4234. / 3055. | 4704. / 3525. | 4383./3367. | 6460. / 5444. | | |
| Solar PV Cogeneration; Two-Axis Concentrators With GaAs Cells (Low Price), Low-Temp. Storage, Oil Backup Boiler, and Utility Electric Backup (Industrial Owner), ... | 487 | 47.0 | 6.77/ 4.01 | 6.04/ 3.65 | 3288./ 2487. | 3752./ 2950. | 3538./2845. | 5597./ 4904. | | |

Reference system

| | | | | | | | | | | | | | | | | | | |
|---|------|-----|-----|----|-----|----|------|---|----|------|---|----|------|---|----|------|---|----|
| Conv. Oil Boiler and Utility Electricity (Municipal Utility Owner) | M480 | 0.0 | NA/ | NA | NA/ | NA | 2187 | / | NA | 2988 | / | NA | 2988 | / | NA | 6553 | / | NA |
|---|------|-----|-----|----|-----|----|------|---|----|------|---|----|------|---|----|------|---|----|

Systems compared to reference system

| | | | | | | | | | | | | | | | | | | |
|---|----------|------|--------|-------|--------|-------|--------|-------|--------|--------|--------|--------|--------|--------|-------|------|------|------|
| Solar Process Heat (180° F), 2-Cover Pond, Low-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Municipal Utility Owner) | M481 | 179 | 5.36/ | 717 | 4.90/ | 661 | 2350. | / | 2550, | 2995 | / | 3195 | 2944 | / | 3133 | 5789 | / | 5979 |
| Solar Process Preheat (180° F max.), 2-Cover Pond, Low-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Municipal Utility Owner) | M482 | 352 | 2.73/ | 365 | 2.49/ | 337 | 1937 | / | 2137 | 2432. | / | 2632. | 2381 | / | 2571 | 4533 | / | 4722 |
| Solar Process Heat (180° F); 2-Cover Pond (Future Price), Low-Temp Storage, Oil Backup Boiler, and Utility Electricity (Municipal Utility Owner) | M481/507 | 179 | 3.97/ | 532 | 3.64/ | 491 | 2197 | / | 2345 | 2842. | / | 2990 | 2805./ | 2946 | 5650 | / | 5791 | |
| Solar Process Preheat (180° F max.); 2-Cover Pond (Future Price), LowTemp. Storage, Oil Backup Boiler, and Utility Electricity (Municipal Utility Owner) | M482/508 | 35.2 | 2.02/ | 2.71 | 1.85/ | 2.50 | 1785 | / | 1933. | 2279./ | 2427. | 2242./ | 2383. | 4394./ | 4535. | | | |
| Solar Process Heat (180° F): Flat-Plates (1977 Prices), LowTemp. Storage, Oil Backup Boiler, and Utility Electricity (Municipal Utility Owner) | M483 | 35.6 | 7.30/ | 10.44 | 6.47/ | 9.44 | 2937. | / | 3625. | 3428./ | 4116. | 3245./ | 3897. | 5380./ | 6032. | | | |
| Solar Process Heat (180° F); Flat-Plates (Future Price), Low-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Municipal Utility Owner) | M483/510 | 35.6 | 4.66/ | 6.70 | 4.13/ | 6.05 | 2358./ | 2805. | 2849./ | 3296. | 2731./ | 3154. | 4867./ | 5289. | | | | |
| Solar Process Heat (350° F); One-Axis Tracker (1977 Design), High-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Municipal Utility Owner) | M484 | 26.9 | 11.77/ | 16.29 | 10.57/ | 14.85 | 3493./ | 4241. | 4060./ | 4807. | 3861 | ./ | 4568. | 6347./ | 7054. | | | |
| Solar Process Heat (350° F); One-Axis Tracker (Future Design), High-Temp. Storage, Oil Backup Boiler, and Utility Electric Backup (Municipal Utility Owner) | M485 | 25.3 | 5.87/ | 8.09 | 5.30/ | 7.39 | 2497./ | 2842. | 3078./ | 3422. | 2988./ | 3314. | 5538./ | 5864. | | | | |
| Solar PV Cogeneration; Two-Axis Concen- trators With GaAs Cells (Med. Price), Low- Temp. Storage, Oil Backup Boiler, and Utility Electric Backup (Municipal Utility Owner) | M486 | 44.7 | 4.57/ | 6.38 | 4.10/ | 5.81 | 2558./ | 3055. | 3028./ | 3525. | 2897./ | 3367. | 4973./ | 5444. | | | | |
| Solar PV Cogeneration; Two-Axis Concen- trators With GaAs Cells (Low Price), Low- Temp. Storage, Oil Backup Boiler, and Utility Electric Backup (Municipal Utility Owner) | M487 | 47.0 | 3.00/ | 4.15 | 2.70/ | 3.79 | 2154./ | 2487. | 2617./ | 2950. | 2530./ | 2845. | 4588./ | 4904. | | | | |

Conventional oil systems

| | | | | | | | | | | | | | | | | | |
|--|------|-----|-----|----|-----|----|--------|----|--------|--------|--------|-------|-------|----|-------|---|----|
| Conv. Engine Cogeneration; Industry Using Oil-Burning Diesel (Industrial Owner) | 488 | 0.0 | NA/ | NA | NA/ | NA | 2319. | / | NA | 2981./ | NA | 2981, | / | NA | 6036. | / | NA |
| Conv. Engine Cogeneration; Oil-Burning Diesel (Municipal Utility Owner) | M488 | 0.0 | NA/ | NA | NA/ | NA | 2082./ | NA | 2744./ | NA | 2744./ | NA | 5799. | / | NA | | |

| Summary description of system | Table number | Percent solar | Effective cost of solar energy (¢/kWh) | | | | Levelized monthly cost of energy service | | | | | | | |
|--|--------------|---------------|--|-------|-----------|------|--|-------|-------------------------|-------|----------------------|-------|----------------------|-------|
| | | | No credits | | 200/0 ITC | | Projection 1 No credits | | Projection 2 No credits | | Projection 2 20% ITC | | Projection 3 20% ITC | |
| <i>Reference system</i> | | | | | | | | | | | | | | |
| Conv. Engine Cogeneration; Oil-Burning Stirling Engine (Industrial Owner) | 489 | 0.0 | NA/ | NA | NA/ | NA | 2254./ | NA | 2890./ | NA | 2890./ | NA | 5822./ | NA |
| <i>Systems compared to reference system</i> | | | | | | | | | | | | | | |
| Solar Engine Cogeneration; Two-Axis Dish, Stirling Engines, High- and Low-Temp. Storage, and Oil Backup (Industrial Owner). | 490 | 52.4 | 14.17/ | 8.22 | 12.63/ | 7.46 | 4680./ | 3278. | 4983./ | 3580. | 4618./ | 3400. | 6012./ | 4795. |
| Reference system | | | | | | | | | | | | | | |
| Conv. Engine Cogeneration; Oil-Burning Stirling (Municipal Utility Owner). | M489 | 0.0 | NA/ | NA | NA/ | NA | 2135./ | NA | 2770./ | NA | 2770./ | NA | 5702./ | NA |
| Systems compared to reference system | | | | | | | | | | | | | | |
| Solar Engine Cogeneration; Two-Axis Dish, Stirling Engines, High- and Low-Temp. Storage, and Oil Backup (Municipal Utility Owner). | M490 | 52.4 | 6.24/ | 8.73 | 5.61/ | 7.97 | 2691./ | 3278. | 2994./ | 3580. | 2844./ | 3400. | 4238./ | 4795. |
| Reference system | | | | | | | | | | | | | | |
| Conv. Gas Boiler and Utility Electricity (Industrial Owner). | G480 | 0.0 | NA/ | NA | NA/ | NA | 1342./ | NA | 2279./ | NA | 2279./ | NA | 3898.1 | NA |
| Systems compared to reference system | | | | | | | | | | | | | | |
| Solar Process Heat (180° F); 2-Cover Pond, Low-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Industrial Owner) | G481 | 17.9 | 11.04/ | 6.80 | 9.91/ | 6.25 | 2379./ | 1911, | 3121./ | 2653. | 2997./ | 2592. | 4437./ | 4033. |
| Solar Process Preheat (180° F max.); 2-Cover Pond, Low-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Industrial Owner). | G482 | 35.2 | 5.62/ | 3.47 | 5.05/ | 3.18 | 2203./ | 1735. | 2759./ | 2291. | 2635./ | 2230. | 3903./ | 3498. |
| Solar Process Heat (180° F); 2-Cover Pond (Future Price), Low-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Industrial Owner). | G481/507 | 17.9 | 8.10/ | 4.95 | 7.28/ | 4.55 | 2054./ | 1706. | 2797./ | 2449. | 2707./ | 2405. | 4147./ | 3845. |
| Solar Process Preheat (180° F max.); 2-Cover Pond (Future Price), Low-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Industrial Owner) | G482/508 | 35.2 | 4.13/ | 2.52 | 3.71/ | 2.32 | 1879./ | 1531. | 2435./ | 2087. | 2345./ | 2042. | 3613./ | 3311. |
| Solar Process Heat (180° F); Flat-Plates (1977 Prices), Low-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Industrial Owner). | G483 | 35.6 | 17.66/ | 10.26 | 15.63/ | 9.26 | 4853./ | 3229. | 5404./ | 3780. | 4958./ | 3561. | 6222./ | 4825. |
| Solar Process Heat (180° F); Flat-Plates (Future Price), Low-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Industrial Owner). | G483/510 | 35.6 | 11.36/ | 6.51 | 10.05/ | 5.87 | 3472./ | 2408. | 4024./ | 2960. | 3736./ | 2819. | 5000./ | 4082. |

| | | | | | | | | | | | | | |
|--|-----------|------|--------|-------|---------|-------|---------|-------|---------|-------|--------------|---------|--------------|
| Solar Process Heat (350° F); One-Axis Tracker (1977 Design), High-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Industrial Owner) | G484 | 26.9 | 26.74/ | 16.05 | 23.80/ | 14.60 | 5494.1 | 3724. | 6140./ | 4370. | 5654./4131 | 7005./ | 5482. |
| Solar Process Heat (350° F); One-Axis Tracker (Future Design), High-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Industrial Owner) | G485 | 25.3 | 13.10/ | 7.83 | 11.69/ | 7.13 | 3125./ | 2303. | 3788./ | 2967. | 3568./12858. | 4935.1 | 4225. |
| Solar PV Cogeneration; Two-Axis Concentrators With GaAs Cells (Med. Price), Low-Temp. Storage, Gas Backup Boiler, and Utility Electric Backup (Industrial Owner) | G486 | 44.7 | 10.51/ | 6.23 | 9.34/ | 5.66 | 3755.1 | 2576. | 4298. / | 3119 | 3977./ | 2961. | 4999. / 3983 |
| Solar PV Cogeneration; Two-Axis Concentrators With GaAs Cells (Low Price), Low-Temp. Storage, Gas Backup Boiler, and Utility Electric Backup (Industrial Owner) | G487 | 47.0 | 6.77/ | 4.01 | 6.04/ | 3.65 | 2791.1 | 1989 | 3330, / | 2529 | 31 17./2424. | 4081. / | 3388. |
| Reference system | | | | | | | | | | | | | |
| Conv. Gas Boiler and Utility Electricity (Municipal Utility Owner) | MG480 | 0.0 | NA/ | NA | NA/ | NA | 1302. / | NA | 2238. / | NA | 2238./ | NA | 3858. / NA |
| Systems compared to reference system | | | | | | | | | | | | | |
| Solar Process Heat (180° F); 2-Cover Pond, Low-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Municipal Utility Owner) | MG481 | 17.9 | 5.36/ | 7.17 | 4.90/ | 6.61 | 1711./ | 1911. | 2453./ | 2653. | 2403./2592. | 3843. / | 4033. |
| Solar Process Preheat (180° F max.); 2-Cover Pond, Low-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Municipal Utility Owner) | MG482 | 35.2 | 2.73/ | 3.65 | 2.49/ | 3.37 | 1535./ | 1735. | 2091./ | 2291. | 2040 /2230. | 3309./ | 3498. |
| Solar Process Heat (180° F); 2-Cover Pond (Future Price), Low-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Municipal Utility Owner) | MG481/507 | 17.9 | 3.97/ | 5.32 | 3.64/ | 4.91 | 1558. / | 1706. | 2301./ | 2449. | 2264./2405. | 3704./ | 3845. |
| Solar Process Preheat (180° F max.); 2-Cover Pond (Future Price, Low-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Municipal Utility Owner) | MG482/508 | 35.2 | 2.02/ | 2.71 | 1.85/ | 2.50 | 1383./ | 1531. | 1939. / | 2087. | 1902./2042. | 3170. / | 3311. |
| Solar Process Heat (180° F); Flat-Plates (1977 Prices), Low-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Municipal Utility Owner) | MG483 | 35.6 | 7.30/ | 10.44 | 6.47/ | 9.44 | 2540. / | 3229. | 3092./ | 3780. | 2909./3561 | 4173./ | 4825. |
| Solar Process Heat (180° F); Flat-Plates (Future Price), Low-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Municipal Utility Owner) | MG483/510 | 35.6 | 4.66/ | 6.70 | 4.1 3/ | 6.05 | 1962. / | 2408. | 2514. / | 2960. | 2396./2819. | 3660. / | 4082. |
| Solar Process Heat (350° F); One-Axis Tracker (1977 Design), High-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Municipal Utility Owner) | MG484 | 26.9 | 11.77/ | 16.29 | 1 0.57/ | 14.85 | 2977. / | 3724. | 3622./ | 4370. | 3423./4131 | 4775. / | 5482 |
| Solar Process Heat (350° F); One-Axis Tracker (Future Design), High-Temp. Storage, Gas Backup, Boiler, and Utility Electricity (Municipal utility Owner) | MG485 | 253 | 5.87/ | 8.09 | 5.30/ | 7.39 | 1959, / | 2303. | 2622. / | 2967. | 2532./2858. | 3899. / | 4225. |

| Summary description of system | Table number | Percent solar | Effective cost of solar energy (¢/kWh) | | | | Levelized monthly cost of energy service | | | |
|--|--------------|---------------|--|-------------|---------------|---------------|--|---------------|--------------------------|--|
| | | | No credit S | | 20% ITC | | Projection 1 No credits | | Project Ion 2 No credits | |
| Systems compared to reference system—Continued | | | | | | | | | | |
| Solar PV Cogeneration; Two-Axis Concentrators With GaAs Cells (Med. Price), Low-Temp. Storage, Gas Backup Boiler, and Utility Electric Backup (Municipal Utility Owner) | MG486 | 44.7 | 4.57/ 6.38 | 4.10/ 5.81 | 2079./ 2576. | 2622./ 3119. | 2490./2961. | 3513. / 3983. | | |
| Solar PV Cogeneration; Two-Axis Concentrators With GaAs Cells (Low Price), Low-Temp. Storage, Gas Backup Boiler, and Utility Electric Backup (Municipal Utility Owner) | MG487 | 47.0 | 3.00/ 4.15 | 2.70/ 3.79 | 1656. / 1989. | 2196./ 2529. | 2109/2424 | 3073.1 3388. | | |
| Conventional gas systems | | | | | | | | | | |
| <i>Conv. Engine Cogeneration; Gas-Burning Diesel (Industrial Owner)</i> | G488 | 0.0 | NA/ NA | NA/ NA | 1275. / NA | 2097./ NA | 2097. / NA | 2857./ NA | | |
| <i>Conv. Engine Cogeneration; Gas-Burning Diesel (Municipal Utility Owner)</i> | MG488 | 0.0 | NA/ NA | NA/ NA | 1037. / NA | 1859. / NA | 1859. / NA | 2619. / NA | | |
| <i>Reference system</i> | | | | | | | | | | |
| <i>Conv. Engine Cogeneration; Gas-Burning Stirling Engine (Industrial Owner)</i> | G489 | 0.0 | NA/ NA | NA/ NA | 1252. / NA | 2041./ NA | 2041. / NA | 2770 / NA | | |
| <i>Systems compared to reference system</i> | | | | | | | | | | |
| <i>Solar Engine Cogeneration; Two-Axis Dish, Stirling Engines, High- and Low-Temp. Storage, and Gas Backup (Industrial Owner)</i> .. | | 52.4 | 14.17/ 8.22 | 12.63/ 7.46 | 4204./ 2801 | 4579. / 3176. | 4214./2997 | 4561. / 3344, | | |
| Reference system | | | | | | | | | | |
| Conv. Engine Cogeneration; Oil-Burning Stirling Engine (Municipal Utility Owner) | MG489 | 0.0 | NA/ NA | NA/ NA | 1133./ NA | 1922./ NA | 1922./ NA | 2651./ NA | | |
| Systems compared to reference system | | | | | | | | | | |
| Solar Engine Cogeneration; Two-Axis Dish, Stirling Engines, High- and Low-Temp. Storage, and Oil Backup (Municipal Utility Owner) | MG490 | 52.4 | 6.24/ 8.73 | 5.61/ 7.97 | 2215./ 2801. | 2590./ 3176. | 2441./2997. | 2787./ 3344. | | |
| OMAHA INDUSTRIAL | | | | | | | | | | |
| Reference system | | | | | | | | | | |
| <i>Conv. Coal Boiler and Utility Electricity (Industrial Owner)</i> | 491 | 0.0 | NA/ NA | NA/ NA | 1813. / NA | 2429. / NA | 2429./ NA | 4563./ NA | | |

| | | | | | | | | | | | | |
|--|------|------|--------|-------|--------|---------|---------------|---------------|--------------|---------------|--|--|
| <i>Systems compared to reference system</i> | | | | | | | | | | | | |
| Solar Process Heat (180° F) 2-Cover Pond Low-Temp Storage, Coal Backup Boiler, and Utility Electricity (Industrial Owner) | 492 | 168 | 18.27/ | 973 | 16 | 41/ 881 | 3530 / 2644 | 4054 / 3168 | 3861 /3073 | 5722 / 4935 | | |
| Solar Process preheat (180 °F max) 2-Cover Pond, Low-Temp Storage, Coal Backup Boiler, and Utility Electricity (Industrial Owner) | 493 | 253 | 12.13/ | 646 | 10 | 90/ 585 | 3440. / 2554. | 3918 / 3032. | 3725 /2937 | 5449. / 4661. | | |
| Solar Process Heat (180° F). 2-Cover Pond (Future Price), Low-Temp Storage Coal Backup Boiler. and Utility Electricity (industrial Owner). | 494 | 168 | 13.36/ | 6.63 | 12.02/ | 5.97 | 3020. / 2323 | 3545. / 2847. | 3406./2779 | 5267. / 4640 | | |
| Solar process Preheat (180° F max.); 2-Cover Pond (Future Price), Low-Temp. Storage, Coal Backup Boiler, and Utility Electricity (Industrial Owner) | 495 | 253 | 8.87/ | 4.40 | 7 | 98/ 396 | 2930. / 2233. | 3409. / 2711. | 3270 /2643. | 4993. / 4366. | | |
| Solar Process Heat (180° F): Flat-Plates (1977 Prices), Low-Temp. Storage, Coal Backup Boiler, and Utility Electricity (Industrial Owner) | 496 | 24.3 | 40.57/ | 22.49 | 35.90/ | 20.20 | 7636./ 4926. | 8120. / 5411 | 7420./5066 | 9159. / 6806 | | |
| Solar Process Heat (1800 F): Flat-Plates (Future Price), Low-Temp. Storage, Coal Backup Boiler, and Utility Electricity (industrial Owner) | 497 | 24.3 | 26.07/ | 13.88 | 23.06/ | 12.40 | 5462./ 3635. | 5946./ 4119. | 5496./3898. | 7235./ 5637 | | |
| Solar Process Heat (3500 F): One-Axis Tracker (1977 Design), High-Temp, Storage, Coal Backup Boiler, and Utility Electricity (industrial Owner) | 498 | 24.5 | 49.12/ | 28.51 | 43.74/ | 25.86 | 8963. / 5854. | 9446./ 6337. | 8634./5938. | *****/ 7675 | | |
| Solar Process Heat (350° F): One-Axis Tracker (Future Design), High-Temp. Storage, Coal Backup Boiler, and Utility Electricity (industrial Owner) | 499 | 25.3 | 23.64/ | 13.11 | 21.09/ | 11.85 | 5231. / 3589. | 5710./ 4068. | 5312./3872. | 7036./ 5596. | | |
| PV Cogeneration System; Two-Axis Concentrators With GaAs Cells (Med. Price), Low-Temp. Storage, Coal Backup Boiler, and Utility Electric Backup (Industrial owner) | 500 | 49.3 | 17.80/ | 10.06 | 15.83/ | 9.09 | 6608./ 4254. | 6938./ 4584. | 6340./4290. | 7497. / 5448 | | |
| PV Cogeneration; Two-Axis Concentrators With GaAs Cells (Low price), Low-Temp. Storage Coal Backup Boiler, and Utility Electric Backup (Industrial Owner) | 501 | 51.9 | 11.43/ | 6.29 | 10.19/ | 5.68 | 4802./ 3159. | 51 14./ 3471. | 471 7./3276. | 5792./ 4350. | | |
| <i>Reference system</i> | | | | | | | | | | | | |
| Conv. Coal Boiler and Utility Electricity (Municipal Utility Owner) | M491 | 0.0 | NA/ | NA | NA/ | NA | 1538. / NA | 2153. / NA | 2153./ NA | 4287. / NA | | |
| <i>Systems compared to reference system</i> | | | | | | | | | | | | |
| Solar Process Heat (180° F): 2-Cover Pond, Low-Temp. Storage, Coal Backup Boiler, and Utility Electricity (Municipal Utility Owner) | M492 | 16,8 | 8.89/ | 2.39 | 8.13/ | 11.47 | 2281. / 2644. | 2806./ 3168. | 2727 /3073 | 4588. / 4935. | | |
| Solar Process Preheat (180 °F max.): 2-Cover Pond Collector, Low-Temp. Storage, Coal Backup Boiler, and Utility Electricity (Municipal Utility owner) | M493 | 25.3 | 5.90/ | 8.22 | 5.40/ | 7.62 | 2191 / 2554. | 2670 / 3032 | 2591 ./2937 | 4314./ 4661. | | |

| Summary description of system | Table number | Percent solar | Effective cost of solar energy (¢/kWh) | | | | Levelized monthly cost of energy service | | | | | | | |
|---|--------------|---------------|--|-------|-----------|-------|--|-------------------------|---------------------|----------------------|--------------|----------|---------|----|
| | | | No credits | | 200/0 ITC | | Projection 1 No credits | Projection 2 No credits | Projection 2 20%ITC | Projection 3 20% ITC | | | | |
| Systems compared to reference system—Continued | | | | | | | | | | | | | | |
| Solar Process Heat (1800 F); 2-Cover Pond (Future Price), Low-Temp. Storage, Coal Backup Boiler, and Utility Electricity (Municipal Utility Owner) | M494 | 16.8 | 6.571 | 9.29 | 6.02/ | 8.63 | 2041./ | 2323. | 2566./ | 2847. | 2509./2779. | 4370./ | 4640. | |
| Solar Process Preheat (180° F max.); 2-Cover Pond (Future Price), Low-Temp. Storage, Coal Backup Boiler, and Utility Electricity (Municipal Utility Owner) | M495 | 25.3 | 4.37/ | 6.17 | 4.00/ | 5.73 | 1951. / | 2233. | 2430./ | 2711. | 2373./2643. | 4096./ | 4366. | |
| Solar Process Heat (180° F); Flat-Plates (1977 Prices), Low-Temp. Storage, Coal Backup Boiler, and Utility Electricity (Municipal Utility Owner) | M496 | 24.3 | 16.77/ | 24.33 | 14.86/ | 22.04 | 3794./ | 4926 | 4278./ | 5411. | 3991./5066. | 5731./ | 6806 | |
| Solar Process Heat (180° F); Flat-Plates (Future Price), Low-Temp. Storage, Coal Backup Boiler, and Utility Electricity (Municipal Utility Owner) | M497 | 24.3 | 10.70/ | 15.72 | 9.47/ | 14.24 | 2884./ | 3635. | 3368. / | 4119. | 3183./3898. | 4923./ | 5637. | |
| Solar Process Heat (350° F); One-Axis Tracker (1977 Design), High-Temp. Storage, Coal Backup Boiler, and Utility Electricity (Municipal Utility Owner) | M498 | 24.5 | 21.71/ | 30.34 | 19.50/ | 27.69 | 4553./ | 5854. | 5036./ | 6337. | 4703./5938. | 6441 . / | 7675. | |
| Solar Process Heat (350° F); One-Axis Tracker (Future Design), High-Temp. Storage, Coal Backup Boiler, and Utility Electricity (Municipal Utility Owner) | M499 | 25.3 | 10.57/ | 14.88 | 9.53/ | 13.62 | 2918./ | 3589. | 3397./ | 4068. | 3234./3872. | 4958.1 | 5596. | |
| PV Cogeneration; Two-Axis Concentrators With GaAs Cells (Med. Price), Low-Temp. Storage, Coal Backup Boiler, and Utility Electric Backup (Municipal Utility Owner) . . | M500 | 49.3 | 7.75/ | 10.96 | 6.95/ | 10.00 | 3278./ | 4254. | 3608./ | 4584. | 3363./4290. | 4521./ | 5448. | |
| <i>PV Cogeneration; Two-Axis Concentrators With GaAs Cells (Low Price), Low-Temp. Storage, Coal Backup Boiler, and Utility Electric Backup (Municipal Utility Owner) . .</i> | M501 | 51.9 | 5.06/ | 7.15 | 4.56/ | 6.54 | 2491./ | 3159. | 2803./ | 3471. | 2641 ./3276. | 3715./ | 4350. | |
| Reference system | | | | | | | | | | | | | | |
| Conv. Engine Cogeneration; Coal-Burning Steam Turbine (Industrial Owner) | 502 | 0.0 | NA\ | NA | NA/ | NA | 1786. / | NA | 2269. / | NA | 2269./ | NA | 3719. / | NA |
| <i>Systems compared to reference system</i> | | | | | | | | | | | | | | |
| <i>Solar Engine Cogeneration; Heliostats, Steam Turbines, High- and Low-Temp. Storage, and Coal Backup (Industrial Owner)</i> | 503 | 44.9 | 18.79/ | 10.03 | 16.76/ | 9.03 | 6015./ | 3845. | 6281 / | 4111 | 5779./3864 | 6578. / | 4662. | |
| Reference system | | | | | | | | | | | | | | |
| Conv. Engine Cogeneration; Coal-Burning Steam Turbine (Municipal Utility Owner) . . . | M502 | 0.0 | NA/ | NA | NA/ | NA | 1315. / | NA | 1799. / | NA | 1799. / | NA | 3249. / | NA |

Systems compared to reference system

| | | | | | | | | |
|--|------|-----|------------|-------------|-------------|-------------|------------|-------------|
| Solar Engine Cogeneration; Heliostats, Steam Turbines, High- and Low-Temp. Storage, and Coal Backup (Municipal Utility Owner). | M503 | 449 | 8.39/ 1193 | 7.56/ 10.93 | 2970 / 3845 | 3236 / 4111 | 3030 /3864 | 3829./ 4662 |
|--|------|-----|------------|-------------|-------------|-------------|------------|-------------|

Reference system

| | | | | | | | | |
|---|-----|----|--------|--------|------------|------------|------------|-----------|
| Conv. Oil Boiler and Utility Electricity (Industrial Owner) | 504 | 00 | NA/ NA | NA/ NA | 2088. / NA | 2840. / NA | 2840. / NA | 6167./ NA |
|---|-----|----|--------|--------|------------|------------|------------|-----------|

Systems compared to reference system

| | | | | | | | | |
|--|-----|------|--------------|--------------|---------------|---------------|--------------|---------------|
| Solar Process Heat (180° F); 2-Cover Pond, Low-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Industrial Owner) | 505 | 168 | 18.27/ 1142 | 16.41/ 10.50 | 3634. / 2924. | 4260./ 3549. | 4067./3454. | 6810 / 6197 |
| Solar Process Preheat (180° F max.); 2-Cover Pond, Low-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Industrial Owner) | 506 | 25.3 | 1 2.13/ 7.58 | 10.90/ 6.98 | 3458./ 2748. | 4020. / 3309 | 3827./3214 | 6274. / 5662. |
| Solar Process Heat (180° F); 2-Cover Pond (Future Price), Low-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Industrial Owner) | 507 | 16.8 | 13.36/ 8.32 | 12.02/ 7.66 | 3125./ 2602. | 3750. / 3228. | 3611 /3160 | 6354. / 5903 |
| Solar Process Preheat (180° F max.); 2-Cover Pond (Future Price), Low-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Industrial Owner) | 508 | 25.3 | 8.87/ 5,53 | 7.98/ 5.09 | 2949./ 2427. | 3510./ 2988. | 3371 ./2920. | 5819./ 5367 |
| Solar Process Heat (180° F); Flat-Plates (1977 Prices), Low-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Industrial Owner) | 509 | 243 | 40.56/ 23.66 | 35.89/ 21.36 | 7662. / 5130. | 8231./ 5699. | 7531 ./5355 | '****'/ 7838 |
| Solar Process Heat (180° F); Flat-Plates (Future Price), Low-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Industrial Owner) | 510 | 243 | 26 08/ 15.05 | 23.07/ 13.57 | 5493./ 3841 | 6063. / 4410. | 5612./4188. | 8094./ 6671 |
| Solar Process Heat (350° F); One-Axis Tracker (1977 Design), High-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Industrial Owner) | 511 | 24.5 | 49.11/ 9.67 | 43.73/ 27.02 | 8987./ 6056, | 9556. / 6624. | 8744./6225. | ● ****/ 8702, |
| Solar Process Heat (350° F); One-Axis Tracker (Future Design), High-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Industrial Owner) | 512 | 25.3 | 23 63/ 4.23 | 21.07/ 12.97 | 5247. / 3782. | 5809./ 4344. | 5412./4148. | 7860./ 6597. |
| PV Cogeneration; Two-Axis Concentrators With GaAs Cells (Med. Price), Low-Temp. Storage, oil Backup Boiler, and Utility Electric Backup (Industrial Owner) | 513 | 49.3 | 17 79/ 10.63 | 15,82/ 966 | 6556. / 4379. | 6955./ 4778 | 6357./4484 | 8114 / 6241 |
| PV Cogeneration; Two-Axis Concentrators With GaAs Cells (Low Price), Low-Temp. Storage, Oil Backup Boiler, and Utility Electric Backup (Industrial Owner) | 514 | 51.9 | 11 .42/ 6.84 | 10,18/ 6.23 | 4765. / 3298 | 5149./ 3682 | 4752 /3487 | 6453./ 5188. |

| Summary description of system | Table number | Percent solar | Effective cost of solar energy (¢/kWh) | | | | Levelized monthly cost of energy service | | | |
|--|--------------|---------------|--|--------------|----------------|---------------|--|---------------|----------------------|--|
| | | | No credits | | 20% ITC | | Projection 1 No credits | | Projection 2 20% ITC | |
| Reference system | | | | | | | | | | |
| Conv. Boiler and Utility Electricity (Municipal Utility Owner) | M504 | 0.0 | NA/ NA | NA/ NA | 2047.1 | NA | 2799./ NA | 2799./ NA | 6127 / NA | |
| Systems compared to reference system | | | | | | | | | | |
| Solar Process Heat (180° F); 2-Cover Pond, Low-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Municipal Utility Owner) | M505 | 16.8 | 8.89/ 11.81 | 8.13/ 10.89 | 2621 / 2924 | 3246. / 3549 | 3167 / 3454 | 5910/ 6197 | | |
| Solar Process Preheat (180° F max.); 2-Cover Pond, Low-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Municipal Utility Owner) | M506 | 25.3 | 5.90/ 7.84 | 5.40/ 7.23 | 2445 / 2748. | 3006./ 3309 | 2927 / 3214 | 5375./ 5662 | | |
| Solar Process Heat (180° F); 2-Cover Pond (Future Price), Low-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Municipal Utility Owner) | M507 | 16.8 | 6.57/ 8.71 | 6.02/ 8.05 | 2381./ 2602. | 3007/ 3228. | 2950./ 3160. | 5692/ 5903 | | |
| Solar Process Preheat (180° F max.); 2-Cover Pond (Future Price), Low-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Municipal Utility Owner) | M508 | 25.3 | 4.37/ 5.79 | 4.00/ 5.35 | 2205./ 2427. | 2767/ 2988 | 2710 / 2920. | 5157. / 5367 | | |
| Solar Process Heat (180° F); Flat-Plates (1977 Prices), Low-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Municipal Utility Owner) | M509 | 24.3 | 16.77/ 23.93 | 14.86/ 21.63 | 4057. / 5130. | 4626. / 5699. | 4340 / 5355 | 6822/ 7838 | | |
| Solar Process Heat (180° F); Flat-Plates (Future Price), Low-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Municipal Utility Owner) | M510 | 24.3 | 10.70/ 15.33 | 9.47/ 13.84 | 3148. / 3841. | 3718. / 4410. | 3533./ 4188. | 6016 / 6671 | | |
| Solar Process Heat (350° F); One-Axis Tracker (1977 Design), High-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Municipal Utility Owner) | M511 | 24.5 | 21.70/ 29.94 | 19.50/ 27.29 | 4814. / 6056. | 5382. / 6624 | 5050 / 6225 | 7527/ 8702 | | |
| Solar Process Heat (350° F); One-Axis Tracker (Future Design), High-Temp. Storage, Oil Backup Boiler, and Utility Electricity (Municipal Utility Owner) | M512 | 25.3 | 10.57/ 14.49 | 9.52/ 13.23 | 3172. / 3782. | 3733/ 4344 | 3571 / 4148 | 6019 / 6597 | | |
| PV Cogeneration; Two-Axis Concentrators With GaAs Cells (Med. Price), Low-Temp. Storage, Oil Backup Boiler, and Utility Electric Backup (Municipal Utility Owner). | M513 | 49.3 | 7.75/ 10.76 | 6.95/ 9.80 | 3463.1 / 4379. | 3862. / 4778 | 3617./ 4484. | 5374. / 6241. | | |
| PV Cogeneration; Two-Axis Concentrators With GaAs Cells (Low Price), Low-Temp. Storage, Oil Backup Boiler, and Utility Electric Backup (Municipal Utility Owner). | M514 | 51.9 | 5.06/ 6.96 | 4.55/ 6.35 | 2691 / 3298. | 3075./ 3682. | 2912./ 3487. | 4613./ 5188. | | |
| Conventional oil systems | | | | | | | | | | |
| Conv. Engine Cogeneration; Oil-Burning Diesel Engine (Industrial Owner). | 515 | 0.0 | NA/ NA | NA/ NA | 2072./ NA | 2644. / NA | 2644. / NA | 5284. / NA | | |

| | | | | | | | | | | | | | | |
|---|------|-----|--------|-------|---------|-------|---------|-------|----------|--------|------------|--------|---------|------|
| Conv Engine Cogeneration; Oil-Burning Diesel Engine (Municipal Utility Owner) | M515 | 00 | NA/ | NA | NA/ | NA/ | 1834./ | NA | 2406./ | NA | 2406./ | NA | 5046./ | NA |
| Reference system | | | | | | | | | | | | | | |
| Conv Engine Cogeneration; Oil-Burning Stirling (Industrial Owner) | 516 | 00 | NA/ | NA | NA/ | NA | 2017 / | NA | 2566 / | NA | 2566 / | NA | 5100 / | NA |
| SYSTEMS compared to reference system | | | | | | | | | | | | | | |
| Solar Engine Cogeneration, Two-Axis Dish, Stirling Engines, High and Low-Temp Storage, and Oil Backup (Industrial Owner) | 517 | 465 | 26331 | 1554 | 23 45/ | 1412 | 6821 / | 4565 | 71 15, / | 4859 | 6512 / | 4562 | 7867 / | 5917 |
| Reference system | | | | | | | | | | | | | | |
| Conv. Engine Cogeneration, Oil-Burning Stirling (Municipal Utility Owner) | M516 | 00 | NA/ | NA/ | NA/ | NA/ | 1898./ | NA | 2447./ | NA | 2447 / | NA | 4980./ | NA |
| Systems compared to reference system | | | | | | | | | | | | | | |
| Solar Engine Cogeneration; Two-Axis Dish, Stirling Engines, High- and Low-Temp Storage, and Oil Backup (Municipal Utility Owner) | M517 | 465 | 46.5 | 1.59/ | 16.11 | 0.41/ | 14.69 | 3914/ | 4859 | 3667./ | 4562 | 5022 / | 5917 | |
| Reference system | | | | | | | | | | | | | | |
| Conv Gas Boiler and Utility Electricity (Industrial Owner) | G504 | 00 | NA/ | NA | NA/ | NA | 1331 / | NA | 2210. / | NA | 2210 / | NA | 3864 / | NA |
| Systems compared to reference system | | | | | | | | | | | | | | |
| Solar Process Heat (180° F); 2-Cover Pond, Low-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Industrial Owner) | G505 | 168 | 78.27/ | 1142 | 16.41/ | 050 | 3075./ | 2365 | 3794./ | 3084. | 3601 / | 2989 | 5108. / | 4496 |
| Solar Process Preheat (180° F max.); 2-Cover Pond, Low-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Industrial Owner) | G506 | 253 | 12.13/ | 758 | 1090/ | 696 | 2999./ | 2289. | 3637. / | 2927 | 344412832, | 4877 / | 4264 | |
| Solar Process Heat (180° F); 2-Cover Pond (Future Price), Low-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Industrial Owner) | G507 | 168 | 13 36/ | 8.32 | 1 2.02/ | 766 | 2566. / | 2044. | 3285. / | 2763. | 3146./ | 2694. | 4653 / | 4201 |
| Solar Process Preheat (180° F max.); 2-Cover Pond (Future Price), Low-Temp Storage, Gas Backup Boiler, and Utility Electricity (Industrial Owner) | G508 | 253 | 25.3 | 8.87/ | 5.53 | 0.98/ | 5.09 | 490./ | 1968. | 128./ | 2606. | 2989./ | 253; | |
| Solar Process Heat (180 °F), Flat-Plates (1977 Prices), Low-Temp Storage, Gas Backup Boiler, and Utility Electricity (Industrial Owner) | G509 | 243 | 24.3 | 0.56/ | 23.66 | 5.89/ | 21.36 | 191./ | 4659. | 339./ | 5307. | 7139./ | 496. | |
| Solar Process Preheat (180° F); Flat-Plates (Future Price), Low-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Industrial Owner) | G510 | 243 | 24.3 | 3.08/ | 15.05 | 1.07/ | 13.57 | 122./ | 3370. | 170./ | 4018. | 5219./ | 3796 | |
| Solar Process Heat (350° F); One-Axis Tracker (1977 Design), High-Temp, Storage, Gas Backup Boiler, and Utility Electricity (Industrial owner) | G511 | 245 | 24.5 | 9.11/ | 29.67 | 1.73/ | 27.02 | 118./ | 5586. | 65./ | 6233. | 8353./ | 583. | |

| Summary description of system | Table number | Percent solar | Effective cost of solar energy (¢/kWh) | | | | Levelized monthly cost of energy service | | | |
|--|--------------|---------------|--|--------------|---------------|---------------|--|----------------------------|-------------------------|------------------------|
| | | | No credits | | 20% ITC | | Projection 1 No credits | Projection 2 No credits | Projection 2 20% ITC | Projection 3 20 ITC |
| Systems compared to reference system—Continued | | | | | | | | | | |
| Solar Process Heat (350° F); One-Axis Tracker (Future Design), High-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Industrial Owner) | G512 | 25.3 | 23.63/1423 | 21.07/12.97 | 4788./3323 | 5427./3961. | 5029./3766. | 6461 / 5198. | | |
| PV Cogeneration; Two-Axis Concentrators With GaAs Cells (Med. Price), Low-Temp. Storage, Gas Backup Boiler, and Utility Electric Backup (Industrial Owner) | G513 | 49.3 | 17.79/1063 | 15.82/9.66 | 6176./3999 | 6639. / 4461 | 6040 /4167. | 6957 / 5084. | | |
| PV Cogeneration; Two-Axis Concentrators With GaAs Cells (Low Price), Low-Temp. Storage, Gas Backup Boiler, and Utility Electric Backup (Industrial Owner) | G514 | 51.9 | 11.42/ 6.84 | 10.18/ 6.23 | 4368 / 2901. | 4818 / 3352 | 4421/3156 | 5245. / 3979 | | |
| Reference system | | | | | | | | | | |
| Conv. Gas Boiler and Utility Electricity (Municipal Utility Owner) | MG504 | 0.0 | NA/ NA | NA/ NA | 1291./ NA | 2169./ NA | 2169. / NA | 3824. / NA | | |
| Systems compared to reference system | | | | | | | | | | |
| Solar Process Heat (180° F); 2-Cover Pond, Low-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Municipal Utility Owner) | MG505 | 16.8 | 8.89/11.81 | 8.13/ 10.89 | 2062./ 2365. | 2781./ 3084. | 2702./2989. | 4209./ 4496. | | |
| Solar Process Preheat (180° F max.); 2-Cover Pond, Low-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Municipal Utility Owner) | MG506 | 5.3 | 5.90/ 7.84 | 5.40/ 7.23 | 1986. / 2289. | 2624./ 2927. | 2545./2832. | 3977. / 4264. | | |
| Solar Process Heat (180° F); 2-Cover Pond (Future Price), Low-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Municipal Utility Owner) | MG507 | 6.8 | 6.57/ 8.71 | 6.02/ 8.05 | 1822./2044. | 2541./ 2763. | 2484./2694. | 3991./ 4201. | | |
| Solar Process Preheat (180° F max.); 2-Cover Pond (Future Price), Low-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Municipal Utility Owner) | MG508 | 25.3 | 4.37/ 5.79 | 4.00/ 5.35 | 1746. / 1968. | 2384.1 2606. | 2327./2537. | 3760./ 3970. | | |
| Solar Process Heat (180° F); Flat-Plates (1977 Prices), Low-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Municipal Utility Owner) | MG509 | 24.3 | 16.77/ 23.93 | 14.86/ 21.63 | 3586./ 4659. | 4234./ 5307. | 3947./4962. | 5389./ 6404. | | |
| Solar Process Heat (180° F); Flat-Plates (Future Price), Low-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Municipal Utility Owner) | MG510 | 24.3 | 10.70/ 15.33 | 9.47/ 13.84 | 2677./ 3370. | 3325./ 4018. | 3141./3796. | 4582./ 5237. | | |
| Solar Process Heat (350° F); One-Axis Tracker (1977 Design), High-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Municipal Utility Owner) | MG511 | 24.5 | 21.70/ 29.94 | 19.50/ 27.29 | 4345./ 5586. | 4991. / 6233. | 4659./5834. | 6099./ 7274. | | |

| | | | | | | | | | | | | | |
|--|-------|------|--------------|---------------|---------------|---------------|-------------|---------------|--|--|--|--|--|
| <i>Solar Process Heat (350° F); One-Axis Tracker (Future Design), High-Temp. Storage, Gas Backup Boiler, and Utility Electricity (Municipal Utility Owner)</i> | | | | | | | | | | | | | |
| | MG512 | 25.3 | 10.57/ 14.49 | 9.52/ 13.23 | 2712 / 3323. | 3351 / 3961 | 3188./3766. | 4620 / 5198 | | | | | |
| <i>PV Cogeneration; Two-Axis Concentrators With GaAs Cells (Med. Price), Low-Temp. Storage, Gas Backup Boiler, and Utility Electric Backup (Municipal Utility Owner)</i> | | | | | | | | | | | | | |
| | MG513 | 493 | 7.75/ 10.76 | 6.95/ 9.80 | 3083 / 3999. | 3545. / 4461. | 3300 /4167. | 4217 / 5084. | | | | | |
| <i>PV Cogeneration; Two-Axis Concentrators With GaAs Cells (Low Price), Low-Temp. Storage, Gas Backup Boiler, and Utility Electric Backup (Municipal Utility Owner)</i> | | | | | | | | | | | | | |
| | MG514 | 51.9 | 5.06/ 6.96 | 4.55/ 6.35 | 2294. / 2901. | 2744./ 3352. | 2581 /3156. | 3404. / 3979 | | | | | |
| Conventional gas systems | | | | | | | | | | | | | |
| <i>Conv. Engine Cogeneration; Gas-Burning Diesel (Industrial Owner)</i> | | | | | | | | | | | | | |
| | G515 | 0.0 | NA/ NA | NA/ NA | 1180. / NA | 1901./ NA | 1901 / NA | 2568. / NA | | | | | |
| <i>Conv. Engine Cogeneration; Gas-Burning Diesel (Municipal Utility Owner)</i> | | | | | | | | | | | | | |
| | MG515 | 0.0 | NA/ NA | NA/ NA | 942. / NA | 1663./ NA | 1663. / NA | 2330. / NA | | | | | |
| Reference system | | | | | | | | | | | | | |
| <i>Conv. Engine Cogeneration; Gas-Burning Stirling (Industrial Owner).</i> | | | | | | | | | | | | | |
| | G516 | 0.0 | NA/ NA | NA/ NA | 1161. / NA | 1853./ NA | 1853. / NA | 2492. / NA | | | | | |
| Systems compared to reference system | | | | | | | | | | | | | |
| <i>Solar Engine Cogeneration; Two-Axis Dish, Stirling Engines, High- and Low-Temp. Storage, and Gas Backup (Industrial Owner).</i> | | | | | | | | | | | | | |
| | G517 | 46.5 | 26.33/ 15.54 | 23.45/ 14.12 | 6363./ 4107. | 6733.1 4477. | 6131 /4181 | 6473. / 4523. | | | | | |
| Reference system | | | | | | | | | | | | | |
| <i>Conv. Heat Engine Cogeneration; Gas- Burning Stirling (Municipal Utility Owner)</i> | | | | | | | | | | | | | |
| | MG516 | 0.0 | NA/ NA | NA/ NA | 1041. / NA | 1734. / NA | 1734. / NA | 2373. / NA | | | | | |
| Systems compared to reference system | | | | | | | | | | | | | |
| <i>Solar Engine Cogeneration; Two-Axis Dish, Stirling Engines, High- and Low-Temp. Storage, and Gas Backup (Municipal Owner).</i> | | | | | | | | | | | | | |
| | MG517 | 46.5 | 11.59/ 1611 | 10.41 / 14.69 | 3162. / 4107. | 3532./ 4477. | 3285./4181. | 3628.1 4523 | | | | | |

CATALOG OF ENERGY SYSTEMS

Footnotes for catalog tables

a 1 Bbl. crude Oil is equivalent to 4.83 mmBtu after 17% loss due to refining, transportation, etc. Combined electrical generation, transmission, and distribution efficiency is 29 percent.

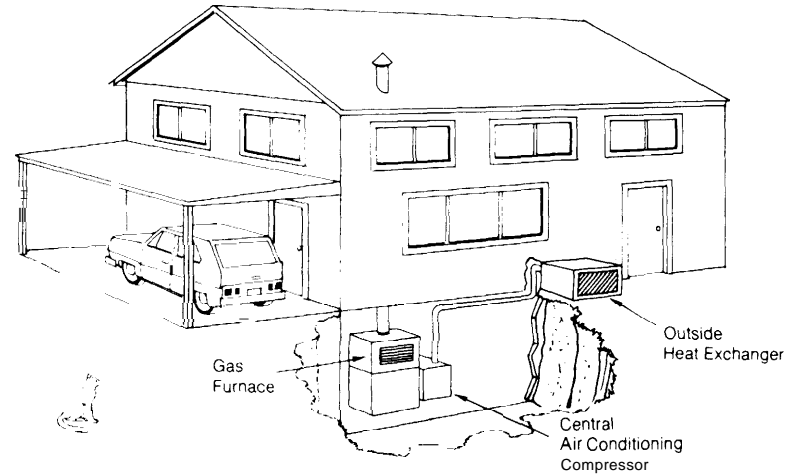
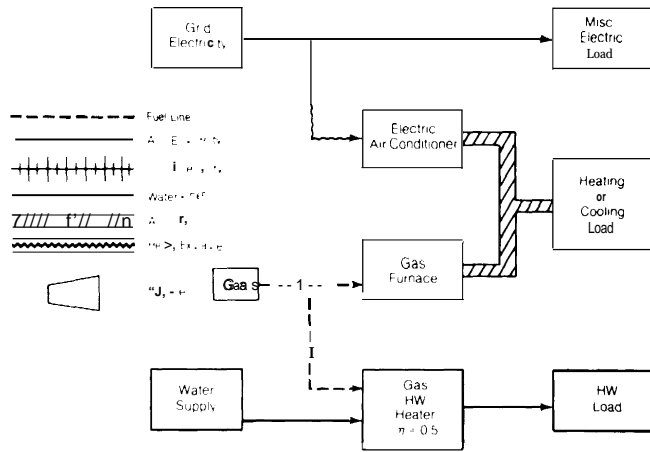
b The energy Cost escalation assumptions are described in detail in chapter II, volume II. In all cases, 5.5 percent inflation is assumed.

C The other costs assume that the energy equipment is owned by the building owners (see page 97). The equipment in the conventional communities is also owned by the owners of each of the buildings, while in the other communities, it is owned by a municipal utility. In all cases, the parenthesized costs assume ownership by an investor-owned utility using normalized accounting.

d "1985 Startup" is the same as "1976 Startup" except that fuel costs have escalated for 9 years. For ease of comparison with "1976 Startup," 5.5 percent inflation between 1976 and 1985 has been removed.

e These levelized prices are computed from the price paid for energy in the reference nonsolar system.

Table IV-1.-Albuquerque: Conventional System—Single Family House Using Gas Heat, Hot Water, and Central Electric A/C (SF-1)



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O&P) | Annual O&M | Life (yrs) |
|-------------------------|-------------------------|------------|------------------------|-------------|------------|
| 1. Gas furnace | 45 M Btu/h 15 S/M Btu/h | | \$675 | 0 | 15 |
| 2. Ductwork | | | 425 | 0 | 30 |
| 3. Central electric a/c | 1.85 tons | 430 \$/ton | 796 | \$30 | 10 |
| 4. Gas water heater | 40 gal | 225 ea. | 225 | 0 | 15 |
| TOTAL | | | \$2,121 | \$30 | |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}

(Conventional reference system is SF-1)

| | Escalation of conventional energy costs | | | | | |
|------------------------------------|---|--------|---------------------------|--------|----------------------------|--------|
| | Constant real energy prices | | Energy price escalation I | | Energy price escalation II | |
| 1. 1976 Startup | | | | | | |
| Total with no incentives | 116. | (128.) | 153. | (165.) | 226. | (238.) |
| Total with 20% ITC | 116. | (128.) | 153. | [165.] | 226. | (238.) |
| Total with full incentives | 116. | (128.) | 153. | (165.) | 226. | [238.] |
| 2. 1985 Startup^d | | | | | | |
| (capital related costs) | 29. | [41.] | 29. | (41.) | 29. | [41.] |
| (operating & maintenance costs) | 4. | [4.] | 4. | (4.) | 4. | (4.) |
| (fuel bill) | 36. | (36.) | 73. | (73.) | 108. | (108.) |
| (electric bill) | 48. | (48.) | 67. | (67.) | 146. | (146.) |
| Total with no incentives | 116. | (128.) | 173. | (185.) | 287. | (299.) |
| Total with 20% ITC | 116. | (128.) | 173. | (185.) | 287. | (299.) |
| Total with full incentives | 116. | (128.) | 173. | (185.) | 287. | [299.] |

C. EFFECTIVE COST OF ENERGY TO CONSUMER

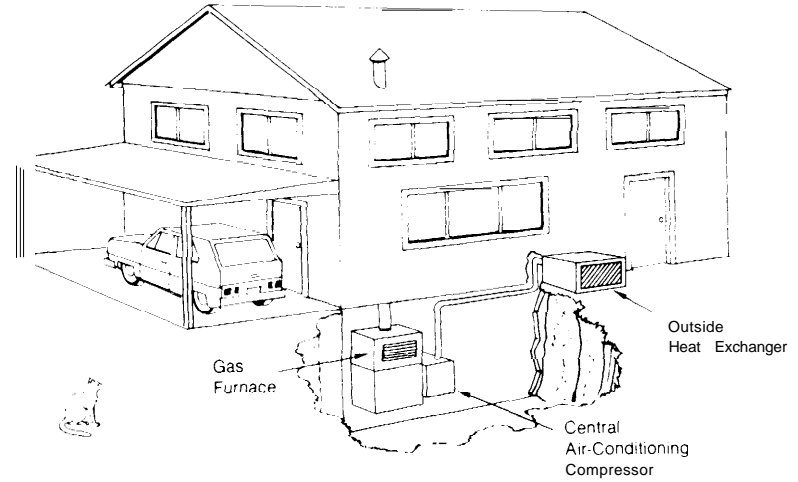
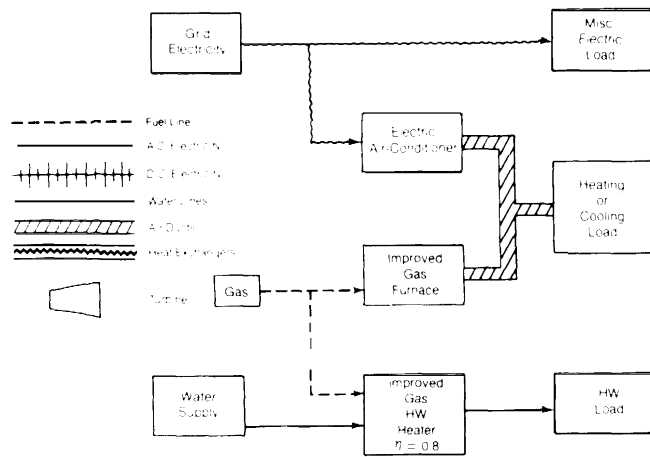
(Conventional reference system is SF-1)

ANNUAL ENERGY FLOWS (Conventional reference system is SF-1)

| | Energy consumed by ref. system | Backup consumed solar/conservation | W/ Energy saved (% of total) |
|--|--------------------------------|------------------------------------|------------------------------|
| Net Electricity (bought-sold) (MWh/unit) | 11.3 | 11.3 | 0. |
| Fuel consumed onsite (MMBtu/unit) | 164. | 164. | 0. |
| Total energy requirement (bbl crude equiv.) ^a | 62. | 62. | 0. |
| Electricity sold to grid annually (MWh, entire building) | | | 0. |
| Annual peak electricity demand (kW, entire building) | | | 5.2 |

| Levelized cost of solar energy or 'conservation' energy ^c | Type of incentives given | | | |
|--|-----------------------------|-------|----------------------------|-------|
| | No incentives | | Full incentives | |
| \$/MMBtu primary (a) | N/A | (N/A) | N/A | (N/A) |
| ¢/kWh electricity | N/A | (N/A) | N/A | (N/A) |
| Escalation of conventional energy cost | | | | |
| Levelized price paid for conventional energy ^{b,*} | Constant real energy prices | | Energy price escalation II | |
| | 3.37 | | 4.86 | |
| \$/MMBtu primary # | 3.97 | | 5.73 | |
| | | | 7.80 | |
| ¢/kWh electricity | 3.97 | | 5.73 | |
| | | | 9.18 | |

Table IV-2.—Albuquerque: Conventional System—Single Family House Using Improved Gas Heat, Hot Water, and Central Electric A/C



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O & P) | Annual Life O & M (yrs) |
|------------------------------|-----------|--------------|--------------------------|-------------------------|
| 1. Gas furnace..... | 45M Btuh | 17 \$/M Btuh | \$765 | 0 |
| 2. Ductwork..... | | | 425 | 0 |
| 3. Central electric a/c..... | 1.85 tons | 430 \$/ton | 796 | \$30 |
| 4. Gas water heater..... | 40 gal | \$275 ea. | 275 | 0 |
| TOTAL..... | | | \$2,261 | \$30 |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}

(Conventional reference system is SF-1)

| | Escalation of conventional energy costs | | |
|--|---|---------------------------|----------------------------|
| | constant real energy prices | Energy price escalation I | Energy price escalation II |
| 1. 1976 Startup | | | |
| a. Costs using solar (conservation) system: | | | |
| Total with no incentives..... | 111. (123.) | 143. (155.) | 210. (223.) |
| Total with 20% IT..... | 111. (123.) | 142. (155.) | 210. (223.) |
| Total with full incentives..... | 110. (122.) | 142. (154.) | 210. (222.) |
| b. Costs using conventional reference system..... | 117. | 154. | 226. |
| 2. 1985 Startup^d | | | |
| a. Costs using solar (conservation) system: | | | |
| (capital related costs)..... | 31. (43.) | 31. (43.) | 31. (43.) |
| (operation & maintenance costs)..... | 4. (4.) | 4. (4.) | 4. (4.) |
| (fuel bill)..... | 28. (28.) | 58. (58.) | 85. (85.) |
| (electric bill)..... | 48. (48.) | 67. (67.) | 146. (146.) |
| Total with no incentives..... | 111. (123.) | 160. (172.) | 266. (278.) |
| Total with 20% IT..... | 111. (123.) | 160. (172.) | 266. (278.) |
| Total with full incentives..... | 110. (122.) | 159. (171.) | 265. (277.) |
| b. Costs using conventional reference system..... | 117. | 174. | 287. |

C. EFFECTIVE COST OF ENERGY TO CONSUMER

(Conventional reference system is SF-1)

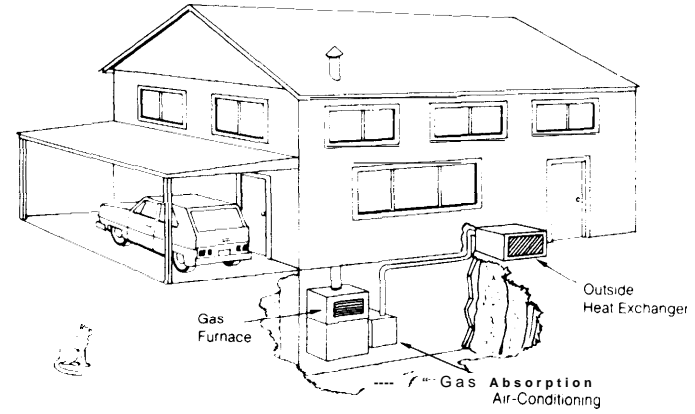
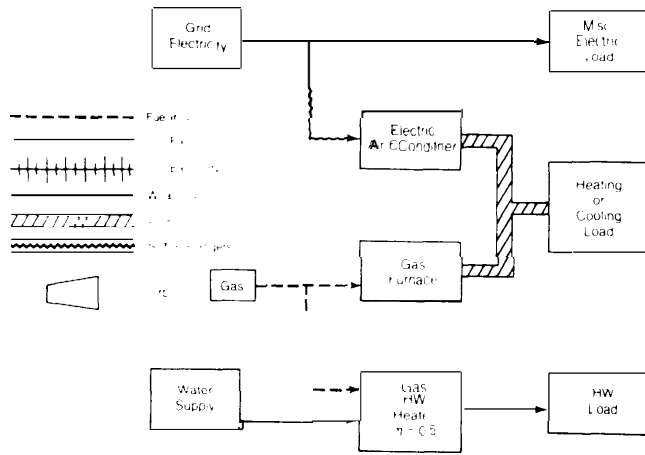
ANNUAL ENERGY FLOWS

(Conventional reference system is SF-1)

| | Energy consumed by ref. system | Backup consumed w/ solar/conservation | Energy saved (% of total) |
|---|--------------------------------|---------------------------------------|---------------------------|
| Net Electricity (bought-sold) (MWh/unit)..... | 11.3 | 11.3 | 0. |
| Fuel consumed onsite (MMBtu/unit)..... | 164. | 129. | 21.4 |
| Total energy requirement (bbl crude equiv.)..... | 62 | 54. | 11.9 |
| Electricity sold to grid annually (MWh, entire building)..... | | | |
| Annual peak electricity demand (kW, entire building)..... | | | 5 ² |

| Levelized cost of solar energy or 'conservation' energy ^a | Type of incentives given | | |
|--|-----------------------------|---|----------------------------|
| | No incentives | 20% ITC | Full incentives |
| \$/MMBtu primary fuel..... | .61 (4.84) | .53 (4.77) | .43 (4.56) |
| ¢/kWh electricity..... | .71 (5.70) | .62 (5.62) | .51 (5.36) |
| Levelized price paid for conventional energy^{b*} | | | |
| | | Escalation of conventional energy costs | |
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| \$/MMBtu primary fuel..... | 3.37 | 4.86 | 7.80 |
| ¢/kWh electricity..... | 3.97 | 5.73 | 9.28 |

Table IV-3.—Albuquerque: Conventional System— Insulated Single Family House Using Gas Heat, Hot Water, and Central Electric A/C



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O&P) | Annual O&M | Life (yrs) |
|---|-------------|---------------|------------------------|-------------|------------|
| 1. Gas furnace..... | .31 M Btu/h | 15 \$/M Btu/h | \$465 | 0 | 15 |
| 2. Ductwork..... | — | — | 425 | 0 | 30 |
| 3. Central electric coil..... | 1.3 tons | 430 \$/ton | 559 | \$30 | 10 |
| 4. Gas water heater..... | 40 gal | 225 ea. | 225 | 0 | 15 |
| 5. Extra insulation, storm doors and windows..... | — | — | 981 | 0 | 30 |
| TOTAL | | | \$2,655 | \$30 | |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}

(Conventional reference system is SF-1)

| | Escalation of conventional energy costs | | | | | |
|--|---|---------|---------------------------|--------|-------------|--------|
| | Constant real energy prices | | Energy price escalation I | | | |
| | | | Escalation II | | | |
| 1. 1976 Startup | | | | | | |
| a. Costs using solar (conservation) system: | | | | | | |
| Total with no incentives..... | 106. | (1 19.) | 136. | (149.) | 201. | (214.) |
| Total with 20% ITC..... | 105. | (1 19.) | 135. | 149.) | 200. | (213.) |
| Total with full incentives..... | 103. | (1 16.) | 133. | 146.) | 198. | (211.) |
| b. Costs using conventional reference system..... | 116. | | 153. | | 226. | |
| 2. 1985 Startup^d | | | | | | |
| a. Costs using solar (conservation) system: | | | | | | |
| (capital related costs)..... | 30. | (43.) | 30. | (43.) | 30. | (43.) |
| (operation & maintenance costs)..... | 4. | (4.) | 4. | (4.) | 4. | (4.) |
| (fuel bill)..... | 26. | (26.) | 54. | (54.) | 80. | (so.) |
| (electric bill)..... | 46. | (46.) | 65. | (65.) | 140. | (140.) |
| Total with no incentives..... | 106. | (119.) | 153. | (166.) | 254. | (267.) |
| Total with 20% ITC..... | 105. | (1 19.) | 152. | 165.) | 253. | (266.) |
| Total with full incentives..... | 103. | (1 16.) | 150. | 162.) | 251. | (264.) |
| b. Costs using conventional reference system..... | 116. | | 173. | | 287. | |

C. EFFECTIVE COST OF ENERGY TO CONSUMER

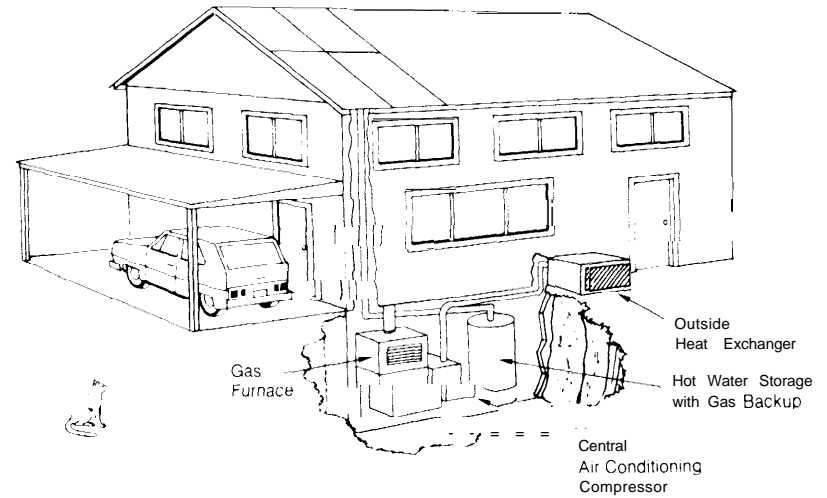
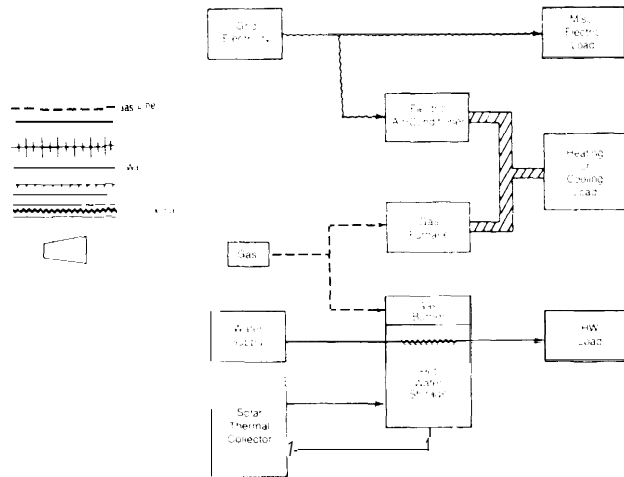
(Conventional reference system is SF-1)

ANNUAL ENERGY FLOWS (Conventional reference system is SF-1)

| | Energy consumed by ref. system | Backup consumed w/ solar/conservation | Energy saved (% of total) |
|--|--------------------------------|---------------------------------------|---------------------------|
| Net Electricity (bought-sold) (MWh/unit)..... | 11.3 | 10.7 | 4.9 |
| Fuel consumed onsite (MMBtu/unit)..... | 164. | 121. | 26.4 |
| Total energy requirement (bbl crude equiv.) ^a | 62. | 51. | 16.8 |
| Electricity sold to grid annually (MWh, entire building)..... | | | 0. |
| Annual peak electricity demand (kW, entire building)..... | | | 4.3 |

| Levelized cost of solar energy or 'conservation' energy ^c | Type of incentives given | | |
|--|-----------------------------|------------|---------------------------|
| | No incentives | 20% ITC | Full incentives |
| \$/MMBtu primary fuel..... | .22 (3.38) | .01 (3.21) | -.45 (2.62) |
| ¢/kWh electricity..... | .26 (3.98) | .02 (3.77) | -.54 (3.08) |
| Escalation of conventional energy costs | | | |
| Levelized price paid for conventional energy ^{b,*} | Constant real energy prices | | Energy price escalation I |
| | | | Escalation II |
| \$/MMBtu primary fuel..... | 3.37 | 4.86 | 7.80 |
| ¢/kWh electricity..... | 3.97 | 5.73 | 9.18 |

Table IV.4.—Albuquerque: Solar Hot Water System—Single Family House Using Flat-Plate Collectors (1977 Prices); Building Equipped With SF-1 Space-Conditioning



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O&P) | Annual O&M | Life (yrs) |
|--|-------------------|-----------------------|------------------------|-------------|------------|
| 1. Gas furnace..... | 45M Btuh | 15 \$/M Btuh | \$675 | 0 | 15 |
| 2. Ductwork..... | — | — | 425 | 0 | 30 |
| 3 Central electric a/c..... | 1.85 tons | 430 \$/ton | 796 | \$30 | 10 |
| 4. Hot water storage with gas fired backup (including heat exchanger). | 100 gal | \$380 | 380 | 0 | 30 |
| 5. Pumps and control..... | — | \$250 | 250 | 0 | 10 |
| 6 Insulated steel pipe..... | 75 ft | \$2.6/ft | 195 | 0 | 30 |
| 7 Flat plate solar collectors..... | 10 m ² | 143 \$/m ² | 1430 | 0 | 30 |
| —Collector cost @ 95 \$/m ² | | | 950 | 0 | 15 |
| —Installation @ 16 \$/m ² | | | 160 | 0 | 15 |
| —Transportation @ \$ 3/m | | | 320 | 0 | 15 |
| —Overhead and profit= 25% | | | 160 | 0 | 15 |
| TOTAL..... | | | \$4,151 | \$30 | |

*½ installed collector cost assumed replaced in 15 yrs., with total replacement in 30 yrs.

ANNUAL ENERGY FLOWS

(Conventional reference system is SF-1)

| | Energy consumed by ref. system | Backup consumed w/ solar/conservation | Energy saved (% of total) |
|--|--------------------------------|---------------------------------------|---------------------------|
| Net Electricity (bought-sold) (MWh/unit)..... | 11.3 | 11.3 | 0. |
| Fuel consumed onsite (MMBtu/unit)..... | 164. | 117. | 28.7 |
| Total energy requirement (bbl crude equiv.) ^a | 62. | 52. | 15.9 |
| Electricity sold to grid annually (MWh, entire building)..... | 0. | 0. | 0. |
| Annual peak electricity demand (kW, entire building)..... | 5.2 | 5.2 | 0. |

8. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{bc}

(conventional reference system is SF-1)

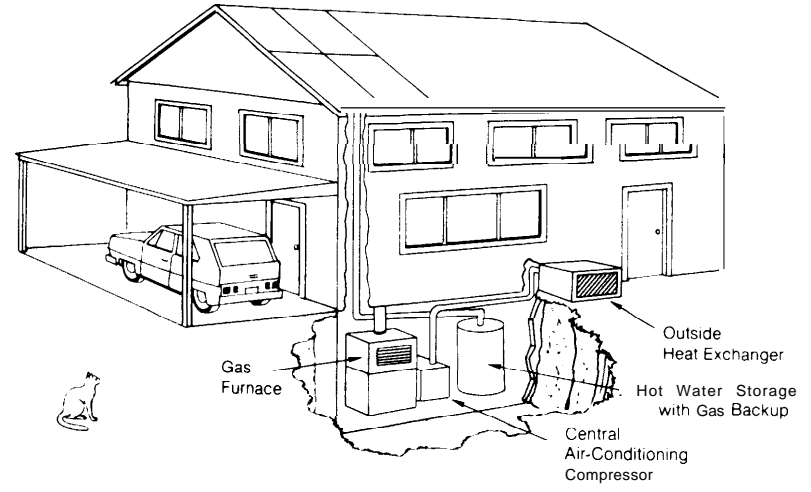
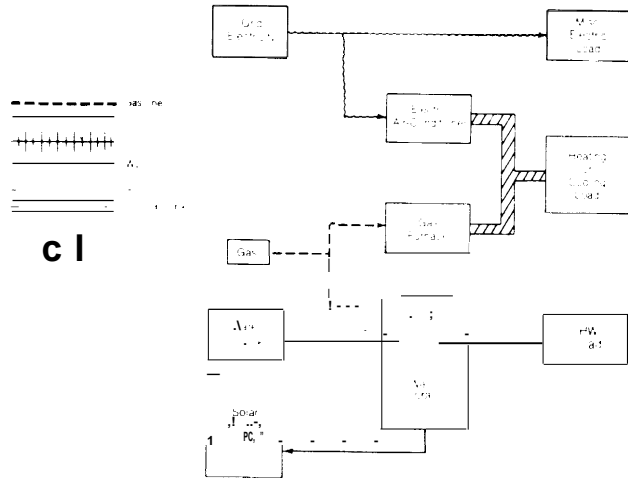
| | Escalation of conventional energy costs | | |
|--|---|---------------------------|----------------------------|
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| 1. 1976 Startup | | | |
| a. Costs using solar (conservation) system: | | | |
| Total with no incentives..... | 127. | 148.) | 157. (178.) |
| Total with 20% IT..... | 124. | 146.) | 154. [176.] |
| Total with full incentives..... | 120. | 136.) | 150. [166.] |
| b. Costs using conventional reference system..... | 117. | | 154. |
| 2. 1985 Startup^d | | | |
| a. Costs using solar (conservation) system: | | | |
| (capital related costs)..... | 50. | (71.) | 50. (71.) |
| (operation & maintenance costs)..... | 4. | (4.) | 4. (4.) |
| (fuel bill)..... | 25. | (25.) | 52. (52.) |
| (electric bill)..... | 48. | (48.) | 67. (67.) |
| Total with no incentives..... | 127. | 148.) | 174. [195.] |
| Total with 20% IT..... | 124. | 146.) | 170. [192.] |
| Total with full incentive..... | 120. | 136.) | 166. [182.] |
| b. Costs using conventional reference system..... | 117. | | 174. |

C. EFFECTIVE COST OF ENERGY TO CONSUMER

(Conventional reference system is SF-1)

| Levelized cost of solar energy or 'conservation' energy ^e | Type of incentives given | | |
|--|--------------------------|--------------|-----------------|
| | No incentives | 20% ITC | Full incentives |
| \$/MMBtu primary fuel..... | 5.33 (10.64) | 4.50 (9.94) | 3.41 (7.58) |
| ¢/kWh electricity..... | 6.27 (12.53) | 5.30 [11.69] | 4.01 [8.92] |
| Levelized price paid for conventional energy^{b*} | | | |
| \$/MMBtu primary fuel..... | 3.37 | 4.86 | 7.80 |
| ¢/kWh electricity..... | 3.97 | 5.73 | 9.18 |

Table IV-5.—Albuquerque: Solar Hot Water System—Single Family House Using Flat-Plate Collectors (Possible Future Price); Building Equipped With SF-1 Space. Conditioning



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O&P) | Annual O&M | Life (yrs) |
|--|----------------------|----------------------|------------------------|------------|------------|
| 1. Gas furnace | 45MMBtu/15 S/M Btu/h | | \$675 | 0 | 15 |
| 2. Ductwork | | | 425 | 0 | 30 |
| 3. Central electric a/c | 1.85 tons | 430 \$/ton | 796 | \$30 | 10 |
| 4. Hot water storage with gas fired backup (including heat exchanger). | 100 gal | \$380 | 380 | 0 | 30 |
| 5. Pumps and control | | \$250 | 250 | 0 | 10 |
| 6. Insulated steel pipe | 75 ft | \$2.6/ft | 195 | 0 | 30 |
| 7. Flat plate solar collectors | 10 m ² | 86 \$/m ² | *430 | 0 | 15 |
| | | | *430 | 0 | 30 |
| —Collector cost @ 50 \$/m ² —installation @ 16 \$/m ² —Transportation @ 3 \$/m ² —Overhead and profit= 25% | | | | | |
| TOTAL | | | \$3,581 | \$30 | |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}

(Conventional reference system is SF-1)

| | Escalation of conventional energy costs | | | |
|--|---|---------------------------|----------------------------|--------|
| | Constant real energy prices | Energy, @ CO escalation I | Energy price escalation II | |
| 1. 1976 Startup | | | | |
| a. Costs using solar (conservation) system: | | | | |
| Total with no incentives | 122. | (140.) | 151. | (170.) |
| Total with 20% ITC | 119. | (138.) | 149. | (168.) |
| Total with full incentives | 116. | (131.) | 146. | (161.) |
| b. Costs using conventional reference system | 117. | | 134. | |
| 2. 1985 Startup ^a | | | | |
| cc. Costs using solar (conservation) system: | | | | |
| (capitol related costs) | 44. | (62.) | 44. | (62.) |
| (operation & maintenance costs) | 4. | (4.) | 4. | (4.) |
| (fuel bill) | 25. | (25.) | 52. | (52.) |
| (electric bill) | 48. | (48.) | 67. | (67.) |
| Total with no incentives | 122. | (140.) | 168. | (186.) |
| Total with 20% ITC | 119. | (138.) | 165. | (184.) |
| Total with full incentives | 116. | (131.) | 162. | (177.) |
| b. Costs using conventional reference system | 117. | | 174. | |
| | | | 226. | |
| | | | 287. | |

C. EFFECTIVE COST OF ENERGY TO CONSUMER

(Conventional reference system is SF-1)

| Levelized cost of solar energy or 'conservation' energy ^c | Type of incentives given | | |
|--|-----------------------------|---------------------------|----------------------------|
| | No incentives | 20% ITC | Full incentives |
| \$/MMBtu primary fuel | 3.83 (8.46) | 3.23 (7.95) | 2.45 (6.25) |
| ¢/kWh electricity | 4.51 (9.95) | 3.80 (9.35) | 2.88 (7.36) |
| Levelized price paid for conventional energy ^{b,*} | | | |
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| \$/MMBtu primary fuel | 3.37 | 4.86 | 7.80 |
| ¢/kWh electricity | 3.97 | 5.73 | 9.18 |

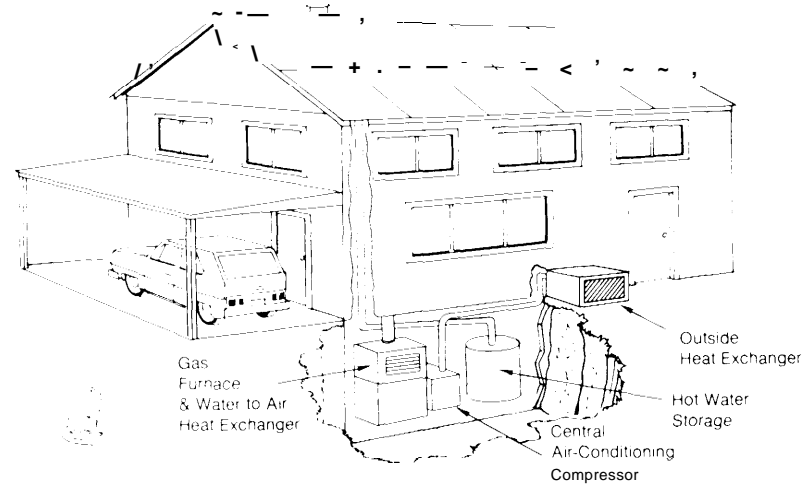
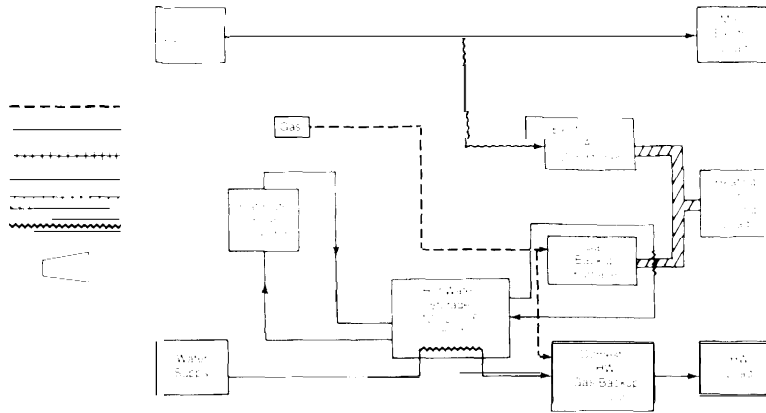
^a 1/2 installed collector cost assumed replaced in 15 yrs., with total replacement in 30 yrs.

ANNUAL ENERGY FLOWS

(Conventional reference system is SF-1)

| | Energy consumed by ref. system | Backup consumed w/ solar/conservation | Energy saved (% of total) |
|--|--------------------------------|---------------------------------------|---------------------------|
| Net Electricity (bought-sold) (MWh/unit) | 11.3 | 11.3 | 0. |
| Fuel consumed onsite (MMBtu/unit) | 164. | 117. | 28.7 |
| Total energy requirement (bbl crude equiv.) ^a | 62. | 52. | 15.9 |
| Electricity sold to grid annually (MWh, entire building) | | | 0. |
| Annual peak electricity demand (kW, entire building) | | | 5.2 |

Table IV-6.—Albuquerque: Solar Hot Water and Heating System—Single Family House Using Flat-Plate Collectors (1977 Prices), Low Temperature Thermal Storage; Building Equipped With SF-1 Space Conditioning



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O&P) | Annual O & M | Life " (yrs) |
|---------------------------------------|-------------------|-----------------------|------------------------|--------------|--------------|
| 1. Gas furnace | 45 M Btuh | 15 \$/M Btuh | \$675 | 0 | 15 |
| 2. Central electric O/C | 1.85 tons | 430 \$/ton | 796 | \$30 | 10 |
| 3. Ductwork | — | — | 425 | 0 | 30 |
| 4. Collectors and associated costs | 45 m ² | 143 \$/m ² | ● 3,218 | 0 | 15 |
| —Collectors @ 95 \$/m ² | | | ● 3,218 | 0 | 30 |
| —Installation @ 16 \$/m ² | | | | | |
| —Transportation @ 3 \$/m ² | | | | | |
| —25 % overhead and profit | | | | | |
| 5. 3/4" insulated steel pipe | 125 ft | \$4.1 | 513 | 0 | 30 |
| 6. Storage (without plumbing) | 200 kWh | \$2.05/kWh | 410 | 0 | 30 |
| 7. Pump, controls, and heat exchanger | — | \$650 | 650 | 0 | 10 |
| TOTAL | | | \$9,905 | \$30 | |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{991c}

(Conventional reference system is SF-1)

| | Escalation of conventional energy costs | | | | | |
|--|---|--------|---------------------------|--------|----------------------------|--------|
| | Constant real energy prices | | Energy price escalation I | | Energy price escalation II | |
| 1. 1976 Startup | | | | | | |
| a. Costs using solar (conservation) system: | | | | | | |
| Total with no incentives | 173. | (222.) | 192. | (240.) | 248. | (297.) |
| Total with 20% IT... | 161. | (211.) | 179. | (230.) | 236. | (286.) |
| Total with full incentives | 144. | (175.) | 163. | (194.) | 219. | (250.) |
| b. Costs using conventional reference system | 117. | | 154. | | 226. | |
| 2. 1985 Startup^a | | | | | | |
| o. Costs using solar (conservation) system: | | | | | | |
| (capital related costs) | 112. | (160.) | 112. | (160.) | 112. | (160.) |
| (operation & maintenance costs) | 4. | (4.) | 4. | (4.) | 4. | (4.) |
| (fuel bill) | 9. | (9.) | 19. | (19.) | 28. | (28.) |
| (electric bill) | 48. | (48.) | 67. | (67.) | 146. | (146.) |
| Total with no incentive! | 173. | (222.) | 202. | (251.) | 290. | (338.) |
| Total with 20% ITC | 161. | (211.) | 190. | (240.) | 277. | (328.) |
| Total with full incentives | 144. | (175.) | 173. | (204.) | 261. | (292.) |
| b. Costs using conventional reference system | 117. | | 174. | | 287. | |

C. EFFECTIVE COST OF ENERGY TO CONSUMER

(Conventional reference system is SF-1)

• 1/2 installed collector cost assumed replaced in 15 yrs., with total replacement in 30 yrs

ANNUAL ENERGY FLOWS

(Conventional reference system is SF-1)

| | Energy consumed by ref. system | Backup consumed w/ sO/O/conservation | Energy saved (% of total) |
|---|--------------------------------|--------------------------------------|---------------------------|
| Net Electricity (bought/sold) (MWh/unit) | 11.3 | 11.3 | 0 |
| Fuel consumed onsite (MMBtu/unit) | 164. | 42. | 74.1 |
| Total energy requirement (bbl/crude equiv. ^a) | 62. | 36. | 41.0 |
| Electricity sold to grid annually (MWh, entire building) | | | 5.2 |
| Annual peak electricity demand (kW, entire building) | | | 5.2 |

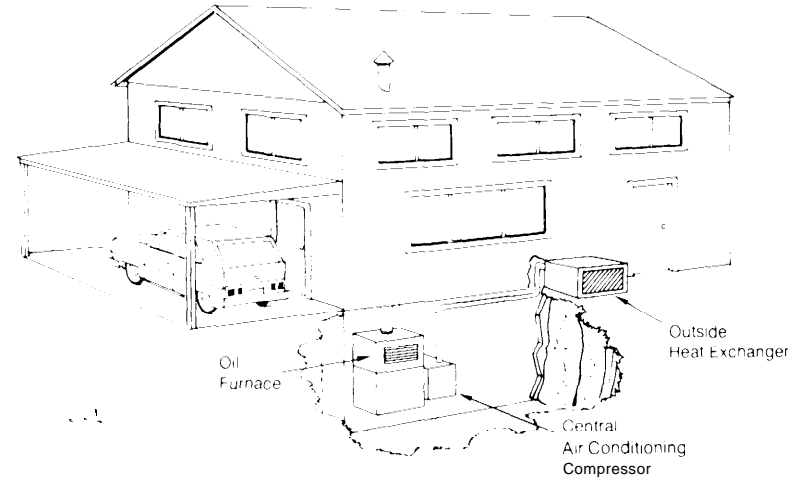
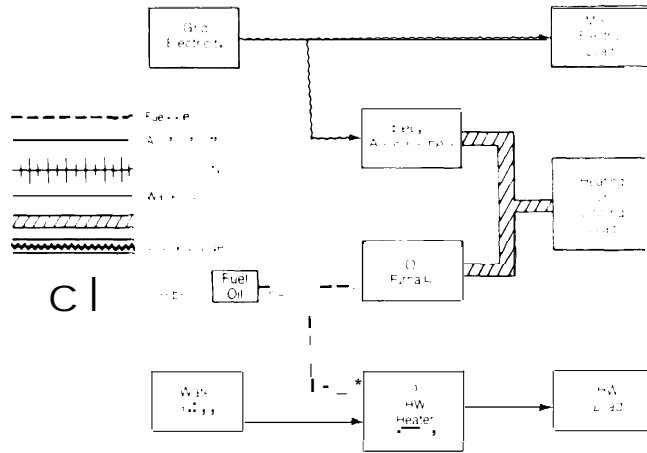
Levelized cost of solar energy or "conservation" energy^b

| | Type of incentives given | | |
|-----------------------|--------------------------|--------------|-----------------|
| | No incentive | 20% ITC | Full Incentives |
| \$/MMBtu primary fuel | 8.15 (12.93) | 6.92 [11.88] | 5.30 (8.37) |
| ¢/kWh electricity | 9.60 (15.22) | 8.14 (13.98) | 6.23 (9.85) |

Escalation of conventional energy costs

| Levelized price paid for conventional energy ^b * | Escalation of conventional energy costs | | |
|---|---|---------------------------|----------------------------|
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| \$/MMBtu primary fuel | 3.37 | 4.86 | 7.80 |
| ¢/kWh electricity | 3.97 | 5.73 | 9.18 |

Table IV-8.—Albuquerque: Conventional System—Single Family House Using Oil Heating and Central Electric A/C (SF-5)



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost ^a (incl. O&P) | Annual O&M | Life (yrs) |
|-------------------------------|------------|--------------|-------------------------------------|-------------|------------|
| 1. Oil furnace e..... | 4.5 M Btuh | 23 \$/M Btuh | \$1,030 | \$30 | 15 |
| 2. Ductwork | — | — | 425 | 0 | 30 |
| 3. Central electric a/c | 1.85 tons | 430 \$/ton | 796 | 30 | 10 |
| 4. Gas hot water heater..... | 40 gal | 225 ea. | 225 | 0 | 15 |
| TOTAL..... | | | \$2,476 | \$60 | |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}
(Conventional reference system is SF-5)

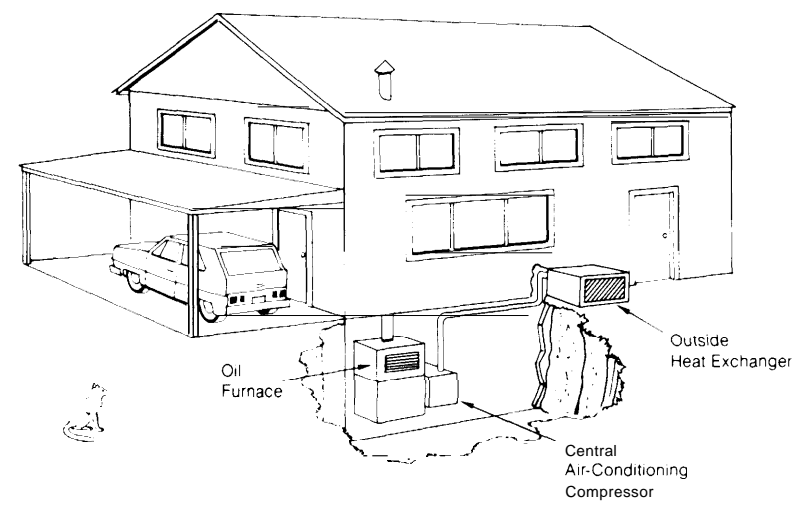
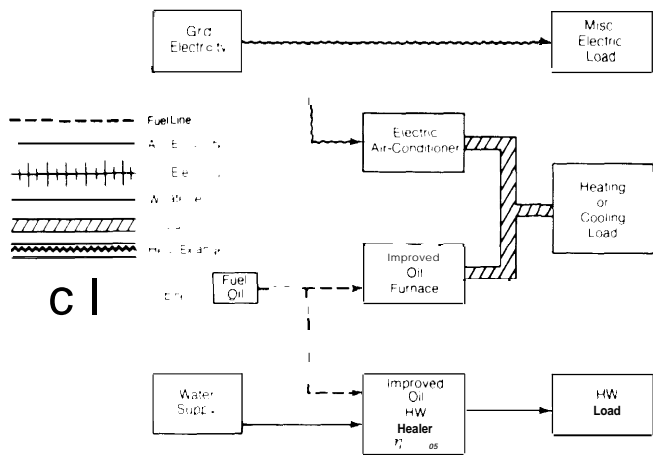
| | Escalation of conventional energy costs | | | | | |
|--------------------------------------|---|--------|---------------------------|--------|----------------------------|--------|
| | Constant real energy prices | | Energy price escalation I | | Energy price escalation II | |
| 1. 1976 Startup | | | | | | |
| Total with no incentives | 179. | (193.) | 212. | (226.) | 358. | (372.) |
| Total with 20% IT..... | 179. | [193.] | 212. | [226.] | 358. | (372.) |
| Total with full incentives | 179. | (193.) | 212. | [226.] | 358. | (372.) |
| 2. 1985 Startup^d | | | | | | |
| (capital related costs) | 33. | [47.] | 33. | [47.] | 33. | [47.] |
| (operation & maintenance costs)..... | 9. | (9.) | 9. | (9.) | 9. | (9.) |
| (fuel bill)..... | 88. | [88.] | 120. | (120.) | 268. | [268.] |
| (electric bill)..... | 49. | [49.] | 68. | [68.] | 14s. | [148.] |
| Total with no incentives | 179. | (193.) | 230. | [244.] | 4s8. | [472.] |
| Total with 20% IT..... | 179. | (193.) | 230. | (24.) | 458. | [472.] |
| Total with full incentives | 179. | (193.) | 230. | [244.] | 458. | (472.) |

C. EFFECTIVE COST OF ENERGY TO CONSUMER
(Conventional reference system is SF-5)

| ANNUAL ENERGY FLOWS (Conventional reference system is SF-5) | | | |
|--|--------------------------------|---------------------------------------|---------------------------|
| | Energy consumed by ref. system | Backup co. summed w/ dar/conservation | Energy saved (% of total) |
| Net Electricity (bought-sold) (MWh/unit)..... | 11.5 | 11.5 | 0 |
| Fuel consumed onsite (MMBtu/unit)..... | 205. | 205. | 0. |
| Total energy requirement (bbl crude equiv.) ^a | 71. | 71. | 0. |
| Electricity sold to grid annually (MWh, entire building)..... | | | 0. |
| Annual peak electricity demand (kW, entire building)..... | | | 5.2 |

| Levelized cost of solar energy or 'conservation' energy ^b | Type of incentives given | | | |
|--|-----------------------------|---------------------------|------|----------------------------|
| | No incentives | 20% ITC | | Full incentives |
| \$/MMBtu primary fuel..... | N/A | (N/A) | N/A | (N/A) |
| ¢/kWh electricity..... | N/A | (N/A) | N/A | (N/A) |
| Escalation of conventional energy costs | | | | |
| Levelized price paid for conventional energy ^{b,c} | Constant real energy prices | Energy price escalation I | | Energy price escalation II |
| | \$/MMBtu primary fuel..... | 4.82 | 5. w | 7.1 15 |
| | ¢/kWh electricity..... | 5.67 | 7.05 | 13.12 |

Table IV.9.—Albuquerque: Conventional System—Single Family House Using Improved Oil Heating and Central Electric A/C (SF-5)



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O&P) | Annual O & M | Life (yrs) |
|-------------------------|--------------------------|------------|------------------------|--------------|------------|
| 1. Oil furnace | 45 M Btu/h 25 \$/M Btu/h | | \$1,120 | \$30 | 15 |
| 2. Ductwork | | | 425 | 0 | 30 |
| 3. Central electric a/c | 1.85 tons | 430 \$/ton | 796 | 30 | 10 |
| 4. Gas water heater | 40 gal | \$275 ea. | 275 | 0 | 15 |
| TOTAL | | | \$2,616 | \$60 | |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}
(Conventional reference system is SF-5)

| | Escalation of conventional energy costs | | | | | |
|---|---|--------|---------------------------|--------|----------------------------|--------|
| | Constant real energy prices | | Energy price escalation I | | Energy price escalation II | |
| 1. 1976 Startup | | | | | | |
| a. Costs using solar (conservation) system: | | | | | | |
| Total with no incentives | 163. | (178.) | 192. | (207.) | 320. | (334.) |
| Total with 20% ITC | 163. | (177.) | 192. | (206.) | 319. | (334.) |
| Total with full incentives | 163. | (177.) | 192. | [206.] | 319. | (333.) |
| b. Costs using conventional reference system | | | | | | |
| | 179. | | 212. | | 358. | |
| 2. 1985 Startup^a | | | | | | |
| a. Costs using solar (conservation) system: | | | | | | |
| (capital related costs) | 35. | [50.] | 35. | [50.] | 35. | [50.] |
| (operation & maintenance costs) | 9. | (9.) | 9. | (9.) | 9. | (9.) |
| (fuel bill) | 69. | (69.) | 94. | (94.) | 211. | [211.] |
| (electric bill) | 50. | (50.) | 70. | (70.) | 152. | (152.) |
| Total with no incentives | 163. | (178.) | 208. | (223.) | 407. | (421.) |
| Total with 20% ITC | 163. | (177.) | 208. | (223.) | 406. | (421.) |
| Total with full incentives | 163. | (177.) | 208. | (222.) | 406. | (420.) |
| b. Costs using conventional reference system | | | | | | |
| | 179. | | 231. | | 458. | |

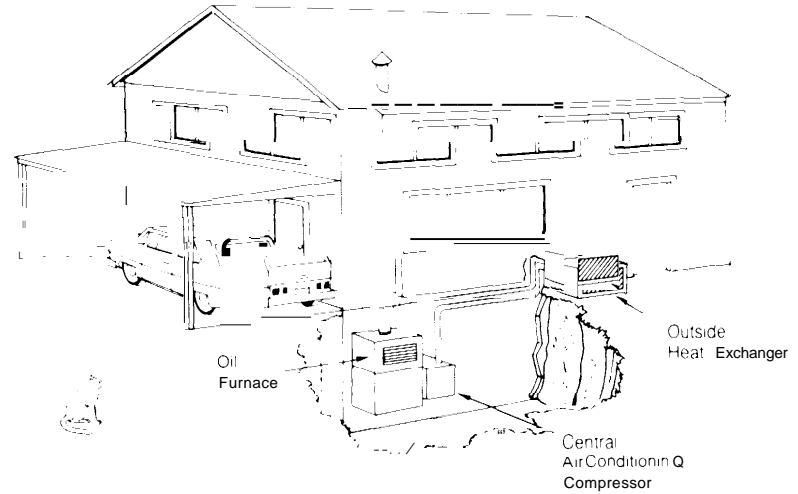
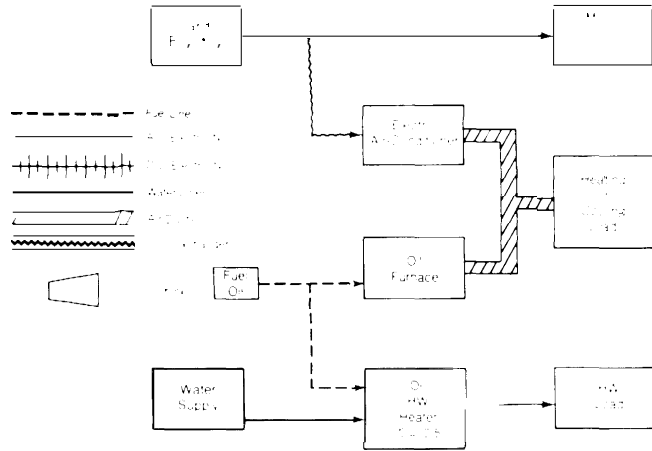
C. EFFECTIVE COST OF ENERGY TO CONSUMER
(Conventional reference system is SF-5)

| Levelized cost of solar energy or 'conservation' energy ^c | Type of incentives given | | |
|--|-----------------------------|------------|-----------------|
| | No incentives | 20% ITC | Full incentives |
| \$/MMBtu primary fuel | .54 (4.94) | .48 (4.89) | .39 (4.69) |
| ¢/kWh electricity | .64 (5.82) | .56 (5.75) | .45 (5.52) |
| Escalation of conventional energy costs | | | |
| Levelized price paid for conventional energy ^{b,e} | Constant real energy prices | | |
| | 4.82 | 5.99 | 7.15 |
| | Energy price escalation I | | |
| | 5.67 | 7.05 | 7.12 |

ANNUAL ENERGY FLOWS
(Conventional reference system is SF-5)

| | Energy consumed by ref. system | Backup consumed w/ 5010r/conservation | Energy saved (% of total) |
|--|--------------------------------|---------------------------------------|---------------------------|
| Net Electricity (bought-sold) (MWh/unit) | 11.5 | 11.9 | -3.5 |
| Fuel consumed onsite (MMBtu/unit) | 205. | 161. | 21.4 |
| Total energy requirement (bbl crude equiv.) ^a | 71. | 63. | 11.5 |
| Electricity sold to grid annually (MWh, entire building) | | | 0. |
| Annual peak electricity demand (kW, entire building) | | | 5.2 |

Table IV-10.— Albuquerque: Conventional System—Insulated Single Family House Using Oil Heating and Central Electric A/C (IF-5)



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O&P) | Annual O&M | Life (yrs) |
|--|------------|---------------|------------------------|-------------|------------|
| 1. Oil furnace .. | 31 M Btu/h | 23 \$/M Btu/h | \$713 | \$30 | 15 |
| 2 . Ductwork | — | — | 425 | 0 | 30 |
| 3. Central electric a/c . . . | 1.3 tons | 430 \$/ton | 559 | 30 | 10 |
| 4 Gas water heater | 40 gal | 225 ea. | 225 | 0 | 15 |
| 5. Extra insulation, storm doors and windows | — | — | 981 | 0 | 30 |
| TOTAL | | | \$2,903 | \$60 | |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{bc}

(Conventional reference system is SF-5)

| | Escalation of conventional energy costs | | | |
|---|---|---------------------------|----------------------------|--------------------|
| | Constant real energy prices | Energy price escalation I | Energy price escalation II | |
| 1. 1976 Startup | | | | |
| a. Costs using solar (conservation) system: | | | | |
| Total with no incentives | 153. | (167.) | 180. | [194.] 298. (313.) |
| Total with 20% ITC | 152. | [166.] | 179. | (194.) 298. (312.) |
| Total with full incentives | 150. | [165.] | 177. | (192.) 296. (310.) |
| b. Costs using conventional reference system | 179. | 212. | 358. | |
| 2. 1985 Startup^d | | | | |
| a. Costs using solar (conservation) system: | | | | |
| (capital related costs) | 33. | (47.) | 33. | (47.) 33. (47.) |
| (operation & maintenance costs) | 9. | (9.) | 9. | (9.) 9. (9.) |
| (fuel bill) | 65. | (65.) | 89. | (89.) 198. (198.) |
| (electric bill) | 46. | (46.) | 65. | (65.) 140. (140.) |
| Total with no incentives | 153. | (167.) | 195. | (209.) 379. (394.) |
| Total with 20% ITC | 152. | (166.) | 194. | (209.) 379. (393.) |
| Total with full incentives | 150. | (165.) | 192. | (207.) 377. (391.) |
| b. Costs using conventional reference system | 179. | 230. | 458. | |

C. EFFECTIVE COST OF ENERGY TO CONSUMER

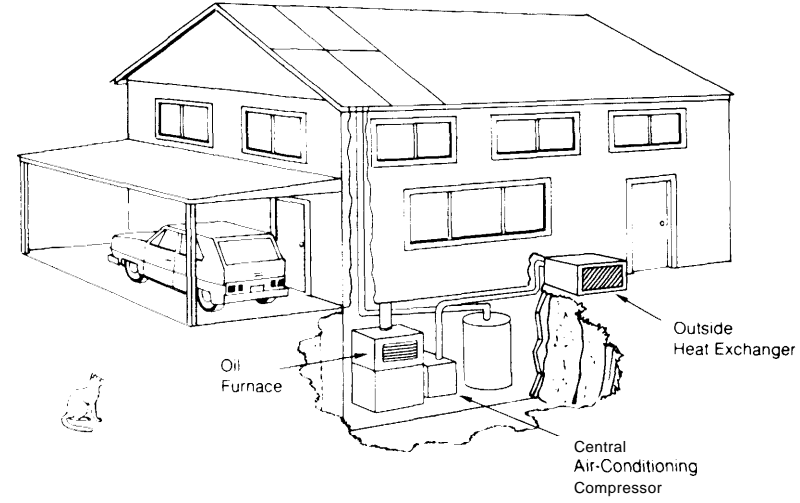
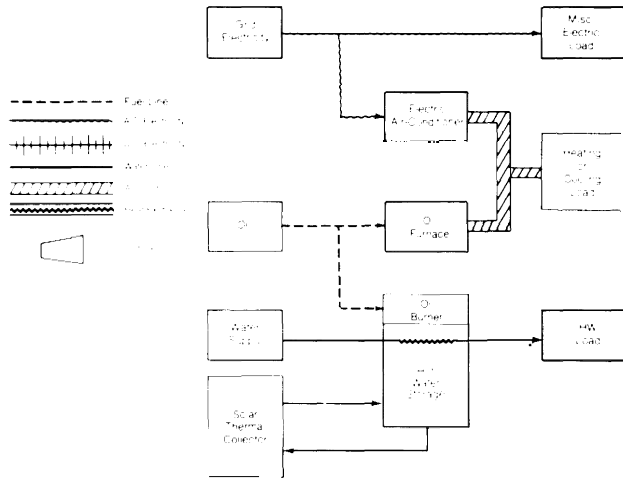
(Conventional reference system is SF-5)

| Levelized cost of solar energy or 'conservation' energy ^e | Type of incentive ^f given | | |
|--|---|---------------------------|----------------------------|
| | No incentives | 20% ITC | Full incentives |
| \$/MMBtu primary fuel | -.08 (2.69) | -.21 (2.58) | -.51 (2.21) |
| ¢/kWh electricity | -10 (3.16) | -25 (3.03) | .60 (2.60) |
| | Escalation of conventional energy costs | | |
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| Levelized price paid for conventional energy^{g*} | | | |
| \$/MMBtu primary fuel | 4.82 | 5 w- | 11.15 |
| ¢/kWh electricity | 5.67 | 7.05 | 13.12 |

ANNUAL ENERGY FLOWS (Conventional reference system is SF-5)

| | Energy consumed by ref. system | Backup consumed solar/conservation | w/ Energy saved (% of total) |
|--|--------------------------------|------------------------------------|------------------------------|
| Net Electricity (bought + sold) (MWh/unit) | 11.5 | 10.7 | 6.5 |
| Fuel consumed onsite (MMBtu/unit) | 205. | 151. | 26.4 |
| Total energy requirement (bbl crude equiv.) ^h | 71. | 58. | 18.5 |
| Electricity sold to grid annually (MWh, entire building) | | | 0. |
| Annual peak electricity demand (kW, entire building) | | | 4.3 |

Table IV-11.—Albuquerque: Solar Hot Water System—Single Family House Using Fiat. Plate Collectors (1977 Prices); Building Equipped With SF-5 Space-Conditioning



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O&P) | Annual O & M | Life (yrs) |
|---|-------------------|-----------------------|------------------------|--------------|------------|
| 1. Oil furnace | 45M Btuh | 23 \$/M Btuh | \$1,030 | \$30 | 15 |
| 2 Ductwork | | | 425 | 0 | 30 |
| 3. Central electric O/C | 1.85 tons | 430 \$/ton | 796 | 30 | 10 |
| 4. Hot water storage with electric backup (including heat exchanger). | 100 gal | \$380 | 380 | 0 | 30 |
| 5 Pumps and control. | — | \$250 | 250 | 0 | 10 |
| 6. Insulated steel pipe | 75 ft | \$2.6/ft | 195 | 0 | 30 |
| 7 Flat plate solar collectors | 10 m ² | 143 \$/m ² | 715 | 0 | 30 |
| —Collector cost @ 95 \$/m ² | | | 715 | 0 | 15 |
| —Installation @ 16 \$/m ² | | | | | |
| —Transportation @ \$3/m | | | | | |
| —Overhead and profit= 25% | | | | | |
| TOTAL | | | \$4,506 | \$60 | |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}
(Conventional reference system is SF-5)

| | Escalation of conventional energy costs | | | | | |
|--|---|--------|---------------------------|--------|----------------------------|--------|
| | Constant real energy prices | | Energy price escalation I | | Energy price escalation II | |
| 1. 1976 Startup | | | | | | |
| a. Costs using solar (conservation) system: | | | | | | |
| Total with no incentives | 174. | (197.) | 201. | (224.) | 319. | (342.) |
| Total with 20% IT... | 171. | (194.) | 198. | (221.) | 316. | (339.) |
| Total with full incentives | 166. | (185.) | 194. | (212.) | 312. | (330.) |
| b. Costs using conventional reference system | 179. | | 212. | | 358. | |
| 2. 1985 Startup^d | | | | | | |
| 0. Costs using solar (conservation) system: | | | | | | |
| (capital related costs) | 54. | (77.) | 54. | (77.) | 54. | (77.) |
| (operation & maintenance costs) | 9. | (9.) | 9. | (9.) | 9. | (9.) |
| (fuel bill) | 63. | (63.) | 86. | (86.) | 191. | (191.) |
| (electric bill) | 48. | (48.) | 67. | (67.) | 146. | (146.) |
| Total with no incentives | 174. | (197.) | 216. | (239.) | 400. | (423.) |
| Total with 20% IT... | 171. | (194.) | 213. | (236.) | 397. | (420.) |
| Total with full incentives | 166. | (185.) | 209. | (227.) | 393. | (411.) |
| b. Costs using conventional reference system | 179. | | 231. | | 458. | |

C. EFFECTIVE COST OF ENERGY TO CONSUMER
(Conventional reference system is SF-5)

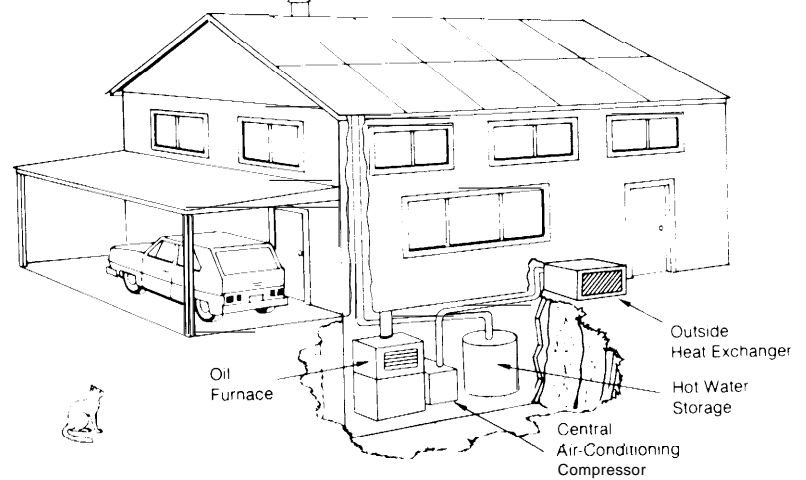
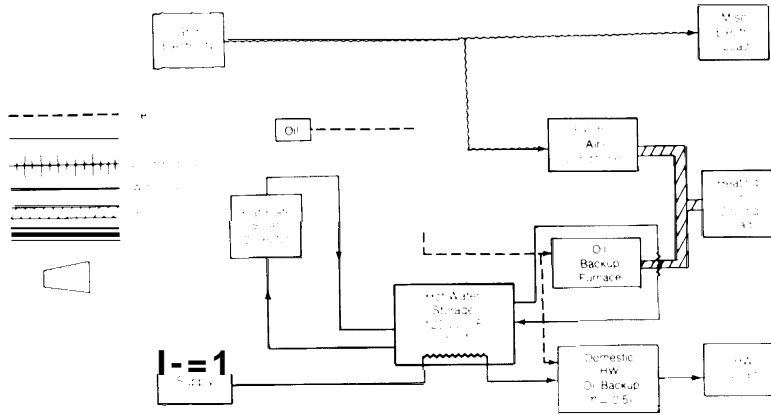
| Levelized cost of solar energy or 'conservation' energy ^c | Type of incentives given | | | | | |
|--|-----------------------------|---------|---------------------------|--------|----------------------------|--------|
| | No incentives | | 20% ITC | | Full incentives | |
| \$/MMBtu primary fuel | 4.10 | (8.58) | 3.46 | (8.03) | 2.62 | (6.22) |
| ¢/kWh electricity | 4.83 | (10.10) | 4.08 | (9.46) | 3.09 | (7.32) |
| Levelized rice paid for conventional energy^{b,*} | | | | | | |
| | Constant real energy prices | | Energy price escalation I | | Energy price escalation II | |
| \$/MMBtu primary fuel | 4.82 | | 5.99 | | 11.15 | |
| ¢/kWh electricity | 5.67 | | 7.05 | | 13.12 | |

^a1/2 installed collector cost assumed replaced in 15 yrs., with total replacement in 30 yrs

ANNUAL ENERGY FLOWS
(Conventional reference system is SF-5)

| | Energy consumed by ref. system | Backup consumed solar/conservation | w/ Energy saved (% of total) |
|--|--------------------------------|------------------------------------|------------------------------|
| Net Electricity (bought-sold)(MWh/unit) | 11.5 | 11.3 | 1.7 |
| Fuel consumed on site (MMBtu/unit) | 205. | 146. | 28.7 |
| Total energy requirement (bbl crude equiv.) ^a | 71 | 5a. | 18.0 |
| Electricity sold to grid annually (MWh, entire building) | | | 0. |
| Annual peak electricity demand (kW, entire building) | | | 5.2 |

Table IV-12.—Albuquerque: Solar Hot Water and Heating System—Single Family House Using Flat-Plate Collectors (1977 Prices); Low-Temperature Thermal Storage; Building Equipped With SF-5 Space-Conditioning



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O & P) | Annual O&M | Life (yrs) |
|---------------------------------------|-------------------|-----------------------|--------------------------|-------------|------------|
| 1. Oil furnace | 45M Btuh | 23 \$/M Btuh | \$1,030 | \$30 | 15 |
| 2. Centrolelectric | 1.85 tons | 430 \$/ton | 796 | 30 | 10 |
| 3. Ductwork | | | 425 | 0 | 30 |
| 4. Collectors and associated costs | 45 m ² | 143 \$/m ² | 3,218 | 0 | 15 |
| —Collectors @ 95 \$/m ² | | | 3,218 | 0 | 30 |
| —Installation @ 16 \$/m ² | | | | | |
| —Transportation @ 3 \$/m ² | | | | | |
| —25% overhead and profit | | | | | |
| 5. 3/4" insulated steel pipe | 125 lf | \$4.1 | 513 | 0 | 30 |
| 6. Storage (without plumbing) | 200 kWh | \$2.05/kWh | 410 | 0 | 30 |
| 7. Pump, controls, and heat exchanger | | \$650 | 650 | 0 | 10 |
| TOTAL | | | \$10,260 | \$60 | |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}
(Conventional reference system is SF-5)

| | Escalation of conventional energy costs | | | | | |
|---|---|--------|---------------------------|--------|----------------------------|--------|
| | Constant real energy prices | | Energy price escalation I | | Energy price escalation II | |
| 1. 1976 Startup | | | | | | |
| 0. Costs using solar (conservation) system: | | | | | | |
| Total with no incentives | 196. | (246.) | 213. | (264.) | 289. | (339.) |
| Total with 20% ITC | 183. | (235.) | 201. | (253.) | 276. | (328.) |
| Total with full incentives | 167. | (200.) | 184. | (218.) | 260. | (293.) |
| b. Costs using conventional reference system | | | 179. | 212. | 358. | |
| 2. 1985 Startup^a | | | | | | |
| 0. Costs using solar (conservation) system: | | | | | | |
| (capital related costs) | 116. | (167.) | 116. | (167.) | 116. | (167.) |
| (operation & maintenance costs) | 9. | (9.) | 9. | (9.) | 9. | (9.) |
| (fuel bill) | 23. | (23.) | 31. | (31.) | 69. | (69.) |
| (electric bill) | 48. | (43.) | 67. | (67.) | 146. | (146.) |
| Total with no incentives | 196. | (246.) | 223. | (274.) | 340. | (391.) |
| Total with 20% ITC | 183. | (235.) | 211. | (263.) | 328. | (380.) |
| Total with full incentives | 167. | (200.) | 194. | (227.) | 311. | (344.) |
| b. Costs using conventional reference system | | | 179. | 231. | 458. | |

C. EFFECTIVE COST OF ENERGY TO CONSUMER

(Conventional reference system is SF-5)

^a If installed collector cost assumed replaced in 15 yrs., with total replacement in 30 yrs

ANNUAL ENERGY FLOWS

(Conventional reference system is SF-5)

| | Energy consumed by ref. system | Backup consumed w/ solar/conservation | Energy saved (% of total) |
|--|--------------------------------|---------------------------------------|---------------------------|
| Net Electricity (bought, sold) (MWh/unit) | 11.5 | 11.3 | 1.7 |
| Fuel consumed onsite (MMBtu/unit) | 205. | 53. | 74.1 |
| Total energy requirement (bbl/crude equiv.) ^a | 71. | 39. | 45.4 |
| Electricity sold to grid annually (MWh, entire building) | | | 0. |
| Annual peak electricity demand (kW, entire building) | | | 5.2 |

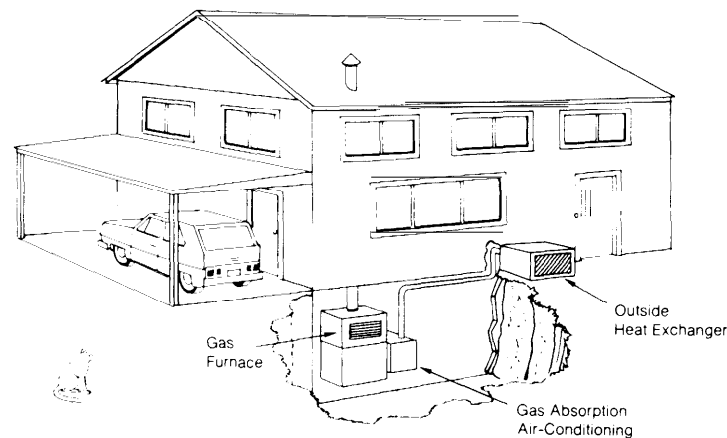
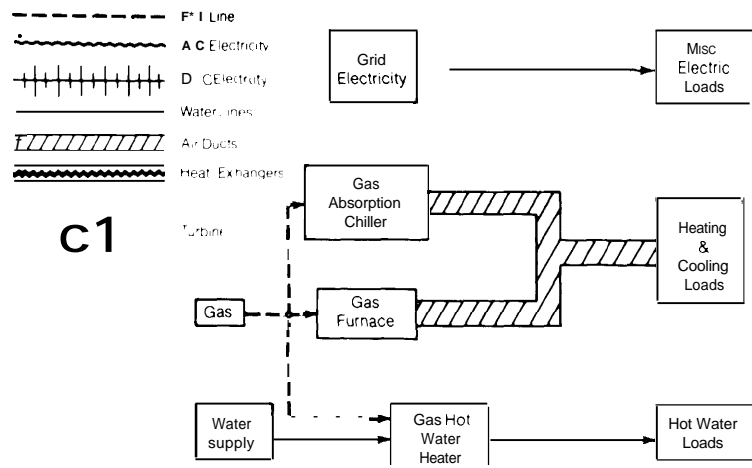
Levelized cost of solar energy or "conservation" energy^a

| | Type of incentives given | | | | | |
|-----------------------|--------------------------|---------|---------|---------|-----------------|--------|
| | No incentives | | 20% ITC | | Full incentives | |
| \$/MMBtu primary fuel | 6.42 | (10.34) | 5.45 | (9.51) | 4.17 | (6.75) |
| ¢/kWh electricity | 7.56 | (12.17) | 6.41 | (11.19) | 4.91 | (7.94) |

Escalation of conventional energy costs

| | Constant real energy prices | | Energy price escalation I | | Energy price escalation II | |
|-----------------------|---|--|---------------------------|--|----------------------------|--|
| | Levelized price paid for conventional energy^{b-a} | | | | | |
| \$/MMBtu primary fuel | 4.82 | | 5.99 | | 11.15 | |
| ¢/kWh electricity | 5.67 | | 7.05 | | 13.12 | |

Table IV-13.-Albuquerque: Conventional System-Single Family House With Gas Heat and Hot Water and Gas-Powered Absorption A/C (IF-7)



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl O&P) | Annual O&M | Life (yrs) |
|---------------------------|-----------|---------------|-----------------------|------------|-------------|
| 1. Gas furnace | 45 MBtu/h | 15 \$ /MBtu/h | \$675 | \$0 | 15 |
| 2 Ductwork | — | — | 425 | 0 | 30 |
| 3 Central absorption A/C | 1.85 tons | 850 \$/ton | 1,570 | 20 | 15 |
| 4 Gas water heater | 40 gal. | 225 ea. | 225 | 0 | 15 |
| TOTAL FOR BUILDING | | | \$2,895 | | \$20 |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}

[Conventional reference system is SF-7]

| | Escalation of conventional energy costs | | | | | |
|------------------------------------|---|--------|---------------------------|--------|----------------------------|--------|
| | Constant real energy prices | | Energy price escalation I | | Energy price escalation II | |
| 1. 1976 Startup | | | | | | |
| Total with no incentives | 122. | (138.) | 165. | (180.) | 233. | (249.) |
| Total with 20% IT | 122. | (138.) | 165. | (180.) | 233. | (249.) |
| Total with full incentives | 122. | (138.) | 165. | (180.) | 233. | (249.) |
| 2. 1985 Startup^d | | | | | | |
| (capital related cost) | 35. | (50.) | 35. | (50.) | 35. | (50.) |
| (operation & maintenance costs) | 3. | (3.) | 3. | (3.) | 3. | (3.) |
| (fuel bill) | 47. | (47.) | 97. | (97.) | 143. | (143.) |
| (electric bill) | 37. | (37.) | 53. | (53.) | 114. | (114.) |
| Total with no incentives | 122. | (138.) | 187. | (203.) | 295. | (310.) |
| Total with 20% IT | 122. | (138.) | 187. | (203.) | 295. | (310.) |
| Total with full incentives | 122. | (138.) | 187. | (203.) | 295. | (310.) |

C. EFFECTIVE COST OF ENERGY TO CONSUMER

(Conventional reference system is SF-7)

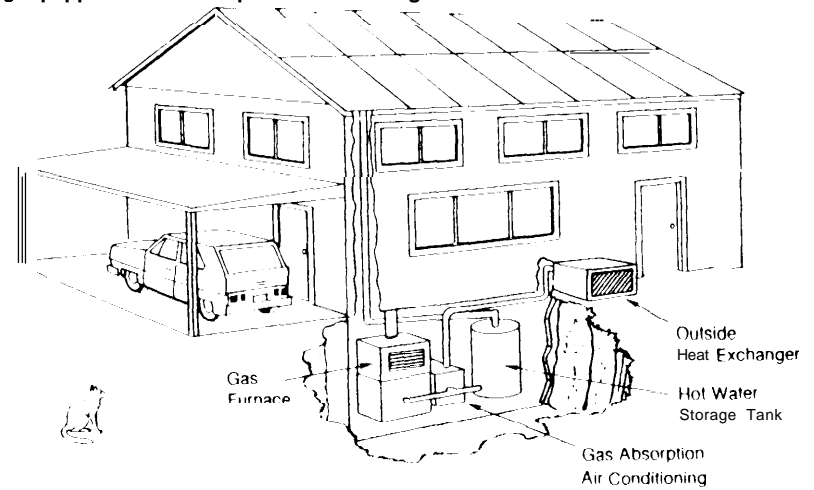
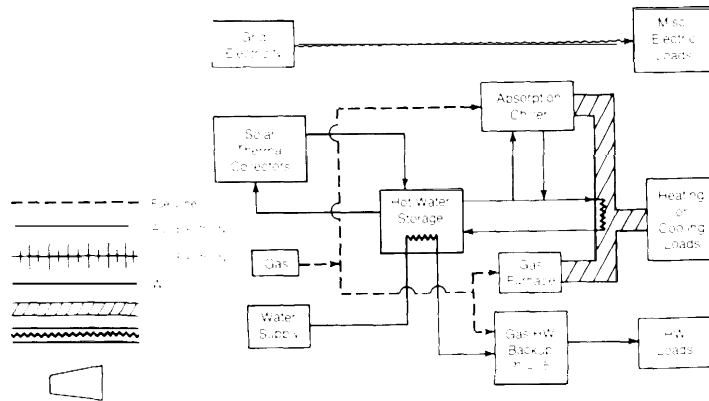
ANNUAL ENERGY FLOWS

[Conventional reference system is SF-7]

| | Energy consumed by ref. system | Backup consumed w/ solar/conservation | Energy saved (% of total) |
|--|--------------------------------|---------------------------------------|---------------------------|
| Net Electricity (bought-sold) (MWh/unit) | 8.0 | 8.0 | 0. |
| Fuel consumed onsite (MMBtu/unit) | 218. | 218. | 0. |
| Total energy requirement (bbl crude equiv.)^a | 65. | 65. | 0. |
| Electricity sold to grid annually (MWh, entire building) | | | 0. |
| Annual peak electricity demand (kW, entire building) | | | 3.5 |

| Levelized cost of solar energy or 'conservation' energy ^d | Type of incentives given | | | | | |
|--|-----------------------------|-------|---------------------------|-------|----------------------------|-------|
| | No incentive | | 20% ITC | | Full incentives | |
| \$ / MMBtu primary fuel | N/A | (N/A) | N/A | (N/A) | N/A | (N/A) |
| ¢ / kWh electricity | N/A | (N/A) | N/A | (N/A) | N/A | (N/A) |
| Levelized price paid for conventional energy^{b,*} | Constant real energy prices | | Energy price escalation I | | Energy price escalation II | |
| \$ / MMBtu primary fuel | 3.25 | | 4.87 | | 7.51 | |
| ¢ / kWh electricity | 3.82 | | 5.73 | | 8.84 | |

Table IV-14-Albuquerque: Solar Hot Water, Heating, and Cooling System—Single Family House Using Flat-Plate Collectors (1977 Prices); Low-Temperature Thermal Storage; Building Equipped With SF-7 Space-Conditioning



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl O&P) | Annual O & M | Life (yrs) |
|--|-------------------|-----------------------|-----------------------|---------------|------------|
| 1. Gas furnace.. | 45 MBtuh | 15\$ MBtuh | \$660 | \$0 | 15 |
| 2 Ductwork | | | 425 | 0 | 30 |
| 3. Absorption A/C. | 1.85 tons | 850 \$/ton | 1,570 | 20 | 15 |
| 4 Storage tank | 200 kWh | 2.05 \$/kWh | 410 | 0 | 30 |
| 5 Heat exchanger, pump, and controls | | | 650 | 0 | 10 |
| 6 Insulated steel pipe | 125 ft. | 4.1 \$/ft. | | 0 | 30 |
| 7 Flat plate solar collectors. | 45 m ² | 143 \$/m ² | 3218 | 0 | 30 |
| —Collector cost @ 95 \$/m ² | | | | | |
| —Installation @ 16 \$/m ² | | | | | |
| —Transportation @ 3 \$/m ² | | | | | |
| —Overhead and profit equals 25 percent | | | | | |
| TOTAL FOR BUILDING | | | \$13,729 | \$2000 | |

Installed collector cost assumed replaced in 15 yrs with total replacement in 10 yrs

ANNUAL ENERGY FLOWS

(Conventional reference system is SF-7)

| | Energy consumed by ref. system | Backup consumed w/ solar/conservation | Energy saved [% of total] |
|---|--------------------------------|---------------------------------------|---------------------------|
| Net Electricity (baught-said) (MWh/unit)..... | 8.0 | 8.0 | 80% |
| Fuel consumed onsite (MMBtu/unit)..... | 218. | 42. | 56.2 |
| Total energy requirement (bbl crude equiv.) ^a | 65. | 28. | |
| Electricity sold to grid annually (MWh, entire building)..... | | | 0. |
| Annual peak electricity demand (kW, entire building)..... | | | 3.5 |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}

(Conventional reference system is SF-7)

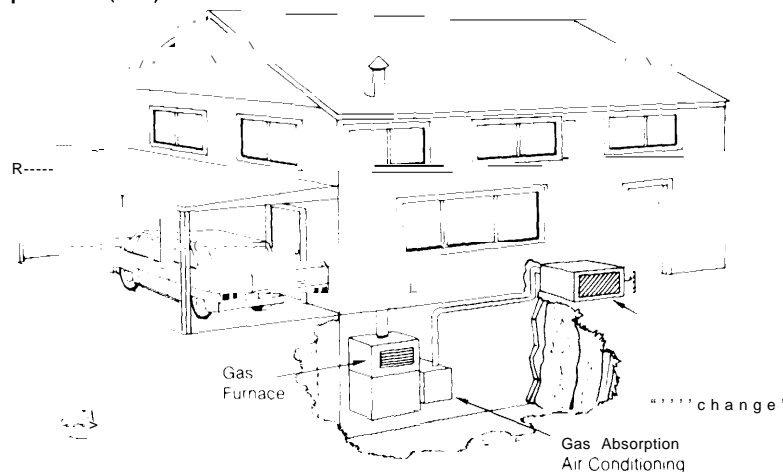
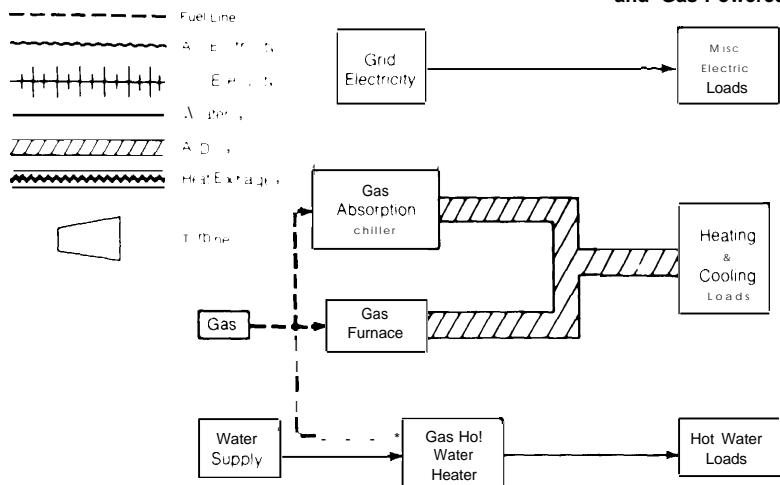
| | Escalation of conventional energy costs | | |
|---|---|---------------------------|----------------------------|
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| 1. 1976 Startup | | | |
| 0. Costs using solar (conservation) system: | | | |
| Total with no incentives..... | 167. (219.) | 183. (235.) | 228. (280.) |
| Total with 20% IT..... | 154. (208.) | 170. (224.) | 215. (269.) |
| Total with full incentives..... | 138. (173.) | 154. (189.) | 199. (234.) |
| b. Costs using conventional reference system..... | 122. | 165. | 233. |
| 2. 1985 Startup ^a | | | |
| a. Costs using solar (conservation) system: | | | |
| (capital related costs)..... | 117. (170.) | 117. (170.) | 117. (170.) |
| (operation & maintenance costs)..... | 3. (3.) | 3. (3.) | 3. (3.) |
| (fuel bill)..... | 9. (9.) | 19. (19.) | 28. (28.) |
| (electric bill)..... | 37. (37.) | 53. (53.) | 114. (114.) |
| Total with no incentives..... | 167. (219.) | 192. (244.) | 262. (314.) |
| Total with 20% IT..... | 154. (208.) | 179. (233.) | 249. (304.) |
| Total with full incentives..... | 138. (173.) | 163. (198.) | 233. (268.) |
| b. Costs using conventional reference system..... | 122. | 187. | 295. |

C. EFFECTIVE COST OF ENERGY TO CONSUMER

(Conventional reference system is SF-7)

| Levelized cost of solar energy or "conservation" energy ^a | Type of incentives given | | |
|--|--------------------------|-------------|-----------------|
| | No incentives | 20% ITC | Full incentives |
| \$/MMBtu primary fuel..... | 5.64 (9.21) | 4.78 (8.48) | 3.66 (6.05) |
| ¢/kWh electricity..... | 6.63 (10.83) | 5.63 (99B) | 4.31 (7.12) |
| Levelized price paid for conventional energy ^{b*} | | | |
| \$/MMBtu primary fuel..... | 3.25 | 4.87 | 7.51 |
| ¢/kWh electricity..... | 3.82 | 5.73 | 8.84 |

Table IV-16.—Albuquerque: Conventional System— Insulated Single Family House With Gas Heat, Hot Water, and Gas-Powered Absorption A/C (IF-7)



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O&P) | Annual O & M | Life (yrs) |
|--|-----------|--------------|------------------------|--------------|------------|
| 1. Gas furnace | 31 MBtu/h | 15 \$/MBtu/h | \$465 | 0 | 15 |
| 2. Ductwork | | | 425 | 0 | 30 |
| 3. Central absorption a/c | 1.3 tons | 850 \$/ton | 1,100 | \$20 | 15 |
| 4. Gas water heater | 40 gal. | 225 ea. | 225 | 0 | 15 |
| 5. Extra insulation, storm doors and windows | | | 981 | 0 | 30 |
| TOTAL FOR BUILDING | | | \$3,196 | \$20 | |
| TOTAL PER UNIT | | | \$3,196 | \$20 | |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}

(Conventional reference system is IF-7)

| | Escalation of conventional energy costs | | | |
|------------------------------------|---|---------------------------|----------------------------|--|
| | Constant real energy prices | Energy price escalation I | Energy price escalation II | |
| 1. 1976 Startup | | | | |
| Total with no incentives | 110. (126.) | 145. (161.) | 206. (222.) | |
| Total with 20% ITC | 110. (126.) | 145. (161.) | 206. (222.) | |
| Total with full incentives | 110. (126.) | 145. (161.) | 206. (222.) | |
| 2. 1985 Startup^d | | | | |
| (capital related costs) | 34. (49.) | 34. (49.) | 34. (49.) | |
| (operation & maintenance costs) | 3. (3.) | 3. (3.) | 3. (3.) | |
| (fuel bill) | 37. [37.] | 75. (75.) | 111. (111.) | |
| (electric bill) | 37. [37.] | 52. (52.) | 112. (112.) | |
| Total with no incentives | 110. (126.) | 163. (179.) | 264. (276.) | |
| Total with 20% ITC | 110. (126.) | 163. (179.) | 260. (276.) | |
| Total with full incentives | 110. (126.) | 163. (179.) | 260. (276.) | |

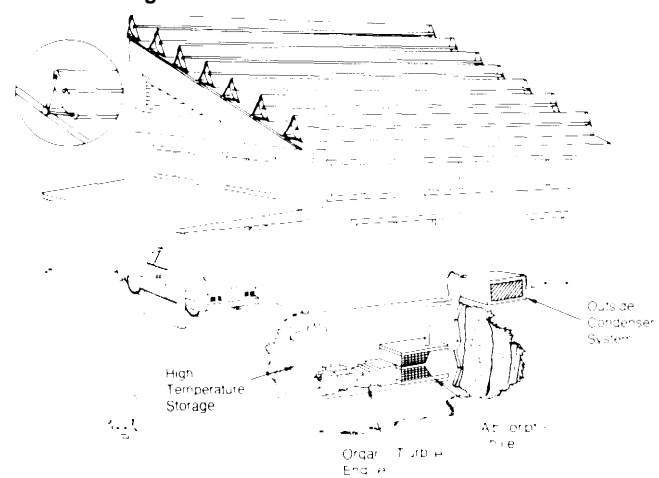
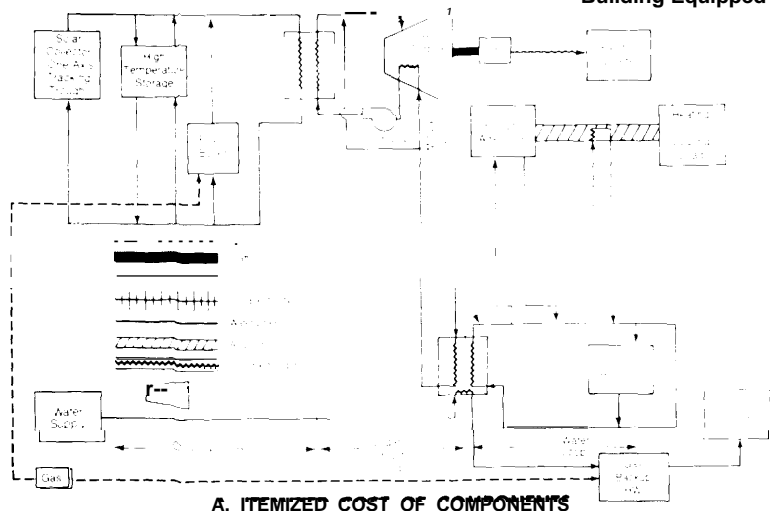
C. EFFECTIVE COST OF ENERGY TO CONSUMER

(Conventional reference system is IF--)

| ANNUAL ENERGY FLOWS (Conventional reference system is IF-7) | | | |
|---|--------------------------------|---------------------------------------|---------------------------|
| | Energy consumed by ref. system | Backup consumed w/ solar/conservation | Energy saved (% of total) |
| Net Electricity (bought-sold) (MWh/unit) | 7.8 | 7.8 | 0 |
| Fuel consumed onsite (MMBtu/unit) | 169. | 169. | 0. |
| Total energy requirement (bbi crude equiv.) ^a | 54. | 54. | 0. |
| Electricity sold to grid annually (MWh, entire building) | | | 0. |
| Annual peak electricity demand (kW, entire building) | | | 3.4 |

| Levelized cost of solar energy or 'conservatism' energy ^c | Type of incentives given | | |
|--|---|---------------------------|----------------------------|
| | No incentives | 20% ITC | Full incentive |
| \$/MMBtu primary fuel | N/A (N/A) | N/A (N/A) | N/A (N/A) |
| ¢/kWh electricity | N/A (N/A) | N/A (N/A) | N/A (N/A) |
| Levelized price paid for conventional energy ^{b,*} | Escalation of conventional energy costs | | |
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| \$/MMBtu primary fuel | 3.37 | 4.97 | 7.79 |
| ¢/kWh electricity | 3.96 | 5.84 | 9.17 |

Table IV-1 8.—Albuquerque: Solar Heat Engine Cogeneration System—Insulated Single Family House Using ORCS With Cooling Tower, One-Axis Tracking Collector (Possible Future Design), High-Temperature Thermal Storage, Gas Backup; Building Equipped With IF-7 Space-Conditioning



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl O&P) | Annual O&M (y IS) | Life |
|---|-------------------|-----------------------|-----------------------|-------------------|------|
| 1. One axis E-W tracking collector | 46 m ² | 129 \$/m ² | \$.2970 | 0 | 30 |
| —Collector @ 80 \$/m ² | | | .2970 | | 0 15 |
| —Installation @ 20\$ m ² | | | | | |
| —Shipping @ 3\$/m ² | | | | | |
| —overhead and profit 25% | | | | | |
| 2 High temperature oil storage | 80 kWh | 19 \$/kWh | 1,520 | 0 | 30 |
| 3. Fossil boiler-cast iron | 21.7 kW | 47 \$/kW | 1,000 | 0 | 15 |
| 4 Absorption a/c | 1.4 tons | 850 \$/ton | 1,200 | \$20 | 10 |
| 5 Water-to-air heat exchanger | 9 kW | 10 \$/kW | 90 | 0 | 15 |
| 6. Insulated steel pipe | 125 ft | 4.1 \$/ft | 513 | 0 | 30 |
| 7 Heat exchanger, pumps and controls | — | — | 500 | 0 | 10 |
| 8. Ductwork | — | — | 425 | 0 | 30 |
| 9. Extra insulation, storm doors and windows | — | — | 981 | 0 | 30 |
| 10. Organic turbine (installed with cooling tower, controls, and high temp heat exchanger, and generator. | 4.3 kW | 490 \$/kW | 2,110 | 30 | 15 |
| TOTAL FOR BUILDING | | | \$14,279 | \$50 | |
| TOTAL PER UNIT | | | \$14,279 | \$50 | |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b, c}
(Conventional reference system is IF-7)

| | Escalation of conventional energy costs | | |
|---|---|---------------------------|----------------------------|
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| 1. 1976 Startup | | | |
| a. Costs using solar (conservation) system: | | | |
| Total with no incentives | 183. (255.) | 196. (268.) | 207. (279.) |
| Total with 20% ITC | 166. (240.) | 178. (253.) | 189. (264.) |
| Total with full incentives | 125. (189.) | 138. (202.) | 149. (213.) |
| b. Costs using conventional reference system | 110. | 14.5. | 206. |
| 2. 1985 Startup^d | | | |
| a. Costs using solar (conservation) system: | | | |
| (capital related costs) | 158. (230.) | 158. (230.) | 158. (230.) |
| (operation & maintenance costs) | 7. (7.) | 7. (7.) | 7. (7.) |
| (fuel bill) | 18. (18.) | 37. (37.) | 55. (55.) |
| (electric bill) | 0. (0.) | 0. (0.) | 0. (0.) |
| Total with no incentives | 183. (255.) | 203. (275.) | 221. (292.) |
| Total with 20% ITC | 166. (240.) | 185. (259.) | 203. (277.) |
| Total with full incentives | 125. (189.) | 144. (209.) | 162. (227.) |
| b. Costs using conventional reference system | 110. | 14.5. | 206. |

C. EFFECTIVE COST OF ENERGY TO CONSUMER
(Conventional reference system is IF-7)

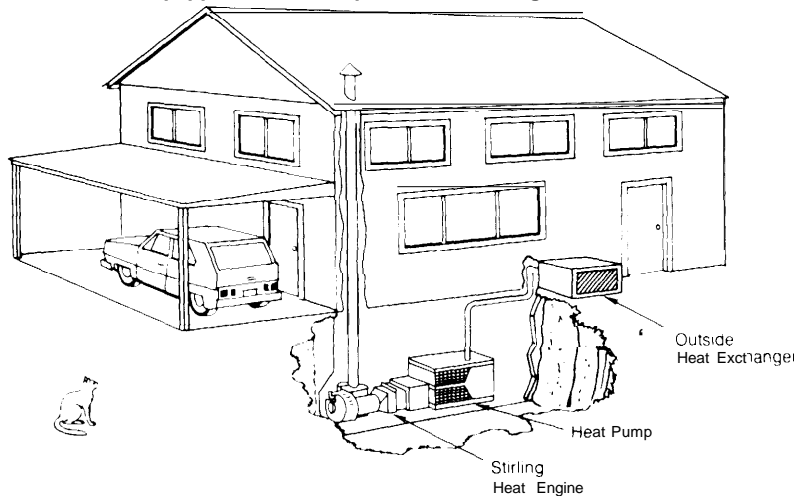
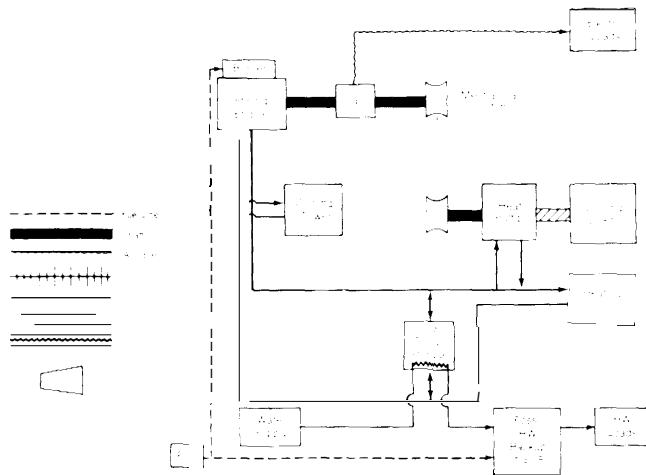
| Levelized cost of solar energy or "conservation" energy ^a | Type of incentive given | | |
|--|-----------------------------|---------------------------|----------------------------|
| | No incentives | 20% ITC | Full incentives |
| \$/MMBtu primary fuel | 8.72 [13.58] | 7.51 [12.55] | 4.77 (9.12) |
| ¢/kWh electricity | 10.26 [15.99] | 8.84 [14.77] | 5.62 (10.74) |
| Levelized price paid for conventional energy^{b, c} | | | |
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| \$/MMBtu primary fuel | 3.37 | 4.97 | 7.79 |
| ¢/kWh electricity | 3.96 | 5.84 | 9.77 |

^a, installed collector cost assumed replaced in 1.5 yrs with total replacement in 30 yrs

ANNUAL ENERGY FLOWS (Conventional reference System is IF-7)

| | Energy consumed by ref. system | Backup consumed w/ solar/conservation | Energy saved (% of total) |
|--|--------------------------------|---------------------------------------|---------------------------|
| Net Electricity (bought-sold) (MWh/unit) | 7.8 | 0. | 100.0 |
| Fuel consumed on site (MMBtu/unit) | 169. | 84. | 50.3 |
| Total energy requirement (bbl crude equiv.) | 54. | 17. | 67.8 |
| Electricity sold to grid annually (MWh, entire building) | | | 0. |
| Annual peak electricity demand (kW, entire building) | | | 0. |

Table IV-20.—Albuquerque: Conventional Heat Engine Cogeneration System— Insulated Single Family House Using Stirling Engine (Low Efficiency) Direct-Drive Heat Pump, Gas Hot Water; Building Equipped With IF-9 Space Conditioning



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O&P) | Annual O & M | Life (yrs) |
|---|-----------|------------|------------------------|--------------|------------|
| 1. Heat Pump..... | 1.30 tons | 800 \$/ton | \$1,040 | \$50 | 10 |
| 2. Ductwork..... | — | — | 425 | 0 | 30 |
| 3. Low temperature hot water storage..... | 50 kWh | 2 \$/kW | 100 | 0 | 30 |
| 4. Fossil water heater..... | 40 gal | 225 eo. | 225 | 0 | 15 |
| 5. Stirling engine ($\eta=0.32$)..... | 7.2 kW | 188 \$/kW | 1,360 | 100 | 10 |
| —Engine (less generator) @ 150 \$/kW | | | | | |
| —Overhead and profit @ 25% | | | | | |
| 6. Generator..... | .55kW | 37 \$/kW | 204 | 0 | 10 |
| 7. Heat exchanger..... | — | 33\$ ea. | 33 | 0 | 30 |
| 8. Extra insulation, storm doors and windows..... | — | — | 981 | 0 | 30 |
| TOTAL..... | | | \$4,358 | \$150 | |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}
(Conventional reference system is IF-7)

| | Escalation of conventional energy costs | | | | | |
|---|---|--------|---------------------------|--------|----------------------------|--------|
| | Constant real energy prices | | Energy price escalation I | | Energy price escalation II | |
| 1. 1976 Startup | | | | | | |
| a. Costs using solar (conservation) system: | | | | | | |
| Total with no incentives..... | 113. | (137.) | 135. | (158.) | 154. | (177.) |
| Total with 20% ITC..... | 111. | (136.) | 133. | (157.) | 152. | (176.) |
| Total with full incentives..... | 107. | (130.) | 128. | (151.) | 147. | (171.) |
| b. Costs using conventional reference system..... | 110. | | 145. | | 206 | |
| 2. 1985 Startup^d | | | | | | |
| a. Costs using solar (conservation) system: | | | | | | |
| (capital related costs)..... | 60. | [84.] | 60. | [84.] | 60. | [84.] |
| (operation & maintenance costs)..... | 22. | (22.) | 22. | (22.) | 22. | (22.) |
| (fuel bill)..... | 31. | (31.) | 63. | (63.) | 93. | (93.) |
| (electric bill)..... | 0. | (0.) | 0. | (0.) | 0. | (0.) |
| Total with no incentives..... | 113. | (137.) | 146. | (170.) | 176. | (200.) |
| Total with 20% ITC..... | 111. | (136.) | 144. | (168.) | 174. | (198.) |
| Total with full incentives..... | 107. | (130.) | 140. | (163.) | 170. | (193.) |
| b. Costs using conventional reference system..... | 110. | | 163. | | 260. | |

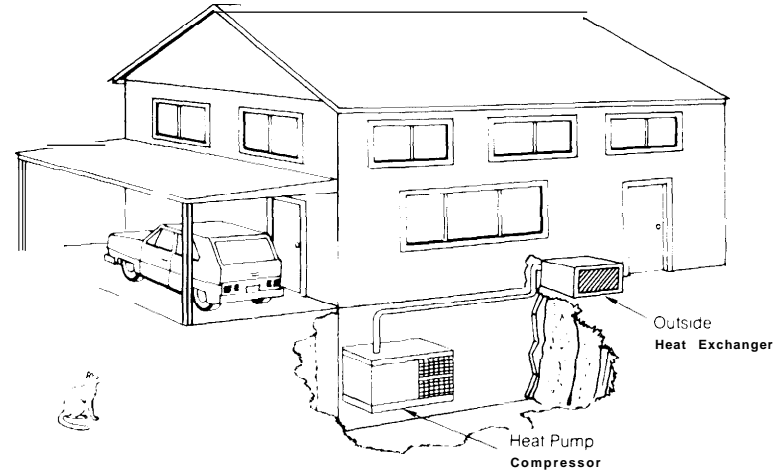
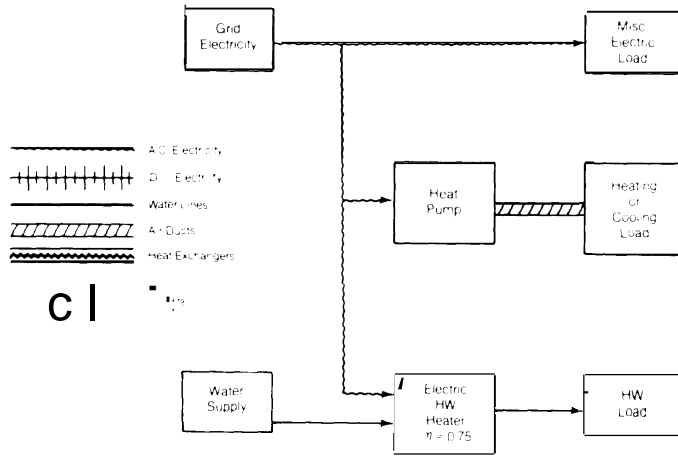
C. EFFECTIVE COST OF ENERGY TO CONSUMER
(Conventional reference system is IF-7)

ANNUAL ENERGY FLOWS (Conventional reference system is IF-7)

| | Energy consumed by ref. system | Backup consumed w/ solar/conservation | Energy saved (% of total) |
|--|--------------------------------|---------------------------------------|---------------------------|
| Net Electricity (bought-sold) (MWh/unit)..... | 7.8 | 0. | 100.0 |
| Fuel consumed on site (MMBtu/unit)..... | 169. | 142. | 16.1 |
| Total energy requirement (bbl crude equiv.) ^a | 54. | 30. | 45.6 |
| Electricity sold to grid annually (MWh, entire building)..... | | | 0. |
| Annual peak electricity demand (kW, entire building)..... | | | 0. |

| Levelized cost of solar energy or conservation energy ^a | Type of incentives given | | |
|--|-----------------------------|---------------------------|----------------------------|
| | No incentives | 20% ITC | Full incentives |
| \$/MMBtu primary fuel..... | 4.63 (7.04) | 4.45 (6.88) | 4.02 (6.34) |
| ¢/kWh electricity..... | 5.45 (8.28) | 5.23 (8.09) | 4.73 (7.46) |
| Levelized price paid for conventional energy^{b,c} | | | |
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| \$/MMBtu primary fuel..... | 3.37 | 4.97 | 7.79 |
| ¢/kWh electricity..... | 3.96 | 5.84 | 9.17 |

Table IV-21.—Albuquerque: Conventional System—All Electric Single Family House Using Heat Pump Heating (SF-2)



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O&P) | Annual O&M | Life (yrs) |
|--------------------------|-----------|------------|------------------------|-------------|------------|
| 1. Heat pump | .185 tons | 800 \$/ton | \$1,480 | \$50 | 10 |
| 2. Ductwork | — | — | 425 | 0 | 30 |
| 3. Electric water heater | 40 gal | 225 ea. | 225 | 0 | 15 |
| TOTAL | | | \$2,130 | \$50 | |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}

[Conventional reference system is SF-2]

| | Escalation of conventional energy costs | | | | | |
|------------------------------------|---|--------|---------------------------|--------|----------------------------|--------|
| | Constant real energy prices | | Energy price escalation I | | Energy price escalation II | |
| 1. 1976 Startup | | | | | | |
| Total with no incentive | 156. | (169.) | 186. | (199.) | 310. | (322.) |
| Total with 20% IT | 156. | (169.) | 186. | (199.) | 310. | (322.) |
| Total with full incentives | 156. | (169.) | 186. | (199.) | 310. | (322.) |
| 2. 1985 Startup^d | | | | | | |
| (capital related costs) | 32. | (44.) | 32. | (44.) | 32. | (44.) |
| (operation & maintenance costs) | 7. | (7.) | 7. | (7.) | 7. | (7.) |
| (fuel bill) | 0. | (0.) | 0. | (0.) | 0. | (0.) |
| (electric bill) | 117. | (117.) | 164. | (164.) | 355. | (355.) |
| Total with no incentives | 156. | (169.) | 203. | (216.) | 395. | (407.) |
| Total with 20% IT | 156. | (169.) | 203. | (216.) | 395. | (407.) |
| Total with full incentives | 156. | (169.) | 203. | (216.) | 395. | (407.) |

C. EFFECTIVE COST OF ENERGY TO CONSUMER

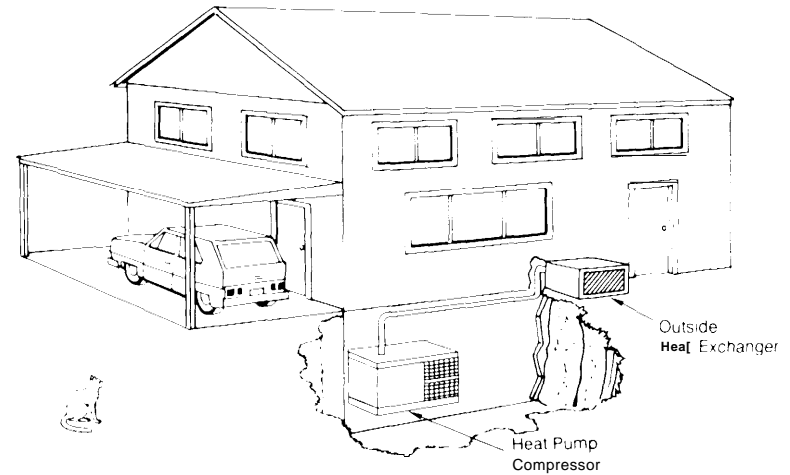
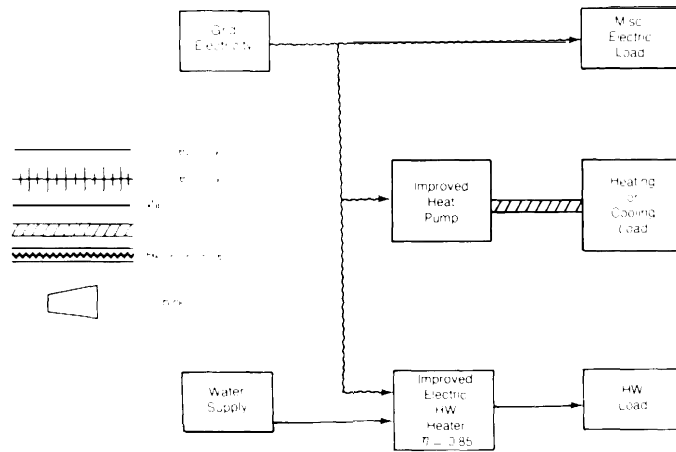
(Conventional reference system is SF-2)

ANNUAL ENERGY FLOWS (Conventional reference system is SF-2)

| | Energy consumed by ref. system | Backup consumed w/ solar/conservation | Energy saved (% of total) |
|--|--------------------------------|---------------------------------------|---------------------------|
| Net Electricity (bought-sold) (MWh/unit) | 32.5 | 32.5 | 0. |
| Fuel consumed onsite (MMBtu/unit) | 0. | 0. | 0. |
| Total energy requirement (bbl crude equiv.) ^a | 79. | 79. | 0. |
| Electricity sold to grid annually (MWh, entire building) | | | 0. |
| Annual peak electricity demand (kW, entire building) | | | 25.6 |

| Levelized cost of solar energy or "conservation" energy ^b | Type of incentives given | | | |
|--|--|-------|---------------------------|-------|
| | No incentives | | Full incentives | |
| \$/MMBtu primary fuel | N/A | (N/A) | N/A | (N/A) |
| ¢/kWh electricity | N/A | (N/A) | N/A | (N/A) |
| Levelized price paid for conventional energy^{b,c} | Escalation of conventional energy costs | | | |
| | Constant real energy prices | | Energy price escalation I | |
| \$/MMBtu primary fuel | 3.66 | 4.61 | 4.61 | 8.47 |
| ¢/kWh electricity | 4.31 | 5.42 | 5.42 | 9.97 |

Table IV.22.—Albuquerque: Conventional System—All Electric Single Family House Using Improved Heat Pump Heating (High Price) (SF-2)



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O&P) | Annual O & M | Life (yrs) |
|-------------------------------|-----------|--------------|------------------------|--------------|------------|
| 1. Heat pump..... | 1.85 tons | 1,440 \$/ton | \$2,660 | \$50 | 10 |
| 2. Ductwork..... | — | — | 425 | 0 | 30 |
| 3. Electric water heater..... | 40 gal | 225 ea. | 225 | 0 | 15 |
| TOTAL..... | | | \$3,310 | \$50 | |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}

(Conventional reference system is SF-2)

| | Escalation of conventional energy costs | | |
|--|---|---------------------------|----------------------------|
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| 1. 1976 Startup | | | |
| a. Costs using solar (conservation) system: | | | |
| Total with no incentives..... | 162. (181.) | 188. (208.) | 295. (315.) |
| Total with 20% IT..... | 160. (180.) | 186. (206.) | 293. (313.) |
| Total with full incentives..... | 155. (174.) | 182. (201.) | 289. (308.) |
| b. Costs using conventional reference system..... | 156. | 186. | 370. |
| 2. 1985 Startup^a | | | |
| 0. Costs using solar (conservation) system: | | | |
| (capital related costs)..... | 53. (73.) | 53. (73.) | 53. (73.) |
| (operation & maintenance costs)..... | 7. (7.) | 7. (7.) | 7. (7.) |
| (fuel bill)..... | 0. (0.) | 0. (0.) | 0. (0.) |
| (electric bill)..... | 101. (101.) | 142. (142.) | 309. (309.) |
| Total with no incentives..... | 162. (181.) | 203. (222.) | 369. (389.) |
| Total with 20% IT..... | 160. (180.) | 201. (221.) | 367. (387.) |
| Total with full incentives..... | 155. (174.) | 196. (215.) | 363. (382.) |
| b. Costs using conventional reference system..... | 156. | 203. | 395. |

C. EFFECTIVE COST OF ENERGY TO CONSUMER

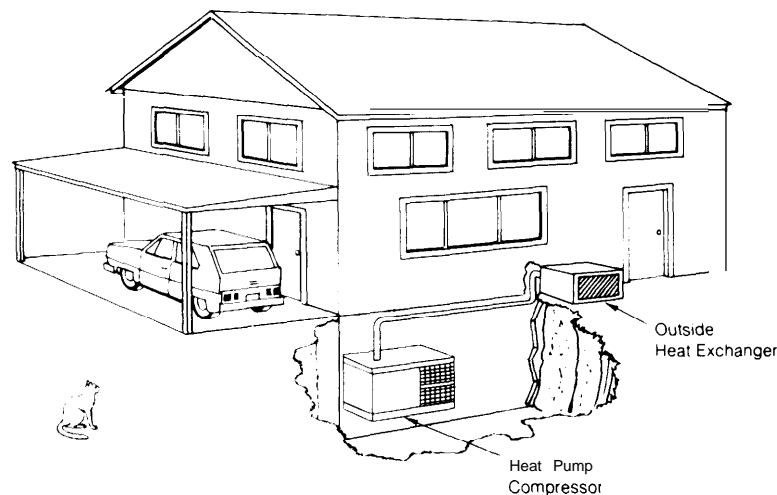
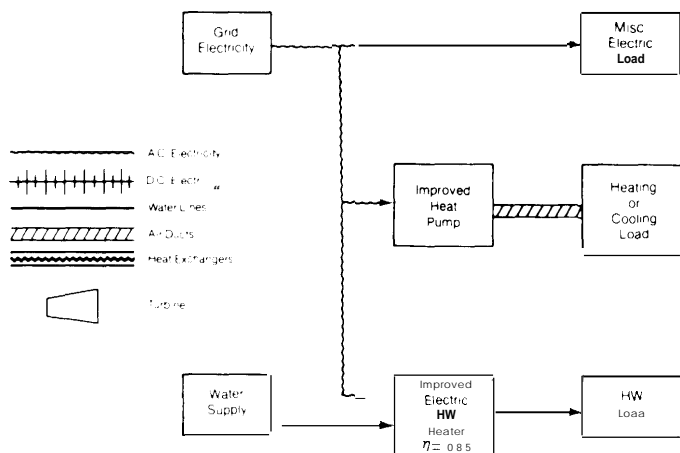
(Conventional reference system is SF-2)

ANNUAL ENERGY FLOWS (Conventional reference system is SF-21)

| | Energy consumed by ref. system | Backup consumed w/ solar/conservation | Energy saved ("%" of total) |
|--|--------------------------------|---------------------------------------|-----------------------------|
| Net Electricity (bought-sold) (MWh/unit)..... | 32.5 | 27.8 | 14.5 |
| Fuel consumed on site (MMBtu/unit)..... | 0. | 0. | 0. |
| Total energy requirement (bbl crude equiv.) ^a | 79. | 68. | 14.5 |
| Electricity sold to grid annually (MWh, entire building)..... | | | 0. |
| Annual peak electricity demand (kW, entire building)..... | | | 25.6 |

| Levelized cost of solar energy or conservation energy ^a | Type of incentives given | | |
|--|-----------------------------|---------------------------|----------------------------|
| | No incentives | 20% ITC | Full incentives |
| \$/MMBtu primary fuel..... | 4.48 (8.77) | 4.06 (8.42) | 3.13 (7.25) |
| ¢/kWh electricity..... | 5.27 (10.32) | 4.78 (9.91) | 3.69 (8.54) |
| Levelized price paid for conventional energy^{b,c} | | | |
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| \$/MMBtu primary fuel..... | 3.66 | 4.61 | 8.47 |
| ¢/kWh electricity..... | 4.31 | 5.42 | 9.97 |

Table IV-23.—Albuquerque: Conventional System—All Electric Single Family House Using Improved Heat Pump Heating (Low Price) (SF-2)



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O&P) | Annual O & M | Life (yrs) |
|--------------------------|-----------|------------|------------------------|--------------|------------|
| 1. Heat pump | 1.85 tons | 960 \$/ton | \$1,780 | \$50 | 10 |
| 2. Ductwork | — | — | 425 | 0 | 30 |
| 3. Electric water heater | 40 gal | 225 ea. | 225 | 0 | 15 |
| TOTAL | | | \$2,430 | \$50 | |

ANNUAL ENERGY FLOWS

(Conventional reference system is SF-2)

| | Energy consumed by ref. system | Backup consumed w/ solar/conservation | Energy saved (% of total) |
|--|--------------------------------|---------------------------------------|---------------------------|
| Net Electricity (bought-sold) (MWh/unit) | 32.5 | 27.8 | 14.5 |
| Fuel consumed onsite (MMBtu/unit) | 0 | 0 | 0 |
| Total energy requirement (bbl/crude equiv.) ^a | 79 | 68 | 14.5 |
| Electricity sold to grid annually (MWh, entire building) | | | 0 |
| Annual peak electricity demand (kW, entire building) | | | 25.6 |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}

(Conventional reference system is SF-2)

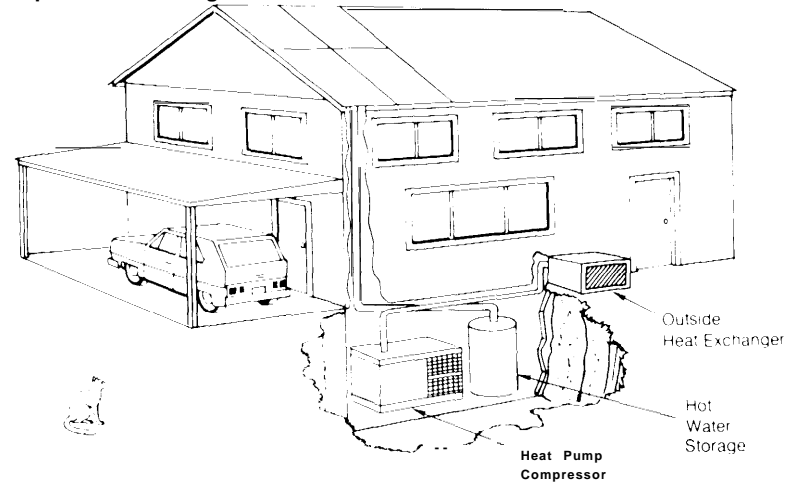
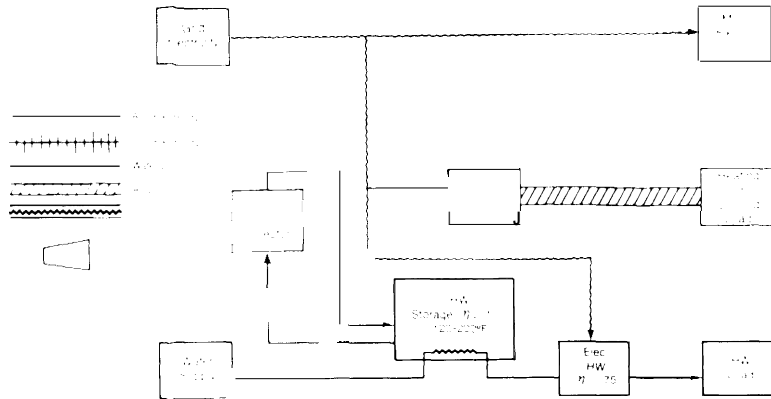
| | Escalation of conventional energy costs | | | | | |
|---|---|--------|---------------------------|--------|----------------------------|--------|
| | Constant real energy prices | | Energy price escalation I | | Energy price escalation II | |
| 1. 1976 Startup | | | | | | |
| a. Costs using solar (conservation) system: | | | | | | |
| Total with no incentives | 147. | (160.) | 173. | (187.) | 280. | (294.) |
| Total with 20% ITC | 146. | (160.) | 172. | (186.) | 279. | (293.) |
| Total with full incentives | 145. | (159.) | 172. | (185.) | 279. | (292.) |
| b. Costs using conventional reference system | 157. | | 187. | | 310. | |
| 2. 1985 Startup^d | | | | | | |
| a. Costs using solar (conservation) system: | | | | | | |
| (capital related costs) | 38. | (52.) | 38. | (52.) | 38. | (52.) |
| (operation & maintenance costs) | 7. | (7.) | 7. | (7.) | 7. | (7.) |
| (fuel bill) | 0. | (0.) | 0. | (0.) | 0. | (0.) |
| (electric bill) | 101. | (101.) | 142. | (142.) | 309. | (309.) |
| Total with no incentives | 147. | (160.) | 187. | (201.) | 354. | (368.) |
| Total with 20% ITC | 146. | (160.) | 187. | (201.) | 353. | (367.) |
| Total with full incentives | 145. | (159.) | 186. | (200.) | 353. | (366.) |
| b. Costs using conventional reference system | 157. | | 204. | | 395. | |

C. EFFECTIVE COST OF ENERGY TO CONSUMER

(Conventional reference system is SF-2)

| Levelized cost of solar energy or 'conservation' energy ^c | Type of incentives given | | |
|--|--|---------------------------|----------------------------|
| | No incentives | 20% ITC | Full incentives |
| \$/MMBtu primary fuel | 1.15 (4.16) | 1.04 (4.07) | .90 (3.78) |
| ¢/kWh electricity | 1.35 (4.90) | 1.23 (4.50) | 1.06 (4.45) |
| Levelized price paid for conventional energy^{b,*} | Escalation of conventional energy costs | | |
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| \$/MMBtu primary fuel | 3.66 | 4.61 | 8.47 |
| ¢/kWh electricity | 4.31 | 5.42 | 9.97 |

Table IV-24 .—Albuquerque: Solar Hot Water System—Single Family House Using Flat-Plate Collectors (1977 Prices); Building Equipped With SF-2 Space-Conditioning



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O&P) | Annual O&M | Life (yrs) |
|---|-------------------|-----------------------|------------------------|-------------|------------|
| 1 Heat pump | 1.85 tons | 800 \$/tons | \$1,480 | 50 | 10 |
| 2 Ducting | — | — | 425 | 0 | 30 |
| 3 Hot water storage with electric backup (including heat exchanger) | 100 gal | \$355 | 355 | 0 | 30 |
| 4 Pumps and controls | — | \$250 | 250 | 0 | 10 |
| 5 Insulated steel pipe | 75 ft | \$2.6/ft | 195 | 0 | 30 |
| 6 Flat plate solar collectors | 10 m ² | 143 \$/m ² | ● 715 | 0 | 15 |
| — Collector cost @ 95 \$/m ² | | | | | |
| — Installation @ 16 \$/m ² | | | | | |
| — Transportation @ \$3/m ² | | | | | |
| — Overhead and profit= 25% | | | | | |
| TOTAL | | | \$4,135 | \$50 | |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}

(Conventional reference system is SF-2)

| | Escalation of conventional energy costs | | |
|---|---|---------------------------|----------------------------|
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| 1. 1976 Startup | | | |
| a. Costs using solar (conservation) system: | | | |
| Total with no incentives | 147. | (169.) | 261. |
| Total with 20% IT | 144. | (166.) | 258. |
| Total With full incentives | 140. | (157.) | 254. |
| b. Costs using conventional reference system | 157. | 187. | 310. |
| 2. 1985 Startup^a | | | |
| 0. Costs using solar (conservation) system: | | | |
| (capital related costs) | 53. | (74.) | 53. |
| (operation & maintenance costs) | 7. | (7.) | 7. |
| (fuel bill) | 0. | (0.) | 0. |
| (electric bill) | 87. | (87.) | 122. |
| Total with no incentives | 147. | (169.) | 264. |
| Total with 20% IT | 144. | (166.) | 264. |
| Total with full incentives | 140. | (157.) | 254. |
| b. Costs using conventional reference system | 157. | 204. | 395. |

C. EFFECTIVE COST OF ENERGY TO CONSUMER

(Conventional reference system is SF-2)

| Levelized cost of solar energy or conservation energy ^a | Type of incentive given | | |
|--|-------------------------|-------------|-----------------|
| | No incentives | 20% ITC | Full incentive! |
| \$/MMBtu primary fuel | 2.30 (4.65) | 1.94 (4.34) | 1.47 (3.33) |
| ¢/kWh electricity | 2.70 (5.47) | 2.28 (5.11) | 1.73 (3.92) |
| Levelized price paid for conventional energy^{b,*} | | | |
| \$/MMBtu primary fuel | 3.66 | 4.61 | 8.47 |
| ¢/kWh electricity | 4.31 | 5.42 | 9.97 |

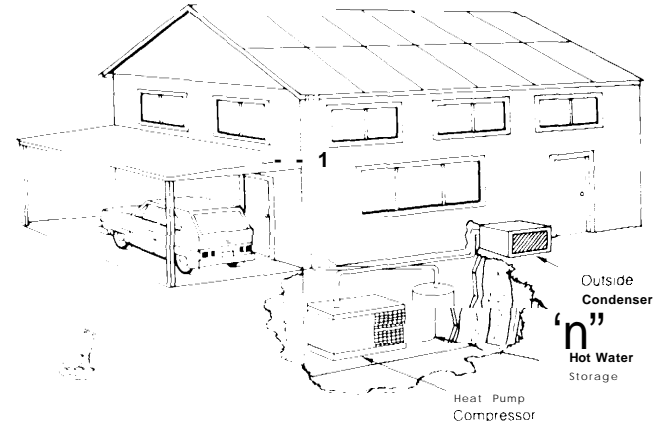
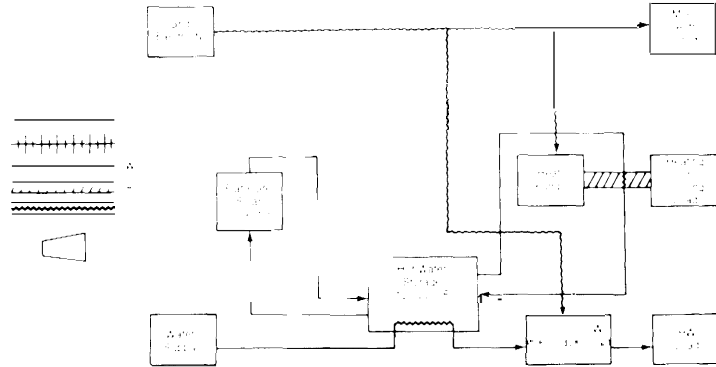
^a 1/2 installed collector cost assumed replaced in 15 yrs., with total replacement in 30 yrs.

ANNUAL ENERGY FLOWS

(Conventional reference system is SF-2)

| | Energy consumed by ref. system | Backup consumed solar/conservation | w/ Energy saved (% of total) |
|--|--------------------------------|------------------------------------|------------------------------|
| Net Electricity (bought-sold) (MWh/unit) | 32.5 | 23.3 | 28.4 |
| Fuel consumed onsite (MMBtu/unit) | 0. | 0. | 0. |
| Total energy requirement (bbl crude equiv.) ^a | 79. | 57. | 28.4 |
| Electricity sold to grid annually (MWh, entire building) | | | 0. |
| Annual peak electricity demand (kW, entire building) | | | 27.3 |

Table IV-26.—Albuquerque: Solar Hot Water and Heating System—Single Family House Using Flat-Plate Collectors (1977 Prices); Building Equipped With SF-2 Space-Conditioning



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O&P) | Annual O & M | Life (yrs) |
|---------------------------------------|-------------------|-----------------------|------------------------|--------------|------------|
| 1 Heat pump | 1.85 tons | 800 \$/ton | \$1,480 | \$50 | 10 |
| 2 Ductwork | — | — | 425 | 0 | 30 |
| 3 Collectors and associated costs | 30 m ² | 143 \$/m ² | * 2,145 | 0 | 30 |
| —Collector! @ 95 \$/m ² | | | " 2,145 | 0 | 15 |
| —Installation @ 16 \$/m ² | | | | | |
| —Transportation @ 3 \$/m ² | | | | | |
| —25% overhead and profit | | | | | |
| 4. 1. insulated steel pipe | 125 ft | 4.1 \$/ft | 513 | 0 | 30 |
| 5 Storage (without plumbing) | 200 kWh | 205 \$/kWh | 410 | 0 | 30 |
| 6 Pumps, controls, and heat exchanger | — | — | 650 | 0 | 10 |
| TOTAL FOR BUILDING | | | \$7,768 | \$50 | |
| TOTAL PER UNIT | | | \$7,768 | \$50 | |

* 1/2 installed collector cost assumed replaced in 15 yrs with total replacement in 30 yrs.

ANNUAL ENERGY FLOWS

(Conventional reference system is SF-2)

| | Energy consumed by ref. system | Backup consumed solar/conservation | Energy saved (% of total) |
|---|--------------------------------|------------------------------------|---------------------------|
| Net Electricity (bought/sold)(MWh/unit)..... | 32.5 | 19.0 | 41.4 |
| Fuel consumed onsite(MMBtu/unit)..... | 0. | 0. | 0. |
| Total energy requirement (bbl crude equiv.) ^a .. | 79. | 47. | 41.4 |
| Electricity sold to grid(annually)(MWh, entire building)..... | | | 0. |
| Annual peak electricity demand(kW, entire building)..... | | | 25.6 |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{bc}

(Conventional reference system is SF-2)

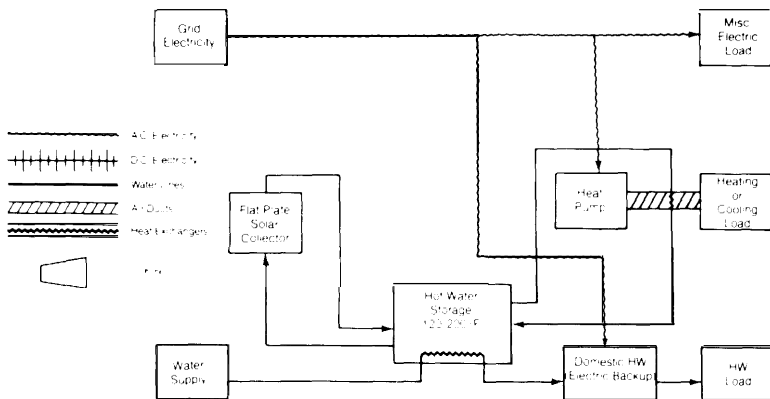
| | Escalation of conventional energy costs | | |
|---|---|---------------------------|----------------------------|
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| 1. 1976 Startup | | | |
| a. Costs using solar (conservation) system: | | | |
| Total with no incentives | 172. | (212.) | 191. |
| Total with 20% ITC..... | 163. | (204.) | 182. |
| Total with full incentives | 143. | (179.) | 162. |
| b. Costs using conventional reference system | 156. | 186. | 310. |
| 2. 1985 Startup^a | | | |
| a. Costs using solar (conservation) system: | | | |
| (capital related costs) | 92. | (132.) | 92. |
| (operation & maintenance costs) | 7. | (7.) | 7. |
| (fuel bill) | 0. | (0.) | 0. |
| (electric bill) | 73. | (73.) | 103. |
| Total with no incentives | 172. | (212.) | 202. |
| Total with 20% ITC..... | 163. | (204.) | 193. |
| Total with full incentives | 143. | (179.) | 172. |
| b. Costs using conventional reference system | 156. | 203. | 395. |

C. EFFECTIVE COST OF ENERGY TO CONSUMER

(Conventional reference system is SF-2)

| Levelized cost of solar energy or 'conservation' energy ^c | Type of incentives given | | |
|--|---|---------------------------|----------------------------|
| | No incentives | 20% ITC | Full incentives |
| \$/MMBtu primary fuel..... | 4.52 | (7.53) | 3.83 |
| ¢/kWh electricity..... | 5.32 | (8.86) | 4.51 |
| | Escalation of conventional energy costs | | |
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| Levelized price paid for conventional energy^b. | | | |
| \$/MMBtu primary fuel | 3.66 | 4.61 | 8.47 |
| ¢/kWh electricity..... | 4.31 | 5.42 | 9.97 |

Table IV-27.—Albuquerque: Solar Hot Water and Heating System—Single Family House Using Flat Plate Collectors (1977 Prices), Low-Temperature Thermal Storage; Building Equipped With SF-2 Space-Conditioning



A. ITEMIZED COST OF COMPONENTS

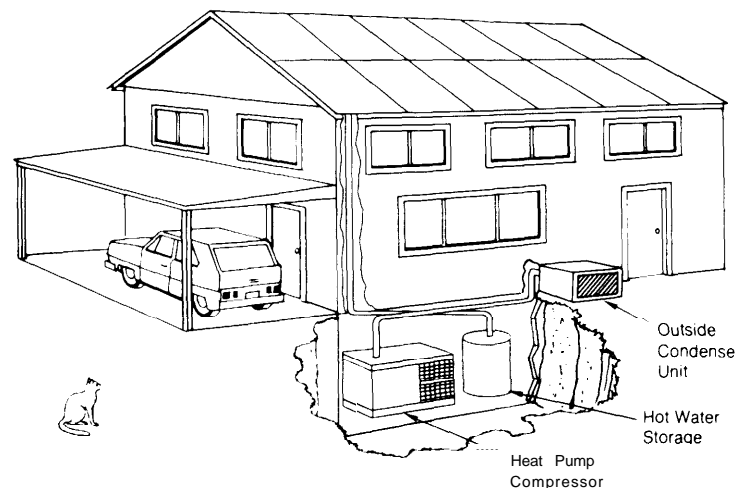
| Component | Size | Unit cost | First cost (incl. O&P) | Annual O&M | Life (yrs) |
|---------------------------------------|-------------------|-----------------------|------------------------|-------------|------------|
| 1. Heat pump | 1.85 ton | 800 \$/ton | \$1,480 | \$50 | 10 |
| 2. Ductwork | — | — | 425 | 0 | 30 |
| 3. Collectors and associated costs | 45 m ² | 143 \$/m ² | 3,217 | 0 | 15 |
| —Collector @ 95 \$/m ² | | | ● 3,217 | 0 | 30 |
| —Installation @ 16 \$/m ² | | | | | |
| —Transportation @ 3 \$/m ² | | | | | |
| —25% overhead and profit | | | | | |
| 4. Insulated steel pipe | 125 ft | \$4.1 | 513 | 0 | 30 |
| 5. Storage (without plumbing) | 200 kWh | \$2.05/kWh | 410 | 0 | 30 |
| 6. Pump, controls, and heat exchanger | — | \$650 | 650 | 0 | 10 |
| TOTAL | | | \$9,912 | \$50 | |

• 1/2 installed collector cost assumed replaced in 15 yrs., with total replacement in 30 yrs

ANNUAL ENERGY FLOWS

(Conventional reference system is SF-2)

| | Energy consumed by ref. system | Backup consumed w/ solar/conservation | Energy saved (% of total) |
|--|--------------------------------|---------------------------------------|---------------------------|
| Net Electricity (bought-sold) (MWh/unit) | 32.5 | 16.8 | 48.4 |
| Fuel consumed onsite (MMBtu/unit) | 0. | 0. | 0. |
| Total energy requirement (bbl crude equiv.) ^a | 79. | 41. | 48.4 |
| Electricity sold to grid annually (MWh, entire building) | | | 0. |
| Annual peak electricity demand (kW, entire building) | | | 25.6 |



B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}

(Conventional reference system is SF-2)

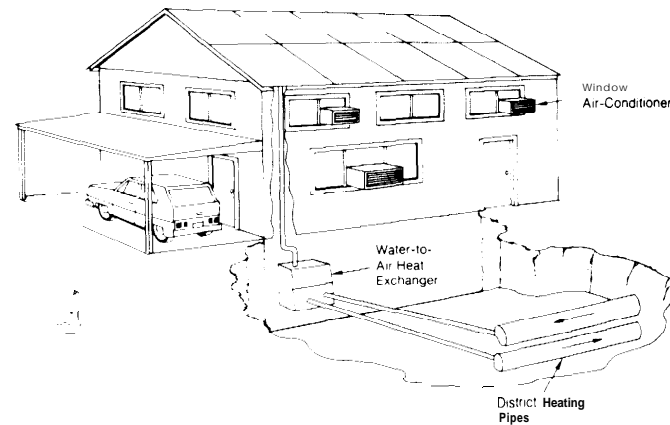
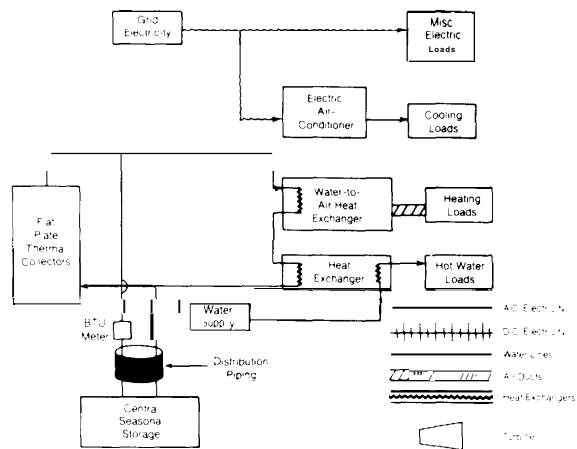
| | Escalation of conventional energy costs | | |
|---|---|---------------------------|----------------------------|
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| 1. 1976 Startup | | | |
| a. Costs using solar (conservation) system: | | | |
| Total with no incentives | 188. | (237.) | 274. |
| Total with 20% ITC | 176. | (226.) | 262. |
| Total with full incentives | 159. | (191.) | 245. |
| b. Costs using conventional reference system | 157. | 187. | 310. |
| 2. 1985 Startup^d | | | |
| 0. Costs using solar (conservation) system: | | | |
| (capitol related costs) | 115. | (164.) | 115. |
| (operation & maintenance costs) | 7. | (7.) | 7. |
| (fuel bill) | 0. | (0.) | 0. |
| (electric bill) | 66. | (66.) | 66. |
| Total with no incentives | 188. | (237.) | 274. |
| Total with 20% ITC | 176. | (226.) | 262. |
| Total with full incentives | 159. | (191.) | 245. |
| b. Costs using conventional reference system | 157. | 204. | 395. |

C. EFFECTIVE COST OF ENERGY TO CONSUMER

(Conventional reference system is SF-2)

| Levelized cost of solar energy or 'conservation' energy ^e | Type of incentives given | | |
|--|---|---------------------------|----------------------------|
| | No incentives | 20% ITC | Full incentives |
| \$/MMBtu primary fuel | 5.35 (8.52) | 4.54 (7.82) | 3.48 (5.52) |
| ¢/kWh electricity | 6.30 (10.02) | 5.35 (9.21) | 4.09 (6. XI) |
| | Escalation of conventional energy costs | | |
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| Levelized price paid for conventional energy^{b,d} | | | |
| \$/MMBtu primary fuel | 3.66 | 4.61 | 8.47 |
| ¢/kWh electricity | 4.31 | 5.42 | 9.97 |

Table IV-29.—Albuquerque: 100-Percent Solar Hot Water and Heating System—Single Family House Using Flat Plate Collectors (Possible Future Price), Community Seasonal Storage; Building Equipped With SF-2 Space-Conditioning



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O&P) | Annual O&M | Life (yrs) |
|---------------------------------------|------------------------|----------------------|------------------------|--------------|------------|
| 1. Fan coil unit | .132 kW | 13 \$/kW | \$170 | | 0 15 |
| 2. Ductwork | — | — | 425 | | 0 30 |
| 3. Control electric etc. | 1.85 tons | 430 \$/ton | 796 | \$30 10 | |
| 4. Hot water tank w/heat exch. | 30 ga | 225 \$/ton | 225 | | 0 15 |
| 5. Collectors and associated cth. | 40 m ² | 86 \$/m ² | 1,720 | | 0 15 |
| —Collectors @ 50 \$/m ² | | | 1,720 | | 0 30 |
| —Installation @ 16 \$/m ² | | | | | |
| —Transportation @ 3 \$/m ² | | | | | |
| —25% overhead and profit | | | | | |
| 6. Controls | — | — | 100 | | 0 15 |
| 7. 1" insulated steel pipe | 100 ft | \$4.1/ft | 410 | | 0 30 |
| 8. Storage (aquifer part) | 17,000 kWh @ 0.1 \$/kW | | 1,700 | | 0 30 |
| 9. Distribution piping | — | — | 3,000 | | 90 30 |
| TOTAL FOR BUILDING | | | \$10,266 | \$120 | |
| TOTAL PER UNIT | | | \$10,266 | \$120 | |

* 1/2 installed collector cost assumed replaced in 15 yrs with total replacement in 30 yrs

ANNUAL ENERGY FLOWS

(Conventional reference system is SF-2)

| | Energy consumed by ref. system | Backup consumed w/ solar/conservation | Energy saved (% of total) |
|---|--------------------------------|---------------------------------------|---------------------------|
| Net Electricity (bought-sold) (MMWh/unit) | 32.5 | 11.3 | 65.4 |
| Fuel consumed on site (MMBtu/unit) | 0. | 0. | 0. |
| Total energy requirement (bbl crude equiv.) | 79. | 28. | 65.4 |
| Electricity sold to grid annually (MMWh, entire building) | | | 0. |
| Annual peak electricity demand (kW, entire building) | | | 5.2 |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b, c}

(Conventional reference system is SF-2)

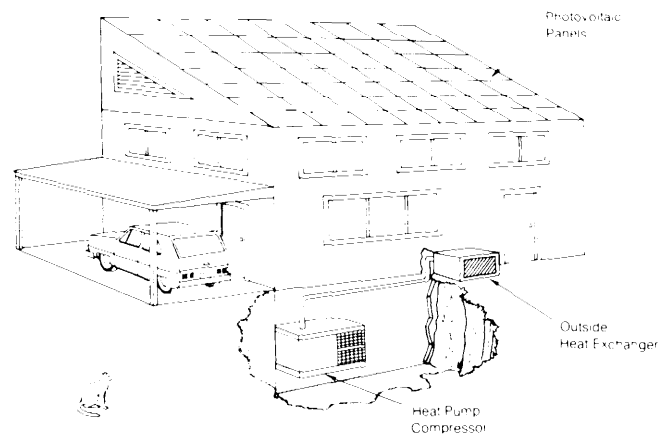
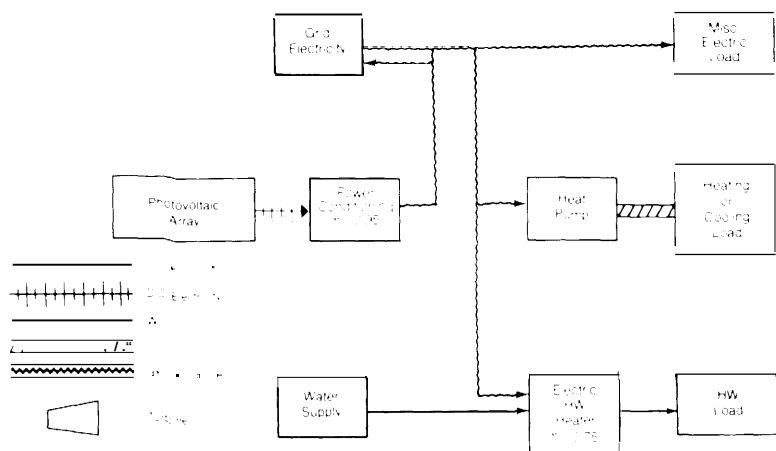
| | Escalation of conventional energy costs | | | | | |
|---|---|---------|---------------------------|--------|----------------------------|--------|
| | Constant real energy prices | | Energy price escalation I | | Energy price escalation II | |
| 1. 1976 Startup | | | | | | |
| a. Costs using solar (conservation) system: | | | | | | |
| Total with no incentives | 166. | (21 1.) | 178. | (224.) | 229. | (274.) |
| Total with 20% it | 153. | (200.) | 165. | (212.) | 216. | (263.) |
| Total with full incentives | 136. | (163.) | 148. | (175.) | 199. | [226.] |
| b. Costs using conventional reference system | 157. | | 187. | | 310. | |
| 2. 1985 Startup^a | | | | | | |
| a. Costs using solar (conservation) system: | | | | | | |
| (capital related costs) | 100. | (146.) | 100. | (146.) | 100. | (146.) |
| (operation & maintenance costs) | 18. | (18.) | 18. | (18.) | 18. | (18.) |
| (fuel bill) | 0. | (0.) | 0. | [0.] | 0. | (0.) |
| (electric bill) | 48. | (48.) | 67. | (67.) | 146. | [146.] |
| Total with no incentives | 166. | (21 1.) | 185. | (231.) | 264. | [309.] |
| Total with 20% IT | 153. | (200.) | 172. | (219.) | 251. | (298.) |
| Total with full incentives | 136. | (163.) | 155. | (182.) | 233. | [261.] |
| b. Costs using conventional reference system | 157. | | 204. | | 3 9 5 . | |

C. EFFECTIVE COST OF ENERGY TO CONSUMER

(Conventional reference system is SF-2)

| Levelized cost of solar energy or 'conservation' energy ^a | Type of incentives given | | | | | |
|--|---|--------|---------------------------|--------|----------------------------|--------|
| | No incentives | | 20% ITC | | Full incentives | |
| \$/MMBtu primary fuel | 3.75 | (5.93) | 3.13 | (5.39) | 2.30 | (3.61) |
| ¢/kWh electricity | 4.42 | (6.98) | 3.68 | (6.35) | 2.71 | (4.25) |
| | Escalation of conventional energy costs | | | | | |
| | Constant real energy prices | | Energy price escalation I | | Energy price escalation II | |
| Levelized price paid for conventional energy ^{b, c} | 3.66 | | 4.61 | | 8.47 | |
| \$/MMBtu primary fuel | 3.66 | | 4.61 | | 8.47 | |
| ¢/kWh electricity | 4.31 | | 5.42 | | 9.97 | |

Table IV-30. — Albuquerque: Solar Photovoltaic System— Single Family House Using Flat-Plate Air-Cooled Silicon Arrays (\$0.50/Watt); Building Equipped With SF-2 Space-Conditioning



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O&P) | Annual O&M | Life (yrs) |
|---|--------------------|----------------------|------------------------|-------------|------------|
| 1. Heat pump..... | 1.85 tons | 800 \$/ton | \$1,480 | \$50 | 10 |
| 2. Ductwork..... | — | — | 425 | 0 | 30 |
| 3. Electric hot water..... | 40 gal | \$225 ea. | 225 | 0 | 15 |
| 4. Air-cooled silicon PV (\$500\$/kw)($\eta = 0.12$)..... | 118 m ² | 88 \$/m ² | \$5,190 | 0 | 30 |
| — Silicon array @ 60 \$/m ² | | | \$5,190 | 0 | 15 |
| — Shipping @ 2 \$/m ² | | | | | |
| — Installation @ 8 \$/m ² | | | | | |
| — 25% overhead and profit | | | | | |
| 5. Power conditioning..... | 4 kW | 108 | 1,510 | 15 | 30 |
| 6. Lightning protection..... | — | — | 300 | 0 | 30 |
| TOTAL..... | | | \$14,320 | \$65 | |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{BT}

(Conventional reference system is SF-2)

| | Escalation of conventional energy costs | | | |
|--|---|---------------------------|----------------------------|--|
| | Constant real energy prices | Energy price escalation I | Energy price escalation II | |
| 1. 1976 Startup | | | | |
| cr. Costs using solar (conservation) system: | | | | |
| Total with no incentives..... | 215. (284.) | 229. (297.) | 283. (351.) | |
| Total with 20% ITC..... | 196. (267.) | 209. (280.) | 263. (334.) | |
| Total with full incentives..... | 170. (211.) | 183. (225.) | 238. (279.) | |
| b. Costs using conventional reference system..... | 157. | 187. | 310. | |
| 2. 1985 Startup^d | | | | |
| a. Costs using solar (conservation) system: | | | | |
| (capitol related Cash..... | 154. [223.] | 154. [223.] | 154. (223.) | |
| (operation & maintenance costs)..... | 10. (10.) | 10. (10.) | 10. (10.) | |
| Fuel bill..... | 0. (0.) | 0. (0.) | 0. (0.) | |
| (electric bill)..... | 51. (51.) | 72. (72.) | 156. [156.] | |
| Total with no incentives..... | 215. (284.) | 236. (304.) | 320. [389.] | |
| Total with 20% ITC..... | 196. (267.) | 217. (288.) | 301. (372.) | |
| Total with full incentives..... | 170. (211.) | 191. (232.) | 275. (316.) | |
| b. Costs using conventional reference system..... | 157. | 204. | 395. | |

C. EFFECTIVE COST OF ENERGY TO CONSUMER

(Conventional reference system is SF-2)

| Levelized cost of solar energy or 'conservation' energy ^f | Type of incentives given | | |
|--|--------------------------|-------------|-----------------|
| | No incentives | 20% ITC | Full incentives |
| \$/MMBtu primary fuel..... | 4.55 (7.05) | 3.83 (6.44) | 2.89 [4.40] |
| ¢/kWh electricity..... | 5.36 (8.30) | 4.51 (7.58) | 3.40 (5.18) |
| Levelized price paid for conventional energy^{b,*} | | | |
| | 3.66 | 4.61 | 8.47 |
| | 4.31 | 5.42 | 9.97 |

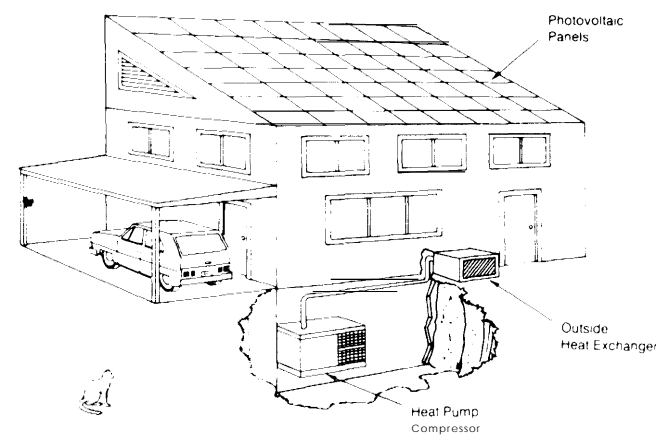
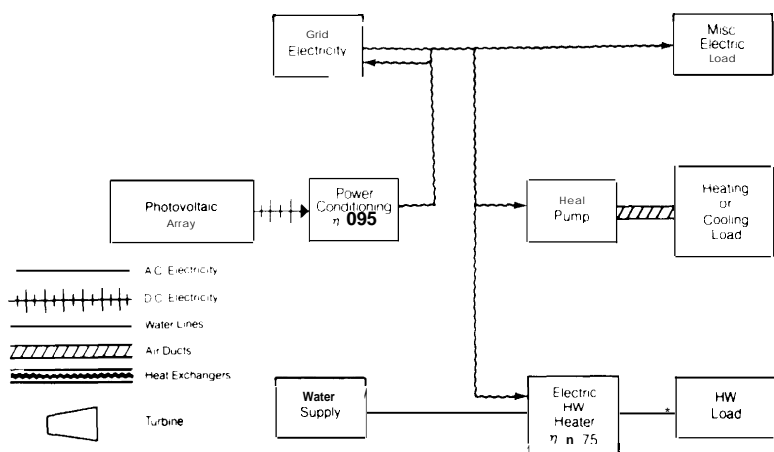
* 1/2 installed collector cost assumed replaced in 15 yrs., with total replacement in 30 yrs.

ANNUAL ENERGY FLOWS

(Conventional reference system is SF-2)

| | Energy consumed by ref. system | Backup consumed w/ solar/conservation | Energy saved (% of total) |
|--|--------------------------------|---------------------------------------|---------------------------|
| Net Electricity (bought-sold) (MWh/unit)..... | 32.5 | 4.7 | 85.6 |
| Fuel consumed on site (MMBtu/unit)..... | 0. | 0. | 0. |
| Total energy requirement (bbl crude equiv.) ^a | 79. | 11. | 85.6 |
| Electricity sold to grid annually (MWh, entire building)..... | | | 15.3 |
| Annual peak electricity demand (kW, entire building)..... | | | 23.5 |

Table IV-31 .—Albuquerque: Solar Photovoltaic System—Single Family House Using Flat-Plate Air-Cooled Thin-Film Arrays (\$0.10/Watt); Building Equipped With SF-2 Space-Conditioning



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O&P) | Annual O & M | Life (yrs) |
|--|--------------------|----------------------|------------------------|--------------|------------|
| 1. Heat pump | .185 tons | \$800/ton | \$1,480 | \$50 | 10 |
| 2. Ductwork | — | — | 425 | 0 | 30 |
| 3. Electric hot water heater | 40 gal | \$225 ea. | 225 | 0 | 15 |
| 4. Thin film module (η = 0.094) thin film @ 100 \$/1kW | 106 m ² | 25 \$/m ² | *1,330 | 0 | 30 |
| —Thin film @ 10 \$/m ² | | | | | |
| —Installation @ 8 \$/m | | | | | |
| —Shipping @ 2 \$/m ² | | | | | |
| —25% overhead and profit | | | | | |
| 5. Power conditioning | 10 kW | 40 \$/kW | 400 | 4 | 30 |
| 6. Lightning protection | — | — | 300 | 0 | 30 |
| TOTAL | | | \$5,490 | \$54 | |

* 1/2 installed collector cost assumed replaced in 15 yrs., with total replacement in 30 yrs.

ANNUAL ENERGY FLOWS

(Conventional reference system is SF-2)

| | Energy consumed by ref. system | Backup consumed solar/conservation | Energy saved (% of total) |
|--|--------------------------------|------------------------------------|---------------------------|
| Net Electricity (bought-sold) (MWh/unit) | 32.5 | 13.0 | 59.9 |
| Fuel consumed onsite (MMBtu/unit) | 0. | 0. | 0. |
| Total energy requirement (bbl crude equiv.) ^a | 79. | 32. | 59.9 |
| Electricity sold to grid annually (MWh, entire building) | | | 9.1 |
| Annual peak electricity demand (kW, entire building) | | | 24.1 |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}

(Conventional reference system is SF-2)

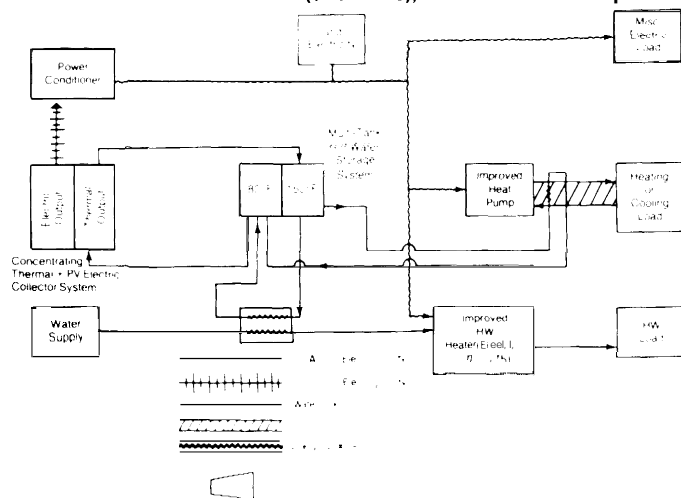
| | Escalation of conventional energy costs | | | |
|---|---|--------------------------|----------------------------|-------------|
| | Constant real energy prices | Energy @ CO escalation I | Energy price escalation II | Scabtim II |
| 1. 1976 Startup | | | | |
| 0. Costs using solar (conservation) system: | | | | |
| Total with no incentives | 142. | (169.) | 160. | (187.) |
| Total with 20% ITC | 137. | (165.) | 154. | (182.) |
| Total with full incentives | 129. | (149.) | 147. | (167.) |
| 2. 1985 Startup^d | 157. | | 187. | 310. |
| a. Costs using solar (conservation) system: | | | | |
| (capital related costs) | 66. | (93.) | 66. | (93.) |
| (operation & maintenance costs) | 8. | (8.) | 8. | (8.) |
| (fuel bill) | 0. | (0.) | 0. | (0.) |
| (electric bill) | 68. | (68.) | 96. | (96.) |
| Total with no incentives | 142. | (169.) | 170. | (197.) |
| Total with 20% ITC | 137. | (165.) | 164. | (192.) |
| Total with full incentives | 129. | (149.) | 157. | (177.) |
| b. Costs using conventional reference system | 157. | | 20.4. | 395. |

c. EFFECTIVE COST OF ENERGY TO CONSUMER

(Conventional reference system is SF-2)

| Levelized cost of solar energy or 'conservation' energy ^e | Type of incentives given | | |
|--|--------------------------|-------------|-----------------|
| | No incentives | 20% ITC | Full incentives |
| \$/MMBtu primary fuel | 1.77 (3.20) | 1.48 (2.96) | 1.11 (2.16) |
| ¢/kWh electricity | 2.08 (3.77) | 1.75 (3.48) | 1.31 (2.54) |
| Levelized price paid for conventional energy^{b,a} | | | |
| \$/MMBtu primary fuel | 3.6d | 4.61 | 8.47 |
| ¢/kWh electricity | 4.31 | 5.42 | 9.97 |

Table IV-32.—Albuquerque: Solar Photovoltaic Cogeneration System—Single Family House Using One-Axis Concentrator With Si Cells (\$15/Cells), Multitank Low-Temperature Thermal Storage; Building Equipped With SF-2 Space-Conditioning



A. ITEMIZED COST OF COMPONENTS

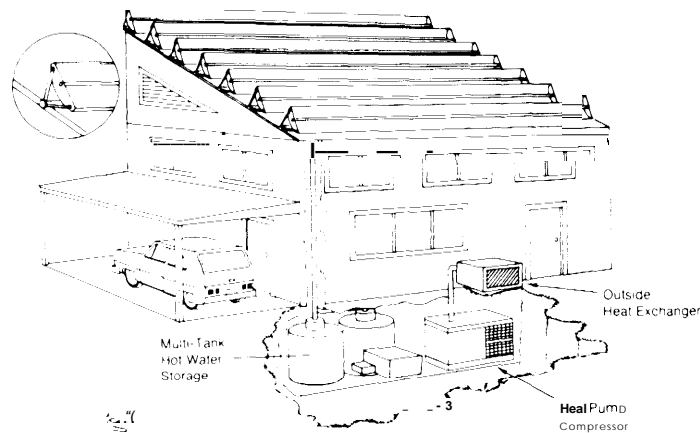
| Component | Size | Unit cost | First cost (incl. O&P) | Annual O&M | Life (yrs) |
|--|-------------------|-----------------------|------------------------|-------------|------------|
| 1. Electric heat pump..... | 1.85 tons | 800 \$/ton | \$1,480 | \$50 | 10 |
| 2. Ductwork..... | — | 425 | 0 | 0 | 30 |
| 3. Multitank electric hot water and storage..... | 200 kWh | 3 \$/kWh | 600 | 0 | 30 |
| 4. Insulated steel pipe..... | 125 ft | 4.1 \$/ft | \$513 | 0 | 30 |
| 5. I-axis tracking silicon module (cells cost \$15,000/kW) (η = 0.099) | 74 m ² | 293 \$/m ² | ● 10,840 | 0 | 30 |
| —Tracking collector @ 130 \$/m ² | | | ● 10,840 | 0 | 15 |
| —Silicon concentrator cells @ 62 \$/m ² | | | | | |
| —Shipping @ 2 \$/m ² | | | | | |
| —Installation @ 40 \$/m ² | | | | | |
| —Overhead and profit @ 25% | | | | | |
| 6 Pumps, controls and hot exchanger and miscellaneous equipment..... | — | — | 500 | 0 | 10 |
| 7 Thermal only collector area..... | 18 m ² | 215 \$/m ² | .1 935 | 0 | 30 |
| 8. Power conditioning..... | 7 kW | 222 \$/kW | 1,550 | 16 | 30 |
| 9. Lightning protection..... | — | — | 300 | 0 | 30 |
| TOTAL..... | | | \$30,918 | \$66 | |

● ½ installed collector cost assumed replaced in 15 yrs., with total replacement in 30 yrs.

ANNUAL ENERGY FLOWS

(Conventional reference system is SF-2)

| | Energy consumed by ref. system | Backup consumed solar/conservation | w / (% of total) | Energy saved (% of total) |
|---|--------------------------------|------------------------------------|------------------|---------------------------|
| Net Electricity (bought-sold) (MWh/unit)..... | 32.5 | 2.4 | 92.7 | 0. |
| Fuel consumed onsite (MMBtu/unit)..... | 0. | 0. | 0. | 92.7 |
| Total energy requirement (bbl crude equiv.)..... | 79. | 8 | | |
| Electricity sold to grid annually (MWh, entire building)..... | | | | 5.7 |
| Annual peak electricity demand (kW, entire building)..... | | | | 25.6 |



B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}

(Conventional reference system is SF-2)

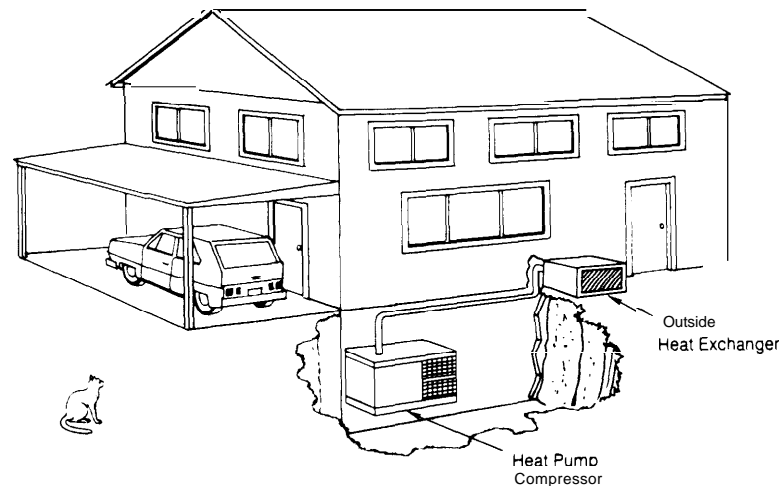
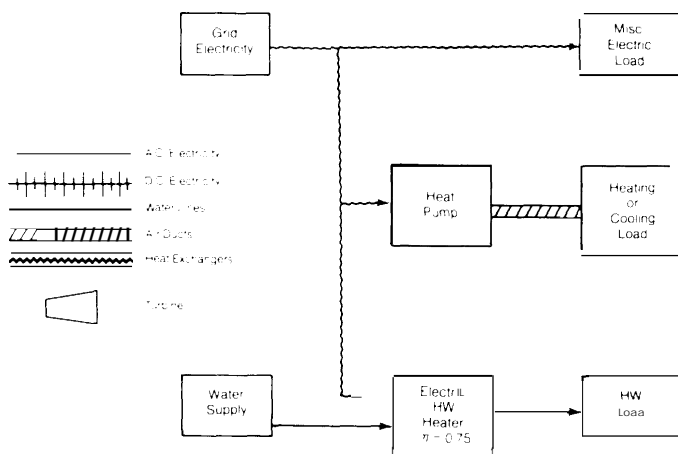
| | Escalation of conventional energy costs | | | |
|--|---|---------------------------|----------------------------|--------|
| | Constant real no/UY prices | Energy price escalation I | Energy price escalation II | |
| 1. 1976 Startup | | | | |
| 0. Costs using solar (conservation) system: | | | | |
| Total with no incentives..... | 362. | (508.) | 369. | (515.) |
| Total with 20% IT..... | 316. | (469.) | 322. | (475.) |
| Total with full incentives..... | 255. | (337.) | 261. | (344.) |
| b. Costs using conventional reference system..... | 157. | 187. | 310. | |
| 2. 1985 Startup^d | | | | |
| a. Costs using solar (conservation) system: | | | | |
| (capital related costs)..... | 327. | [473.] | 327. | [473.] |
| (operation & maintenance costs)..... | 10. | (10.) | 10. | (10.) |
| (fuel bill)..... | 0. | (0.) | 0. | (0.) |
| (electric bill)..... | 25. | (25.) | 36. | (36.) |
| Total with no incentives..... | 362. | [508.] | 372. | [519.] |
| Total with 20% IT..... | 316. | (469.) | 326. | (479.) |
| Total with full incentives..... | 255. | (337.) | 265. | (348.) |
| b. Costs using conventional reference system..... | 157. | 204. | 395. | |

C. EFFECTIVE COST OF ENERGY TO CONSUMER

(Conventional reference system is SF-2)

| Levelized cost of solar energy or 'conservation' energy ^a | Type of incentives given | | |
|--|-----------------------------|---------------------------|----------------------------|
| | No incentives | 20% ITC | Full incentives |
| \$/MMBtu primary fuel..... | 10.04 (14.98) | 8.47 (13.65) | 6.41 (9.20) |
| ¢/kWh electricity..... | 11.81 (17.64) | 9.97 [16.06] | 7.55 (10.83) |
| Levelized price paid for conventional energy^{b,*} | | | |
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| \$/MMBtu primary fuel..... | 3.66 | 4.61 | 8.47 |
| ¢/kWh electricity..... | 4.31 | 5.42 | 9.97 |

Table IV-33.—Albuquerque: Conventional System—Insulated Single Family All Electric House With Heat Pump Heating (IF-2)



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O&P) | Annual O&M | Life (yrs) |
|--|----------|------------|------------------------|-------------|------------|
| 1. Heat pump | 1.3 tons | 800 \$/ton | \$1,040 | \$50 | 10 |
| 2. Ductwork | — | — | 425 | 0 | 30 |
| 3. Electric water heater | 40 gal | 225 ea. | 225 | 0 | 15 |
| 4. Extra insulation, storm doors and windows | — | — | 981 | 0 | 30 |
| TOTAL | | | \$2,671 | \$50 | |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}

(Conventional reference system is IF-2)

| | Escalation of conventional energy costs | | | | | |
|------------------------------------|---|--------|---------------------------|--------|----------------------------|--------|
| | Constant real energy prices | | Energy price escalation I | | Energy price escalation II | |
| 1. 1976 Startup | | | | | | |
| Total with no incentives | 142. | (155.) | 168. | (181.) | 275. | (289.) |
| Total with 20% ITC | 142. | (155.) | 168. | (181.) | 275. | (289.) |
| Total with full incentives | 142. | (155.) | 168. | (181.) | 275. | (289.) |
| 2. 1985 Startup^d | | | | | | |
| (capital related costs) | 32. | (46.) | 32. | (46.) | 32. | (46.) |
| (operation & maintenance costs) | 7. | (7.) | 7. | (7.) | 7. | (7.) |
| fuel bill | 0. | (0.) | 0. | (0.) | 0. | (0.) |
| electric bill | 102. | (102.) | 143. | (143.) | 311. | (311.) |
| Total with no incentives | 142. | (155.) | 183. | (196.) | 350. | (364.) |
| Total with 20% ITC | 142. | (155.) | 183. | (196.) | 350. | (364.) |
| Total with full incentive | 142. | (155.) | 183. | (196.) | 350. | (364.) |

C. EFFECTIVE COST OF ENERGY TO CONSUMER

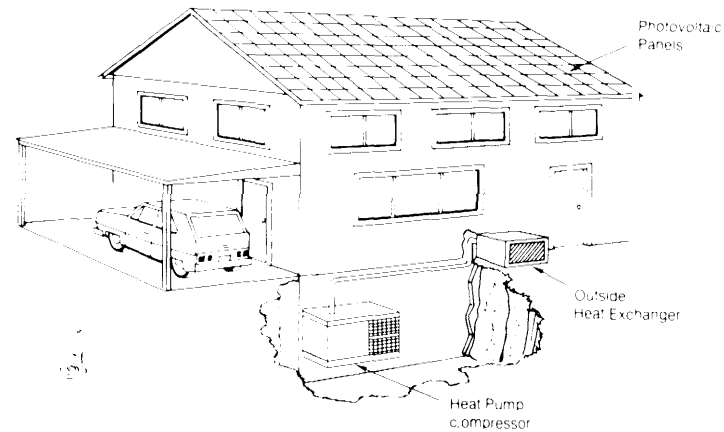
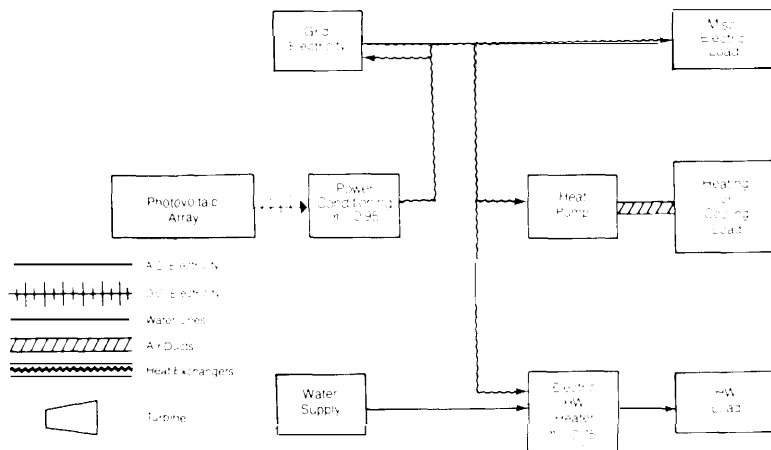
(Conventional reference system is IF-2)

ANNUAL ENERGY FLOWS (Conventional reference system is IF-2)

| | Energy consumed by ref. system | Backup consumed w/ solar/conservation | Energy saved (% of total) |
|--|--------------------------------|---------------------------------------|---------------------------|
| Net Electricity (bought-sold) (MWh/unit) | 28.0 | 28.0 | 0. |
| Fuel consumed onsite (MMBtu/unit) | 0. | 0. | 0. |
| Total energy requirement (bbl crude equiv.) ^a | 68. | 68. | 0. |
| Electricity sold to grid annually (MWh, entire kiting) | | | 0. |
| Annual peak electricity demand (kW, entire building) | | | 22.1 |

| Levelized cost of solar energy or 'conservation' energy ^a | Type of incentives given | | | | | |
|--|-----------------------------|-------|---------------------------|-------|----------------------------|-------|
| | No incentives | | 20% ITC | | Full incentives | |
| \$/MMBtu primary fuel | N/A | (N/A) | N/A | (N/A) | N/A | (N/A) |
| ¢/kWh electricity | N/A | (N/A) | N/A | (N/A) | N/A | (N/A) |
| Escalation of conventional energy costs | | | | | | |
| Levelized price paid for conventional energy ^{b,c} | Constant real energy prices | | Energy price escalation I | | Energy price escalation II | |
| | 3.72 | 4.68 | 5.51 | 10.12 | a d o | |
| \$/MMBtu primary fuel | | | | | | |
| ¢/kWh electricity | 4.38 | 5.51 | 10.12 | | | |

Table IV-34.—Albuquerque: Solar Photovoltaic System—Insulated Single Family House Using Flat-Plate Air-Cooled Silicon Arrays (\$0.50/Watt); Building Equipped With IF-2 Space-Conditioning



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O&P) | Annual O & M (yrs) |
|--|-------------------|----------------------|------------------------|--------------------|
| 1. Heat pump | 1.3 tons | 800 \$/ton | \$1,040 | \$50 10 |
| 2 Ductwork | — | — | 425 | 0 30 |
| 3. Electric hot water | 40 gal | \$225 ea. | 225 | 0 15 |
| 4. Air-cooled silicon PV [500 \$/kW] ($\eta = 0.12$) | 59 m ² | 88 \$/m ² | *2,600 | 0 30 |
| —Silicon array @ 60 \$/m ² | | | *2,600 | 0 15 |
| —Shipping @ 2 \$/m ² | | | | |
| —Installation @ 8 \$/m ² | | | | |
| —25% overhead and profit | | | | |
| 5. Power conditioning | 7.6 kW | 113 | 859 | 9 30 |
| 6. Lightning protection | — | — | 300 | 0 30 |
| 7. Extra insulation, storm doors and windows | — | — | 981 | 0 30 |
| TOTAL | | | \$9,030 | \$59 |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}
(Conventional reference system is IF-2)

| | Escalation of conventional energy costs | | |
|--|---|---------------------------|----------------------------|
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| 1. 1976 Startup | | | |
| cc. Costs using solar (conservation) system: | | | |
| Total with no incentives | 172. (214.) | 189. (231.) | 258. (301.) |
| Total with 20% IT | 161. (206.) | 178. (223.) | 248. (292.) |
| Total with full incentives | 14a. (176.) | 165. (194.) | 234. (263.) |
| b. Costs using conventional reference system | 142. | 168. | 276. |
| 2. 1985 Startup ^d | | | |
| CC. Costs USING solar (conservation) system: | | | |
| (capital related Cash) | 97. (140.) | 97. (140.) | 97. (140.) |
| (operation & maintenance costs) | 9. (9.) | 9. (9.) | 9. (9.) |
| (fuel bill) | 0. (0.) | 0. (0.) | 0. (0.) |
| (electric bill) | 66. (66.) | 92. (92.) | 200. (200.) |
| Total with no incentives | 172. (214.) | 198. (241.) | 306. (349.) |
| Total with 20% IT | 161. (206.) | 188. (232.) | 296. (340.) |
| Total with full incentives | 148. (176.) | 174. (203.) | 282. (311.) |
| b. Costs using conventional reference system | 142. | 183. | 350. |

C. EFFECTIVE COST OF ENERGY TO CONSUMER
(Conventional reference system is IF-2)

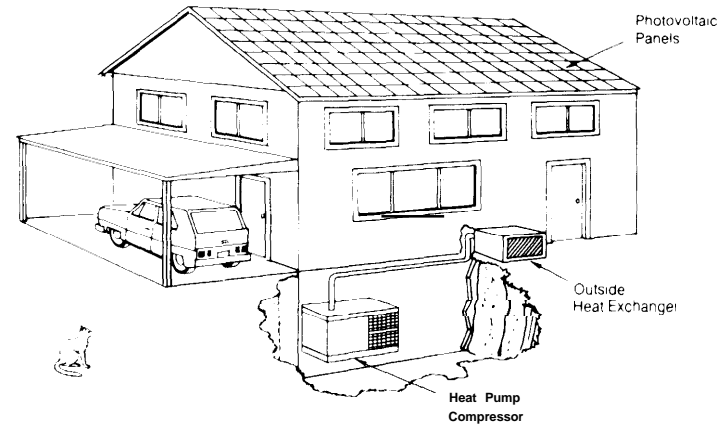
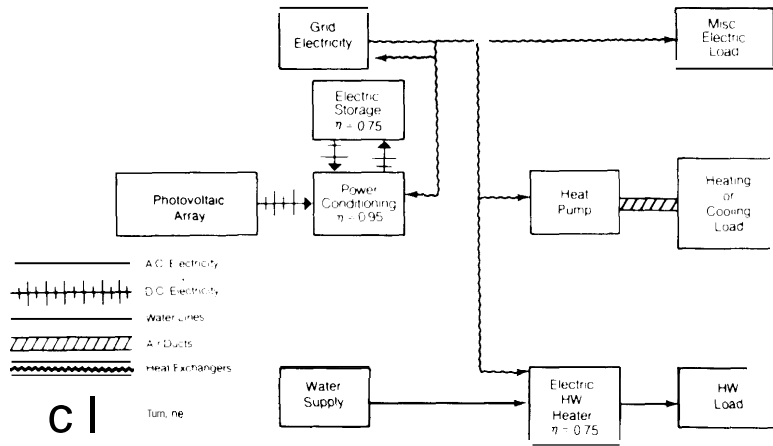
| Levelized cost of solar energy or 'conservation' energy ^a | Type of incentives given | | |
|--|---|---------------------------|----------------------------|
| | No incentives | 20% ITC | Full incentives |
| \$/MMBtu primary fuel | 4.62 (7.62) | 3.91 (7.01) | 2.96 (4.97) |
| ¢/kWh electricity | 5.44 (8.97) | 4.60 (8.25) | 3.49 (5.85) |
| Levelized price paid for conventional energy ^{b,*} | Escalation of conventional energy costs | | |
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| \$/MMBtu primary fuel | 3.72 | 4.68 | 8.60 |
| ¢/kWh electricity | 4.38 | 5.51 | 10.12 |

^a 1/2 installed collector cost assumed replaced in 15 yrs., with total replacement in 30 yrs

ANNUAL ENERGY FLOWS
(Conventional reference system is IF-2)

| | Energy consumed by ref. system | Backup consumed w/ solar/conservation | Energy saved (% of total) |
|--|--------------------------------|---------------------------------------|---------------------------|
| Net Electricity (bought, sold) (MWh/unit) | 28.0 | 13.4 | 51.9 |
| Fuel consumed onsite (MMBtu/unit) | 0. | 0. | 0. |
| Total energy requirement (bbl crude equiv.) ^a | 68. | 33. | 51.9 |
| Electricity sold to grid annually (MWh, entire building) | | | 6.7 |
| Annual peak electricity demand (kW, entire building) | | | 19.6 |

Table IV-35.-Albuquerque: Solar Photovoltaic System— Single Family House Using Flat-Plate, Air-Cooled Silicon Arrays (\$0.50/Watt), Battery Electrical Storage; Building Equipped With IF-2 Space-Conditioning



A. ITEMIZED COST OF COMPONENTS

| component | Size | Unit cost | First cost (incl. O&P) | Annual O & M | Life (yrs) |
|---|-------------------|----------------------|------------------------|--------------|------------|
| 1. Heat pump | 1.3 tons | 800 \$/ton | \$1,040 | \$50 | 10 |
| 2. Ductwork | — | — | 425 | 0 | 30 |
| 3. Electric hot water | 40 gal | \$225 ea. | 225 | 0 | 15 |
| 4. Air-coded silicon PV (500 \$/kW)(η = 0.12) | 59 m ² | 88 \$/m ² | 2,800 | 0 | 30 |
| — Silicon array @ 60 \$/m ² | | | 2,600 | 0 | 15 |
| — Shipping @ 2 \$/m ² | | | | | |
| — Installation @ 8 \$/m ² | | | | | |
| — 25% overhead and profit | | | | | |
| 5. Power conditioning | 7 kW | 114 | 800 | 8 | 30 |
| 6. Lightning protection | — | — | 300 | 0 | 30 |
| 7. Batteries | 20 kWh | 70 kWh | 1,400 | 4 | 10 |
| 8. Extra insulation, storm doors and windows | — | — | 981 | 0 | 30 |
| TOTAL | | | \$10,371 | \$62 | |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}

(Conventional reference system is IF-2)

| | Escalation of conventional energy costs | | |
|---|---|---------------------------|----------------------------|
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| 1. 1976 Startup | | | |
| a. Costs using solar (conservation) system: | | | |
| Total with no incentives | 192. (243.) | 207. (259.) | 272. (323.) |
| Total with 20% ITC | 179. (232.) | 195. (248.) | 260. (313.) |
| Total with full incentives | 163. (197.) | 179. (213.) | 243. (277.) |
| b. Costs using conventional reference system | 142. | 168. | 276. |
| 2. 1985 Startup^d | | | |
| a. Costs using solar (conservation) system: | | | |
| (capitol related costs) | 121. (172.) | 121. (172.) | 121. (172.) |
| (operation & maintenance costs) | 9. (9.) | 9. (9.) | 9. (9.) |
| (fuel bill) | 0. (0.) | 0. (0.) | 0. (0.) |
| (electric bill) | 61. (61.) | 86. (86.) | 186. (186.) |
| Total with no incentive | 192. (243.) | 216. (267.) | 317. (368.) |
| Total with 20% ITC | 179. (232.) | 204. (257.) | 304. (357.) |
| Total with full incentives | 163. (197.) | 188. (222.) | 288. (322.) |
| b. Costs using conventional reference system | 142. | 183. | 350. |

C. EFFECTIVE COST OF ENERGY TO CONSUMER

(Conventional reference system is IF-2)

| Levelized cost of solar energy or 'conservation' energy ^c | Type of incentives given | | |
|--|--------------------------|--------------|-----------------|
| | No incentives | 20% ITC | Full incentives |
| \$/MMBtu primary fuel | 7.30 (1.43) | 6.31 (10.58) | 4.99 (7.75) |
| ¢/kWh electricity | 8.60 [13.45] | 7.42 [12.45] | 5.88 [9.12] |
| Levelized price paid for conventional energy^{b,e} | | | |
| \$/MMBtu primary fuel | 3.72 | 4.68 | 8.60 |
| ¢/kWh electricity | 4.38 | 5.5J | 10. J2 |

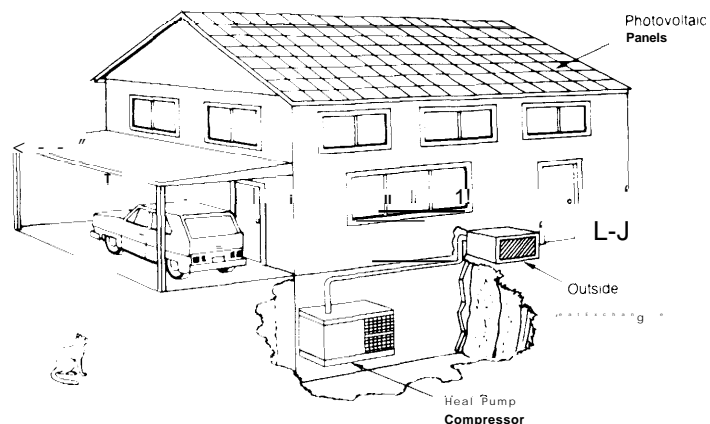
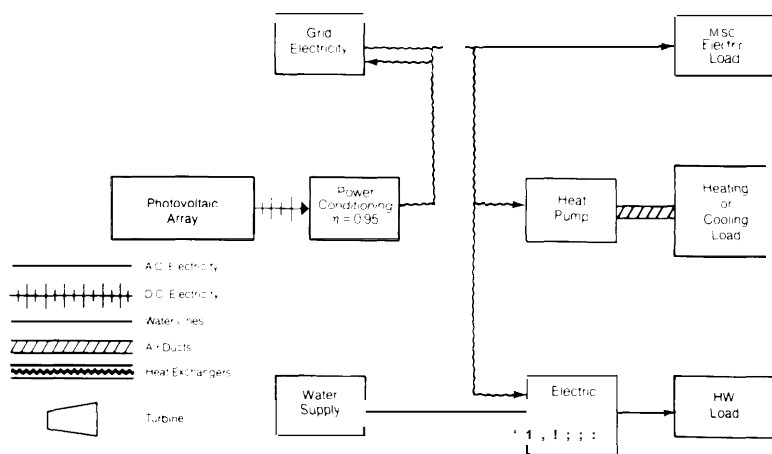
• 1/2 installed collector cost assumed replaced in 15 yrs., with total replacement in 30 yrs

ANNUAL ENERGY FLOWS

(Conventional reference system is IF-2)

| | Energy consumed by ref. system | Backup consumed solar/conservation | Energy saved (% of total) |
|--|--------------------------------|------------------------------------|---------------------------|
| Net Electricity (bought-sold) (MWh/unit) | 28.0 | 15.3 | 45.2 |
| Fuel consumed onsite (MMBtu/unit) | 0. | 0. | 0. |
| Total energy requirement (bbl crude equiv.) ^a | 68. | 37. | 45.2 |
| Electricity sold to grid annually (MWh, entire building) | | | .1 |
| Annual peak electricity demand (kW, entire building) | | | 19.6 |

Table IV-37.—Albuquerque: Solar Photovoltaic System—Insulated Single Family House Using Flat²Plate Air. Cooled Thin-Film Arrays (\$0.30/Watt); Building Equipped With IF-2 Space-Conditioning



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl O&P) | Annual O & M | Life (yrs) |
|--|-------------------|-----------|-----------------------|--------------|------------|
| 1. Electric heat prep..... | 1.3 tons | \$800 | \$1,040 | \$50 | 10 |
| 2. Ductwork..... | — | — | 425 | 0 | 30 |
| 3. Electric water heater..... | 40 gal | 225 ea. | 225 | 0 | 15 |
| 4. Thin film module (η = .073) 300 \$/kW..... | 53 m ² | 40 | 1 060 | 0 | 30 |
| —Thin film @ 22 \$/m ² | | | 1 060 | | 0 15 |
| —Installation @ 8 \$/m ² | | | | | |
| —Shipping @ 2 \$/m ² | | | | | |
| —25% overhead and profit | | | | | |
| 5. Power conditioning..... | 4.3 kw | 118 | 507 | 5 | 30 |
| 6. Lightning protection..... | — | — | \$300 | 0 | 30 |
| 7. Extra insulation, stater doors and windows..... | — | — | \$981 | 0 | 30 |

¹ Installed collector cost assumed replaced in 15 yrs with total replacement in 30 yrs

ANNUAL ENERGY FLOWS

(Conventional reference system is IF-2)

| | Energy consumed by mf. system | Backup consumed w/ solar/conservation | Energy saved [% of total] |
|---|-------------------------------|---------------------------------------|---------------------------|
| Net Electricity (bought-sold)(MWh/unit)..... | 28.0 | 19.8 | 29.1 |
| Fuel consumed onsite (MMBtu/unit)..... | 0. | 0. | |
| Total energy requirement (bblcrudeequiv.) ^a | 68. | 49. | 29% |
| Electricity sold to grid annually (MWh, entire building)..... | | | 2.4 |
| Annual peak electricity demand (kW, entire building)..... | | | 20.0 |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c,d}

(Conventional reference system is IF-2)

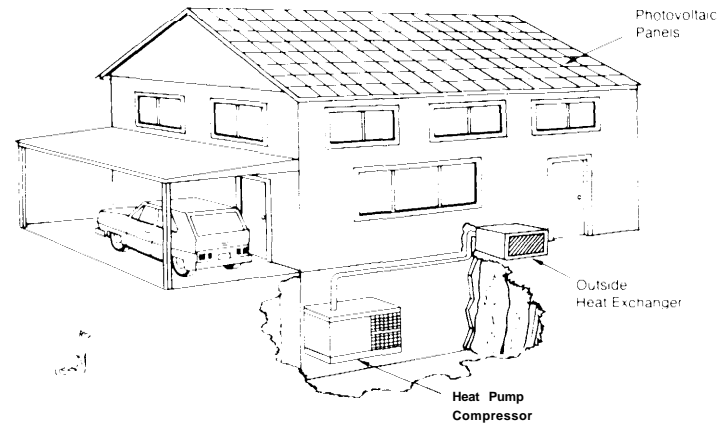
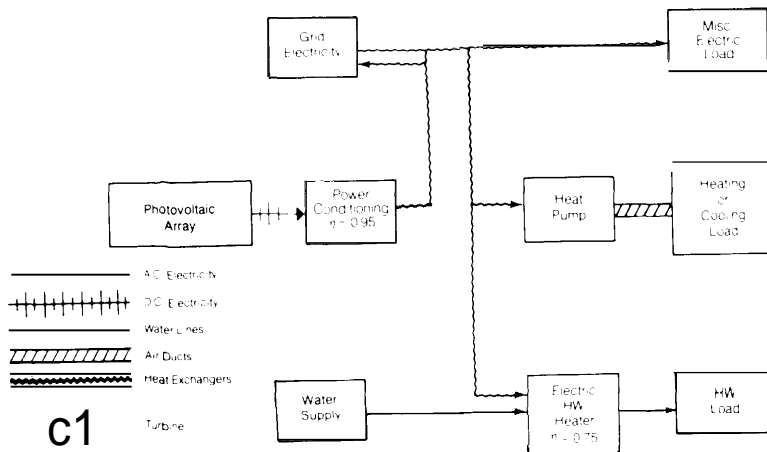
| | Escalation of conventional energy costs | | |
|--|---|---------------------------|----------------------------|
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| 1. 1976 Startup | | | |
| a. Costs using solar (conservation) system: | | | |
| Total with no incentives..... | 149. | (175.) | 169. |
| Total with 20% IT..... | 14. | (171.) | 164. |
| Total with full incentives..... | 138. | (157.) | 158. |
| b. Costs using conventional reference system..... | 142. | | 168. |
| 2. 1985 Startup^d | | | |
| a. Costs using solar (conservation) system: | | | |
| (capital related costs)..... | 61. | (87.) | 61. |
| (operation & maintenance costs)..... | 8. | (8.) | 8. |
| (fuel bill)..... | 0. | (0.) | 0. |
| (electric bill)..... | 79. | (79.) | 112. |
| Total with no incentives..... | 149. | (175.) | 181. |
| Total with 20% IT..... | 14. | (171.) | 176. |
| Total with full incentives..... | 138. | (157.) | 170. |
| b. Costs using conventional reference system..... | 142. | | 183. |
| | | | 350. |

C. EFFECTIVE COST OF ENERGY TO CONSUMER

(Conventional reference system is IF-2)

| Levelized cost of solar energy or 'conservation' energy ^a | Type of incentives given | | |
|--|---|---------------------------|----------------------------|
| | No incentives | 20% ITC | Full incentives |
| \$/MMBtu primary fuel..... | 3.66 | (6.95) | 3.07 |
| ¢/kWh electricity..... | 4.30 | (8.18) | 3.61 |
| | | | |
| | Escalation of conventional energy costs | | |
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| \$/MMBtu primary fuel..... | 3.72 | 4.68 | 8.60 |
| ¢/kWh electricity..... | 4.38 | 5.51 | 10.12 |

Table V-38.—Albuquerque: Solar Photovoltaic System—Insulated Single Family House Using Flat-Plate Air-Cooled Thin-Film Arrays (\$0.10/Watt); Building Equipped With IF-2 Space-Conditioning



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O&P) | Annual O & M | Life (yrs.) |
|--|----------|-----------|------------------------|--------------|-------------|
| 1. Electric heat pump..... | 1.3 tons | \$800 | \$1,040 | \$50 | 10 |
| 2. Ductwork | — | — | 425 | 0 | 30 |
| 3. Electric water heater | 40 gal | 225 ea | 225 | 0 | 15 |
| 4. Thin film module (η = 0.94) 100\$/kW | 53 mm' | 25 | .663 | 0 | 30 |
| —Thin film (61 10 \$/m ²) | — | — | .663 | 0 | 15 |
| —insulation @ 8 \$/m ² | — | — | — | — | — |
| —Shipping 22 \$/m ² | — | — | — | — | — |
| —25% overhead and profit | — | — | — | — | — |
| 5. power conditioning | 5.5 kW | 40 | 220 | 2 | 30 |
| 6. Lighting protection | — | — | 300 | 0 | 30 |
| 7. Extra insulation, storm doors and windows | — | — | 981 | 0 | 30 |

... installed collector cost assumed replaced in 15 yrs with total replacement in 30 yrs

ANNUAL ENERGY FLOWS

(Conventional reference system is IF-2)

| | Energy consumed by ref. system | Backup consumed w/ u+Or/consolation | Energy saved (% of total) |
|--|--------------------------------|-------------------------------------|---------------------------|
| Net Electricity (bought-sold) (MWh/unit)..... | 28.0 | 17.5 | 37.5 |
| Fuel consumed on site (MMBtu/unit)..... | 0. | 0. | — |
| Total energy requirement (bbl crude equiv.) ^a | 68. | 43. | 37.5 |
| Electricity sold to grid annually (MWh, entire building) | — | — | 3.9 |
| Annual peak electricity demand (kW, entire building) | — | — | 19.9 |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}

(Conventional reference system is IF-2)

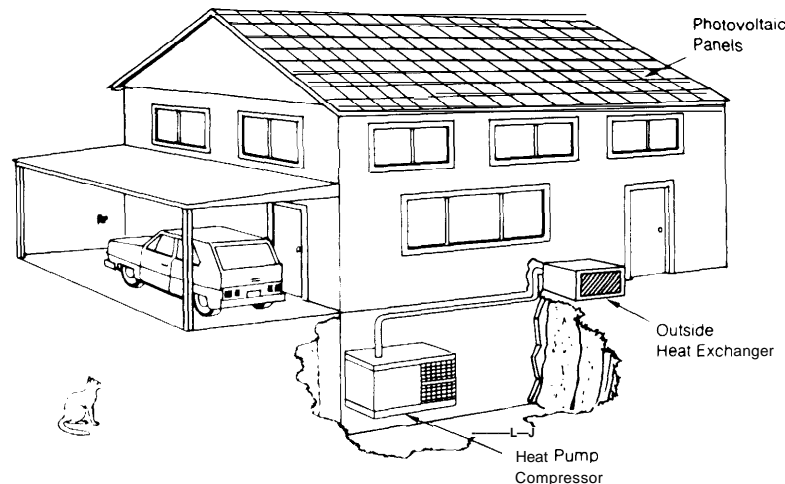
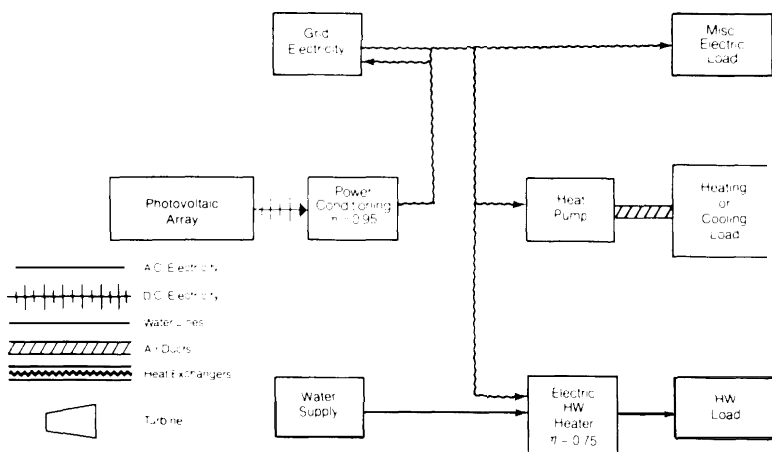
| | Escalation of conventional energy costs | | | | | |
|---|---|--------|---------------------------|--------|----------------------------|--------|
| | Constant real energy prices | | Energy price escalation I | | Energy price escalation II | |
| 1 1976 Startup | | | | | | |
| a. Costs using solar (conservation) system: | | | | | | |
| Total with no incentives | 132. | (154.) | 152. | (173.) | 23a | (251.) |
| Total with 20% IT | 129. | (151.) | 149. | (170.) | 227. | (249.) |
| Total with full incentives | 125. | (143.) | 145. | (162.) | 223. | (24a) |
| b. Costs using conventional reference system | 142. | | 168. | | 276. | |
| 2 1985 Startup^d | | | | | | |
| a. Costs using solar (conservation) system: | | | | | | |
| (capital related Cost) ^e | 50. | (72.) | 50. | (72.) | 50. | (72.) |
| (operation & maintenance costs) | 8. | (8.) | 8. | (8.) | 8. | (8.) |
| (fuel bill) | 0. | (0.) | 0. | (0.) | 0. | (0.) |
| (electric bill) | 74. | (74.) | 104. | (104.) | 226. | (226.) |
| Total with no incentives | 132. | (154.) | 162. | (184.) | 284. | (306.) |
| Total with 20% IT | 129. | (151.) | 159. | (181.) | 281. | (303.) |
| Total with full incentives | 125. | (143.) | 155. | (173.) | 277. | (295.) |
| b. Costs using conventional reference system | 142. | | 183. | | 330. | |

C. EFFECTIVE COST OF ENERGY TO CONSUMER

(Conventional reference system is IF-2)

| Levelized cost of solar energy or 'conservation' energy ^f | Type of incentives given | | |
|--|-----------------------------|---------------------------|----------------------------|
| | No incentives | 20% ITC | Full incentives |
| \$/MMBtu primary fuel | 1.77 (3.85) | 1.48 (3.61) | 1.10 (2.79) |
| ¢/kWh electricity | 2.08 [4.53] | 1.74 [4.24] | 1.30 [3.28] |
| Escalation of conventional energy costs | | | |
| Levelized price paid for conventional energy^{g,h} | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| | \$/MMBtu primary fuel | 3.72 | 4.68 |
| ¢/kWh electricity | 4.38 | 5.51 | 10.12 |

Table IV-39.—Albuquerque: Solar Photovoltaic System — Insulated Single Family House Using Flat-Plate Air-Cooled Thin-Film Arrays (\$0.10/Watt); Building Equipped With Improved SF-2 Space-Conditioning



A. ITEMIZED COST OF COMPONENTS

| component | Size | Unit cost | First cost (incl. O&P) | Annual O & M | Life (yrs) |
|---|-------------------|----------------------|------------------------|--------------|------------|
| 1. Electric heat pump..... | 1.3 tons | 960 \$/ton | \$1,250 | \$50 | 10 |
| 2. Ductwork..... | | | 425 | 0 | 30 |
| 3. Electric water heater..... | 40 gal | \$225 ea. | 225 | 0 | 15 |
| 4. Thin film module (q = 0.094) 100 \$/kW ... | 53 m ² | 25 \$/m ² | ● 663 | 0 | 30 |
| —Thin film @ 10 \$/m ² | | | ● 663 | 0 | 15 |
| —Installation @ 8 \$/m ² | | | | | |
| —Shipping @ 2 \$/m ² | | | | | |
| —2.5% overhead and profit | | | | | |
| 5. Power conditioning..... | 5 kW | 40 \$/kW | 200 | 2 | 30 |
| 6. Lightning protection..... | | | 300 | 0 | 30 |
| 7. Extra insulation, storm doors and windows..... | | | 981 | 0 | 30 |
| TOTAL..... | | | \$4,707 | \$52 | |

* ¼ installed collector cost assumed replaced in 15 yrs., with total replacement in 30 yrs.

ANNUAL ENERGY FLOWS

(conventional reference system is IF-2)

| | Energy consumed by ref. system | Backup consumed w/ solar/conservation | Energy saved (% of total) |
|--|--------------------------------|---------------------------------------|---------------------------|
| Net Electricity (bought-sold)(MWh/unit)..... | 28.0 | 15.0 | 46.2 |
| Fuel consumed onsite(MMBtu/unit)..... | 0. | 0. | 0. |
| Total energy requirement (bbl crude equiv.) ^a | 68. | 37. | 46.2 |
| Electricity sold to grid annually(MWh, entire building)..... | | | 3.9 |
| Annual peak electricity demand (kW, entire building)..... | | | 17.0 |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}

(Conventional reference system is IF-2)

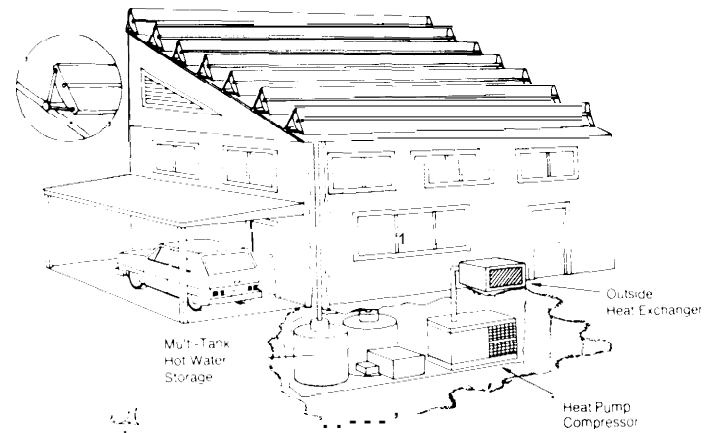
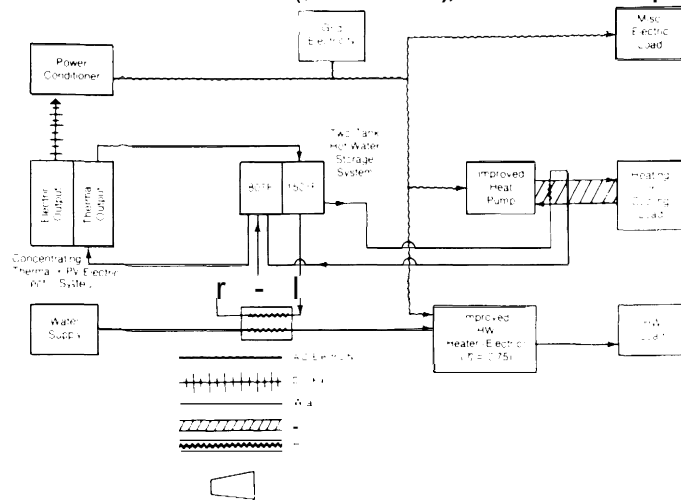
| | Escalation of conventional energy costs | | | |
|---|---|---------------------------|----------------------------|--------|
| | Constant real energy prices | Energy price escalation I | Energy price escalation II | |
| 1. 1976 Startup | | | | |
| a. Costs using solar (conservation) system: | | | | |
| Total with no incentives..... | 128. | (151.) | 145. | (168.) |
| Total with 20% ITC..... | 125. | (148.) | 142. | (165.) |
| Total with full incentives..... | 120. | (139.) | 138. | (156.) |
| b. Costs using conventional reference system..... | 142. | | 168. | 276. |
| 2. 1985 Startup^d | | | | |
| a. Costs using solar (conservation) system: | | | | |
| (capital related com.)..... | 54. | (77.) | 54. | (77.) |
| (operation & maintenance costs)..... | 8. | (8.) | 8. | (8.) |
| (fuel bill)..... | 0. | (0.) | 0. | (0.) |
| (electric bill)..... | 66. | (66.) | 93. | (93.) |
| Total with no incentives..... | 128. | (151.) | 155. | (177.) |
| Total with 20% ITC..... | 125. | (148.) | 151. | (175.) |
| Total with full incentives..... | 120. | (139.) | 147. | (165.) |
| b. Costs using conventional reference system..... | 142. | | 183. | 330. |

C. EFFECTIVE COST OF ENERGY TO CONSUMER

(Conventional reference system is IF-2)

| Levelized cost of solar energy or 'conservation' energy ^a | Type of incentives given | | |
|--|--------------------------|---------|-----------------|
| | No incentives | 20% ITC | Full incentives |
| \$/MMBtu primary fuel..... | 1.71 | (3.50) | 1.46 |
| ¢/kWh electricity..... | 2.02 | (4.12) | 1.71 |
| | | | (3.86) |
| | | | 1.12 |
| | | | (2.55) |
| | | | 1.31 |
| | | | (3.00) |
| | | | 8.60 |
| | | | 10.12 |

Table IV-40.—Albuquerque: Solar Photovoltaic Cogeneration System—Insulated Single Family House Using One-Axis Concentrator With Si Cells (\$15/Watt cells), Multitank Low-Temperature Thermal Storage; Building Equipped With IF-2 Space. Conditioning



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O&P) | Annual Life O&M (yin) |
|---|---------|-----------------------|------------------------|-----------------------|
| 1. Electric heat pump... | 1.3 ton | 964 \$/ton | \$1,250 | \$50 10 |
| 2. Ductwork..... | | | 425 | 0 30 |
| 3. Multitank electric hot water and storage..... | 200 kWh | 3 \$/kWh | 600 | 0 30 |
| 4 Insulated steel pipe .. | 125 ft | 4.1 \$/ft | 513 | 0 30 |
| 5 1-axis tracking silicon module (cells cost \$15,000/kW) (η = n n ₀) | 37 | 293 \$/m ² | *54,201 | 0 30 |
| — Tracking collector @ 130 \$/m ² | | | | o 15 |
| — Silicon concentrator cells 62 \$/m ² | | | | |
| — Shipping @ 2\$, m ² | | | | |
| — install iron @ 40 \$/m ² | | | | |
| — Overhead and profit @ 25% | | | | |
| 6. Pumps, controls and heat exchanger and miscellaneous equipment | | | 500 | 0 10 |
| 7. Thermal only collector area..... | 9 | 215 \$/m ² | .968 | 0 30 |
| 8. Power conditioning..... | 4 kW | 233 \$/kW | 932 | 9 30 |
| 9. Lightning protection..... | | | 300 | 0 30 |
| 10. Extra insulation, storm doors and windows | | | 981 | 0 30 |
| TOTAL..... | | | \$115,839 | \$59 |

*1/2 installed collector cost assumed replaced in 15 yrs., with total replacement in 30 yrs.

ANNUAL ENERGY FLOWS (Conventional reference system is IF-2)

| | Energy consumed by ref. system | Backup consumed w/ solar/conservation | Energy saved (% of total) |
|---|--------------------------------|---------------------------------------|---------------------------|
| Net Electricity (bought/sold) (MWh/unit)..... | 28.0 | 6.5 | 76.7 |
| Fuel consumed on site (MMBtu/unit)..... | o. | o. | o. |
| Total energy requirement (bbl crude equiv.) ^a ... | 68. | 16. | 76.7 |
| Electricity sold to grid annually (MWh, entire building)..... | | | 2.0 |
| Annual peak electricity demand (kW, entire building)..... | | | 17.7 |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}

(Conventional reference system is IF-2)

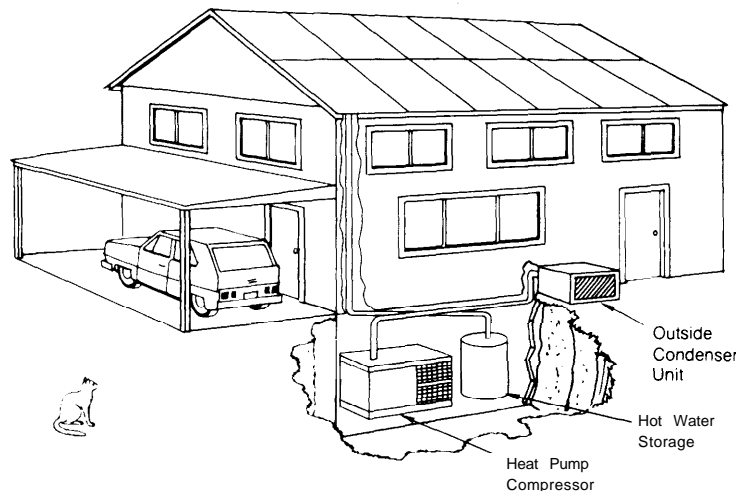
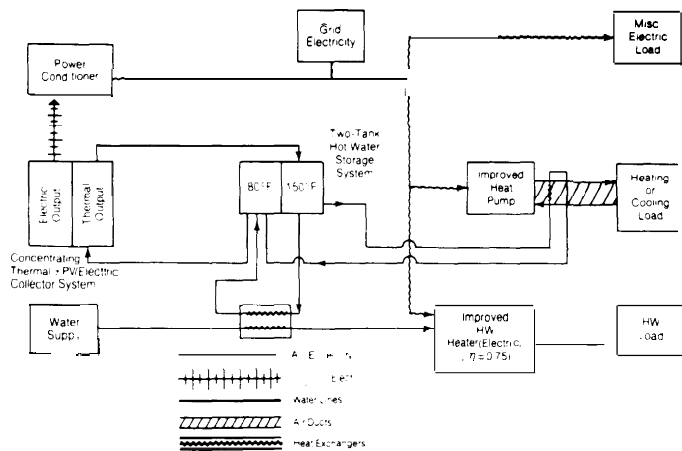
| | Escalation of conventional energy costs | | |
|--|---|---------------------------|----------------------------|
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| 1. 1976 Startup | | | |
| a. Costs using solar (conservation) system: | | | |
| Total with no incentives..... | 235. (323.) | 244. (332.) | 281. (370.) |
| Total with 20% IT..... | 210. [302.] | 219. (311.) | 256. (348.) |
| Total with full incentives..... | 153. (230.) | 162. (240.) | 199. (277.) |
| b. Costs using conventional reference system..... | 142 | 142. | 275. |
| 2. 1985 Startup^d | | | |
| a. Costs using solar (conservation) system: | | | |
| (capital related costs)..... | 191. (279.) | 191. (279.) | 191. [279.] |
| (operation & maintenance costs)..... | 9. (9.) | 9. (9.) | 9. (9.) |
| (fuel bill)..... | o. (o.) | o. (o.) | o. (0.) |
| (electric bill)..... | 35. (35.) | 50. (50.) | 108. (108.) |
| Total with no incentives..... | 235. [323.] | 249. (337.) | 307. (395.) |
| Total with 20% IT..... | 210. (302.) | 224. (316.) | 282. (374.) |
| Total with full incentives..... | 153. (230.) | 167. (245.) | 225. [303.] |
| b. Costs using conventional reference system..... | 142. | 142. | 350. |

C. EFFECTIVE COST OF ENERGY TO CONSUMER

(Conventional reference system is IF-2)

| | Type of incentives given | | |
|---|--------------------------|--------------|-----------------|
| | No incentives | 20% ITC | Full incentives |
| Levelized cost of solar or 'conservation' energy^a | | | |
| \$/MMBtu primary fuel..... | 7.60 (11.80) | 6.41 (10.78) | 3.71 (7.40) |
| ¢/kWh electricity..... | 8.95 [13.89] | 7.55 (12.69) | 4.36 [8.70] |
| Levelized price paid for conventional energy^{b,c} | | | |
| \$/MMBtu primary fuel..... | 3.72 | 4.68 | 8.60 |
| ¢/kWh electricity..... | 4.38 | 5.51 | 10.12 |

Table IV-41.—Albuquerque: Solar Photovoltaic Cogeneration System—insulated Single Family House Using Plastic Dye Photovoltaic Concentrator Multitank Low Temperature Storage; Building Equipped With IF-2 Space-Conditioning



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O&P) | Annual O & M | Life (yrs) |
|---|-------------------|-----------------------|------------------------|--------------|----------------|
| 1. Electric heat pump | 1.3 tons | 800 \$/ton | \$1,040 | | \$50 10 |
| 2. Ductwork | | | 425 | | 0 30 |
| 3. Electric hot water and multitank low temperature storage | 200 kWh | 3 \$/kWh | 600 | | 0 30 |
| 4. Insulated steel pipe | 125 ft | 4.1 \$/ft | 513 | | 0 30 |
| 5. Nontracking 100X plastic concentrator with 30% efficient cells | 38 m ² | 103 \$/m ² | •1,960 | | 0 30 |
| —Plexiglass and dyes @ 45 \$/m ² | | | | | 0 15 |
| —Cells @ 15 \$/m ² | | | | | |
| —Shipping @ 2 \$/m ² | | | | | |
| —Installation @ 20 \$/m ² | | | | | |
| —25% overhead and profit | | | | | |
| 6. Pumps, controls, and heat exchanger | | | 500 | | 0 10 |
| 7. Power conditioning | 8.5 kW | 53 \$/kW | 450 | | 7 30 |
| 8. Lightning protection | | | 300 | | 0 30 |
| 9. Extra insulation, storm doors and windows | | | 981 | | 0 30 |
| TOTAL | | | \$8,729 | | \$57 |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}
(Conventional reference system is IF-2)

| | Escalation Of conventional energy costs | | |
|--|---|---------------------------|----------------------------|
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| 1. 1976 Startup | | | |
| a. Costs using solar (conservation) system: | | | |
| Total with no incentives | 124. (166.) | 129. (171.) | 153. (195.) |
| Total with 20% IT | 114. (157.) | 120. (163.) | 143. (187.) |
| Total with full incentives | 92. (130.) | 98. (135.) | 121. (159.) |
| b. Costs using conventional reference system | 142. | 168. | 275. |
| 2. 1985 Startup^d | | | |
| a. Costs using solar (conservation) system: | | | |
| (capital related Cash) | 93. (135.) | 93. (135.) | 93. (135.) |
| (operation & maintenance costs) | 8. (8.) | 8. (8.) | 8. (8.) |
| (fuel bill) | 0. (0.) | 0. (0.) | 0. (0.) |
| (electric bill) | 22. (22.) | 31. (31.) | 68. (68.) |
| Total with no incentives | 124. (166.) | 133. (175.) | 170. (211.) |
| Total with 20% IT | 114. (157.) | 123. (166.) | 160. (203.) |
| Total with full incentives | 92. (130.) | 101. (139.) | 138. (175.) |
| b. Costs using conventional reference system | 142. | 163. | 350. |

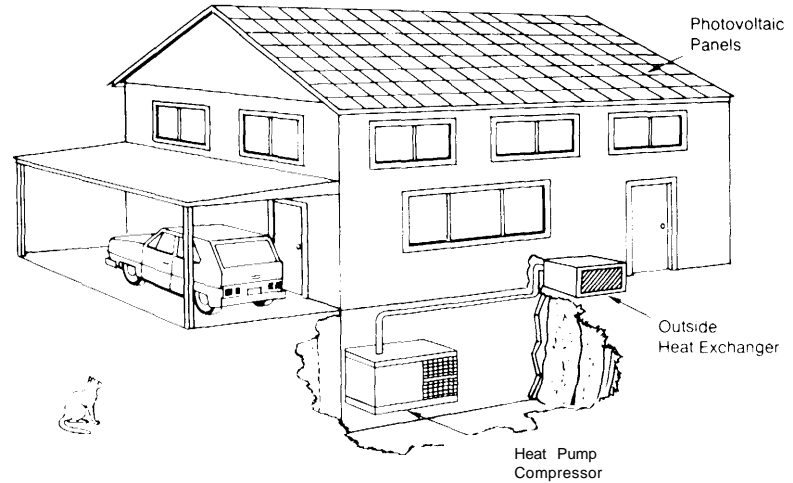
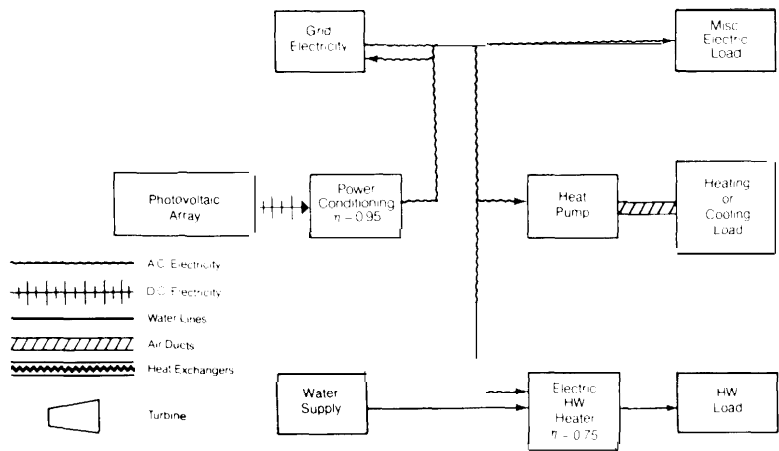
c. EFFECTIVE COST OF ENERGY TO CONSUMER
(Conventional reference system is IF-2)

| Levelized cost of solar energy or "conservation" energy ^a | Type of incentives given | | |
|--|--------------------------|-------------|-----------------|
| | No incentives | 20% ITC | Full incentives |
| \$/MMBtu primary fuel | 2.23 (3.75) | 1.88 (3.45) | 1.08 (2.45) |
| ¢/kWh electricity | 2.63 (4.41) | 2.21 (4.05) | 1.27 (2.88) |
| Levelized price paid for conventional energy^{b,c} | | | |
| | | | |
| \$/MMBtu primary fuel | 3.72 | 4.68 | 8.60 |
| ¢/kWh electricity | 4.38 | 5.51 | 10.12 |

^a 1/2 installed collector cost assumed replaced in 15 yrs., with total replacement in 30 yrs.
ANNUAL ENERGY FLOWS (Conventional reference system is IF-2)

| | Energy consumed by ref. system | Backup consumed solar/conservation | Energy saved (% of total) |
|--|--------------------------------|------------------------------------|---------------------------|
| Net Electricity (bought/sold) (MWh/unit) | 28.0 | -2 | 100.8 |
| Fuel consumed onsite (MMBtu/unit) | 0. | 0. | 0. |
| Total energy requirement (bbl crude equiv.) ^a | 68. | -1. | 100.8 |
| Electricity sold to grid annually (MWh, entire building) | | | 9.5 |
| Annual peak electricity demand (kW, entire building) | | | 19.8 |

Table IV-42.—Albuquerque: Solar Photovoltaic System—Insulated Single Family House Using Plastic Dye Photovoltaic Concentrator With Passive Cooling; Building Equipped With IF-2 Space-Conditioning



ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O&P) | Annual O & M | Life (yrs.) |
|--|-------------------|-----------------------|------------------------|--------------|-------------|
| 1. Electric heat Wimp..... | 1.3 tons | 800 \$/ton | \$1,040 | \$50 | 10 |
| 2. Ductwork..... | — | — | 425 | 0 | 30 |
| 3. Electric water heater..... | 40 gals | 225 ea. | 225 | 0 | 15 |
| 5. Nontracking 100x plastic concentrator with 30% efficient cells. | 39 m ² | 103 \$/m ² | 2,010 | 0 | 30 |
| — Plexiglass and dyes @ 45 \$/m ² | | | 2,010 | 0 | 15 |
| — Cells @ 15 \$/m ² | | | | | |
| — Shipping @ 2 \$/m ² | | | | | |
| — Installation @ 20 \$/m ² | | | | | |
| — 25% overhead and profit | | | | | |
| 7. Power conditioning..... | 13.1 | 53 \$/kw | 690 | 4 | 30 |
| & Lightning protection..... | — | — | 300 | 0 | 30 |
| 9. Extra insulation, storm doors and windows..... | — | — | 981 | 0 | 30 |
| TOTAL | | | \$11,381 | \$54 | |

* 1, installed collector cost assumed replaced in 5 yrs with total replacement in 30 yrs

ANNUAL ENERGY FLOWS
[Conventional reference system is IF-2]

| | Energy consumed by ref. system | Backup consumed w/ solar/conservation | Energy saved (% of total) |
|--|--------------------------------|---------------------------------------|---------------------------|
| Net Electricity (bought-sold) (MWh/unit)..... | 28.0 | 2.8 | 90.0 |
| Fuel consumed on site (MMBtu/unit)..... | 0. | 0. | 0. |
| Total energy requirement (bbt/crude equiv.)^a | 6s. | 7. | 90.0 |
| Electricity sold to grid annually (MWh, entire billing)..... | | | 14.4 |
| Annual peak electricity demand (kW, entire building)..... | | | 19.0 |

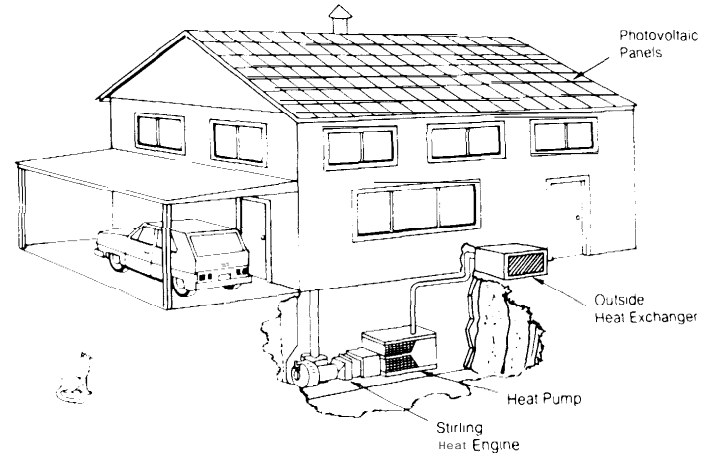
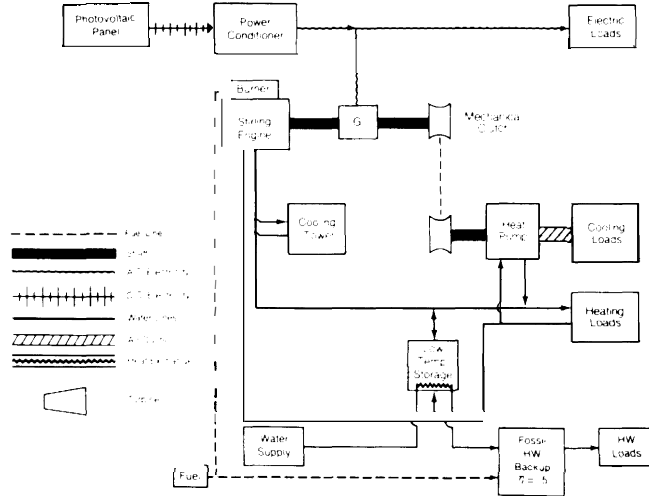
B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}
[Conventional reference system is IF-2]

| | Escalation of conventional energy costs | | |
|---|---|---------------------------|----------------------------|
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| 1. 1976 Startup | | | |
| a. Costs using solar (conservation) system: | | | |
| Total with no incentives..... | 133. (170.) | 144. (181.) | 190. (227.) |
| Total with 20% ITC..... | 125. (163.) | 136. (174.) | 182. (220.) |
| Total with full incentives..... | 106. (140.) | 118.6 (151.) | 164. (198.) |
| b. Costs using conventional reference system | 142. | | 275. |
| 2. 1985 Startup^d | | | |
| a. Costs using solar (conservation) system: | | | |
| (capital related costs)..... | 81. (118.) | 81. (118.) | 81. (118.) |
| (operation & maintenance)..... | 8. (8.) | 8. (8.) | 8. (8.) |
| (fuel bill)..... | 0. (0.) | 0. (0.) | 0. (0.) |
| (electric bill)..... | 44. (44.) | 61. (61.) | 133. (133.) |
| Total with no incentives..... | 133. (170.) | 150. (187.) | 222. (259.) |
| Total with 20% ITC..... | 125. (163.) | 142. (181.) | 214. (252.) |
| Total with full incentives..... | 106. (140.) | 124. (158.) | 196. (230.) |
| b. Costs using conventional reference system | 142. | 183. | 350. |

C. EFFECTIVE COST OF ENERGY TO CONSUMER
[Conventional reference system is IF-2]

| Levelized cost of solar energy or conservation ^a per \$ | Type of incentives given | | |
|--|---|---------------------------|----------------------------|
| | No incentives | 20% ITC | Full incentives |
| \$/MMBtu primary fuel..... | 2.00 (3.50) | 1.68 (3.23) | .94 (2.30) |
| ¢/kWh electricity..... | 2.36 (4.12) | 1.98 (3.80) | 1.10 (2.71) |
| | Escalation of conventional energy costs | | |
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| Levelized price paid for conventional energy ^{b,c} | | | |
| \$/MMBtu primary fuel..... | 3.72 | 4.68 | 8.60 |
| ¢/kWh electricity..... | 4.38 | 5.51 | 10.12 |

Table IV-43.—Albuquerque: Solar Photovoltaic System—Insulated Single Family House Using Flat-Plate Air-Cooled Silicon Arrays (\$0.50/Watt), Low-Temperature Thermal Storage; Building Equipped With Improved IF-2 Space-Conditioning



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O&P) | Annual O&M | life (yrs) |
|---|-------------------|----------------------|------------------------|--------------|------------|
| 1. Heat pump | 1.3 tons | 800 \$/ton | \$1,040 | \$50 | 10 |
| 2. Ductwork | — | — | 425 | 0 | 30 |
| 3. Electric hot water | 40 gal | \$225 ea. | 225 | 0 | 15 |
| 4. Air-cooled silicon PV (500 \$/kW)($\eta = 0.12$) | 59 m ² | 88 \$/m ² | *2,600 | 0 | 30 |
| —Silicon array @ 60 \$/m ² | | | *2,600 | 0 | 15 |
| —Shipping @ 2 \$/m ² | | | | | |
| —Installation @ 8 \$/m ² | | | | | |
| —25% overhead and profit | | | | | |
| 5. Power conditioning | 7 kW | 114 | 800 | 8 | 30 |
| 6. lightning protection | — | — | 300 | 0 | 30 |
| 7. Backup engine and generator | 6.53 kW | 225 \$/kW | 1,470 | 53 | 10 |
| 8. Hot water exchange | — | 33 ea. | 33 | 0 | 30 |
| 9. Low temperature stly. | 50 kWh | 2 \$/kWh | 100 | 0 | 30 |
| 10. Extra insulation, storm doors and windows | — | — | 981 | 0 | 30 |
| TOTAL | | | \$10,574 | \$111 | |

*1/3 installed collector cost assumed replaced in 15 yrs., with total replacement in 30 yrs.

ANNUAL ENERGY FLOWS

(Conventional reference system is IF-2)

| | Energy consumed by ref. system | Backup consumed w/ solar/conservation | Energy saved (% of total) |
|--|--------------------------------|---------------------------------------|---------------------------|
| Net Electricity (bought-sold)(MWh/unit) | 28.0 | 0. | 100.0 |
| Fuel consumed onsite(MMBtu/unit) | 0. | 86. | 0. |
| Total energy requirement (bbl crude equiv.)^a | 68. | 18. | 73.9 |
| Electricity sold to grid annually (MWh, entire building) | | | 0. |
| Annual peak electricity demand (kW, entire building) | | | 0. |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}
(Conventional reference system is IF-2)

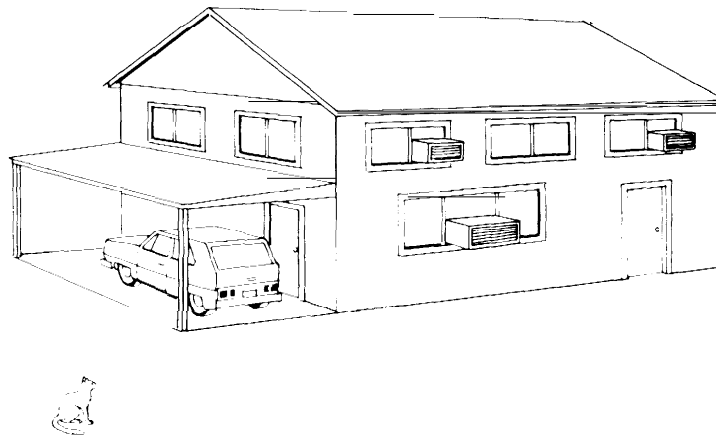
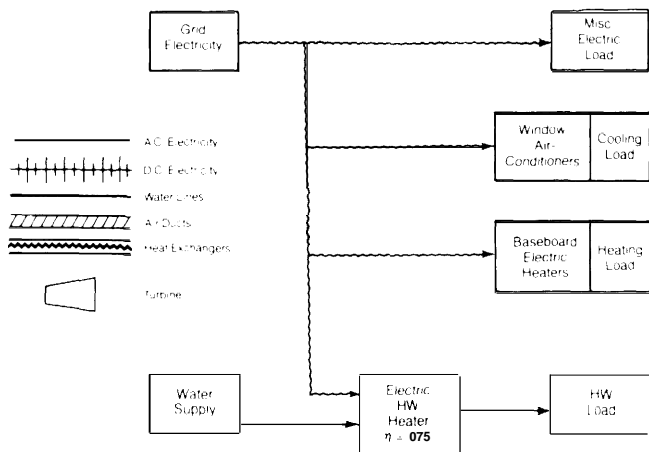
| | Escalation of conventional energy costs | | |
|---|---|---------------------------|----------------------------|
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| 1. 1976 Startup | | | |
| a. Costs using solar (conservation) system: | | | |
| Total with no incentives | 159. (211.) | 171. (224.) | 183. (235.) |
| Total with 20% IT... | 146. (200.) | 159. (213.) | 170. (224.) |
| Total with full incentives | 129. (164.) | 142. (177.) | 154. (188.) |
| b. Costs using conventional reference system | 142. | 168. | 276. |
| 2. 1985 Startup^d | | | |
| a. costs using solar (conservation) system: | | | |
| (capital related costs) | 124. (176.) | 124. (176.) | 124. (176.) |
| (operation & maintenance costs) | 16. (16.) | 16. (16.) | 16. (16.) |
| fuel bill | 19. (19.) | 38. (38.) | 57. (57.) |
| (electric bill) | 0. (0.) | 0. (0.) | 0. (0.) |
| Total with no incentives | 159. (211.) | 178. (231.) | 197. (249.) |
| Total with 20% IT... | 146. (200.) | 166. (220.) | 184. (238.) |
| Total with full incentives | 129. (164.) | 149. (184.) | 167. (202.) |
| b. Costs using conventional reference system | 142. | 183. | 330. |

C. EFFECTIVE COST OF ENERGY TO CONSUMER

(Conventional reference system is IF-2)

| Levelized cost of solar energy or 'conservation' energy ^e | Type of incentives given | | |
|--|-----------------------------|--|----------------------------|
| | No incentives | 20% ITC | Full incentives |
| \$/MMBtu primary load | 4.94 (7.52) | 4.32 (6.98) | 3.49 (5.20) |
| ¢/kWh electricity | 5.82 (8.85) | 5.08 (8.22) | 4.11 (6.12) |
| Levelized price paid for conventional energy^{b,c} | | | |
| | | Escalation of conventional energy cash | |
| | Constant real energy prices | Energy price escalation I | Energy price escalation II |
| \$/MMBtu primary load | 3.72 | 4.68 | 8.60 |
| ¢/kWh electricity | 4.38 | 5.51 | 10.12 |

Table [V.44.—Albuquerque: Conventional System—All Electric Single Family House Using Electric Resistance Heat and Window A/C (SF-3)



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O&P) | Annual O & M (Y in) | Lif. (Y in) |
|---------------------------------|-----------|------------|------------------------|---------------------|-------------|
| 1. Baseboard electric heat..... | 13.1 | 67 \$/kW | \$878 | | 30 |
| 2. Window electric a/c..... | 1.85 tons | 280 \$/ton | 518 | \$3: | 10 |
| 3. Electric water heater..... | 40 gal | \$225 ea. | 225 | 0 | 15 |
| TOTAL..... | | | \$1,621 | \$30 | |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}
(Conventional reference system is SF-3)

| | Escalation of conventional energy costs | | | | | |
|--------------------------------------|---|--------|---------------------------|--------|----------------------------|--------|
| | Constant real energy prices | | Energy price escalation I | | Energy price escalation II | |
| 1. 1976 Startup | | | | | | |
| Total with no incentives..... | 177. | (185.) | 216. | (224.) | 378. | (386.) |
| Total with 20% IT..... | 177. | (185.) | 216. | (224.) | 378. | (386.) |
| Total with full incentives..... | 177. | (185.) | 216. | (224.) | 378. | (386.) |
| 2. 1985 Startup^d | | | | | | |
| (capital related costs)..... | 19. | (27.) | 19. | (27.) | 19. | (27.) |
| (operation & maintenance costs)..... | 4. | (4.) | 4. | (4.) | 4. | (4.) |
| (fuel bill)..... | 0. | (0.) | 0. | (0.) | 0. | (0.) |
| (electric bill)..... | 153. | (153.) | 215. | (215.) | 467. | (467.) |
| Total with no incentives..... | 177. | (185.) | 239. | (246.) | 490. | (498.) |
| Total with 20% IT..... | 177. | (185.) | 239. | (246.) | 490. | (498.) |
| Total with full incentive..... | 177. | (185.) | 239. | (246.) | 490. | (498.) |

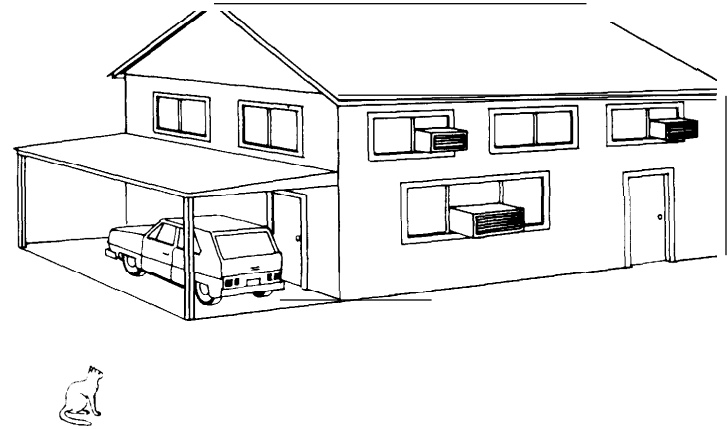
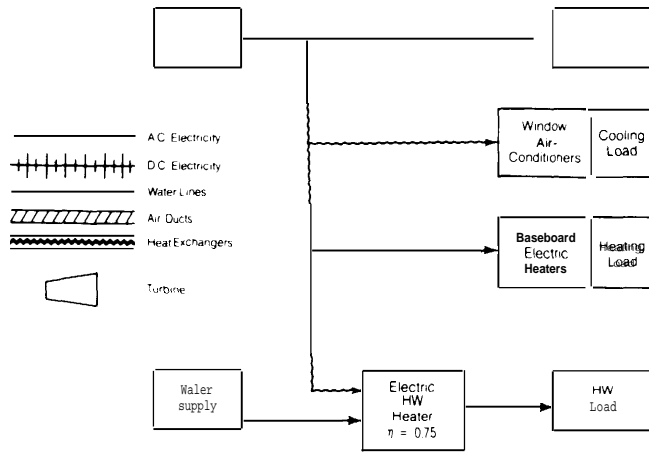
C. EFFECTIVE COST OF ENERGY TO CONSUMER
(Conventional reference system is SF-3)

ANNUAL ENERGY FLOWS
(Conventional reference system is SF-3)

| | Energy consumed by ref. system | Backup consumed solar/conservation | Energy saved (% of total) |
|--|--------------------------------|------------------------------------|---------------------------|
| Net Electricity (bought/sold) (MWh/unit)..... | 43.8 | 43.8 | 0. |
| Fuel consumed on site (MMBtu/unit)..... | 0. | 0. | 0. |
| Total energy requirement (bbl crude equiv.)^a | 107. | 107. | 0. |
| Electricity sold to grid annually (MWh, entire building)..... | | | 0. |
| Annual peak electricity demand (kW, entire building) | | | 27.3 |

| Levelized cost of solar energy or 'conservation' energy ^a | Type of incentives given | | | | | |
|--|---|-------|---------------------------|-------|----------------------------|-------|
| | No incentives | | 20% ITC | | Full incentives | |
| \$/MMBtu primary fuel..... | N/A | (N/A) | N/A | (N/A) | N/A | (N/A) |
| ¢/kWh electricity..... | N/A | (N/A) | N/A | (N/A) | N/A | (N/A) |
| | Escalation of conventional energy costs | | | | | |
| | Constant real energy prices | | Energy price escalation I | | Energy price escalation II | |
| Levelized price paid for conventional energy ^{b,*} | | | | | | |
| \$/MMBtu primary fuel..... | 3.57 | | 4.49 | | 8.25 | |
| ¢/kWh electricity..... | 4.20 | | 5.29 | | 9.72 | |

Table IV-45.—Albuquerque: Conventional System—All Electric Single Family I-House Using Electric Resistance Heat and Window A/C, 65/85 Thermostat Settings (SF-3)



A. ITEMIZED COST OF COMPONENTS

| Component | Size | Unit cost | First cost (incl. O & P) | Annual O&M (yrs) | Life |
|---------------------------------|-----------|------------|--------------------------|------------------|------|
| 1. Baseboard electric heat..... | 13.1 | 67 \$/kW | \$878 | 0 | 30 |
| 2. Window electric a/c..... | 1.85 tons | 280 \$/ton | 518 | \$30 | 10 |
| 3. Electric water heater..... | 40 gal | \$225 ea. | 225 | 0 | 15 |
| TOTAL | | | \$1,621 | \$30 | |

B. LEVELIZED MONTHLY COSTS PER UNIT TO CONSUMER (Dollars)^{b,c}

(Conventional reference system is SF-3)

| | Escalation of conventional energy costs | | | |
|--|---|--------------------|---------------------------|----------------------------|
| | constant energy prices | real energy prices | Energy price escalation I | Energy price escalation II |
| 1. 1976 Startup | | | | |
| 0. Costs using solar (conservation) system: | | | | |
| Total with no incentives..... | 171. | (179.) | 209. | (217.) |
| Total with 20% ITC..... | 171. | (179.) | 209. | (217.) |
| Total with full incentives..... | 171. | (179.) | 209. | (217.) |
| b. Costs using conventional reference system..... | 177. | | 216. | 378 |
| 2. 1985 Startup^d | | | | |
| a. Costs using solar (conservation) system: | | | | |
| (capital related costs)..... | 19. | (27.) | 19. | (27.) |
| (operation & maintenance costs)..... | 4. | (4.) | 4. | (4.) |
| (fuel bill)..... | 0. | (0.) | 0. | (0.) |
| electric &..... | 147. | [147.] | 207. | (207.) |
| Total with no incentives..... | 171. | (179.) | 230. | (238.) |
| Total with 20% ITC..... | 171. | (179.) | 230. | (238.) |
| Total with full incentives..... | 171. | (179.) | 230. | (238.) |
| b. Costs using conventional reference system..... | 177. | | 239. | 490. |

C. EFFECTIVE COST OF ENERGY TO CONSUMER

Conventional reference system is SF-3)

| Levelized cost of solar energy or 'conservation' energy ^e | Type of incentives given | | |
|--|---|---------------------------|----------------------------|
| | No incentives | 20% ITC | Full incentives |
| \$/MMBtu primary fuel..... | -0.00 [4.36] | -0.00 (4.36) | -0.00 (4.36) |
| ¢/kWh electricity..... | -0.00 (5.13) | -0.00 (5.13) | -0.00 (5.13) |
| Levelized price paid for conventional energy^{b,a} | Escalation of conventional costs | | |
| | constant energy prices | Energy price escalation I | Energy price escalation II |
| \$/MMBtu primary fuel..... | 3.57 | 4.49 | 8.25 |
| ¢/kWh electricity..... | 4.20 | 5.29 | 9.72 |

ANNUAL ENERGY FLOWS

(Conventional reference system is SF-3)

| | Energy consumed by ref. system | Backup consumed w/ solar/conservation | Energy saved (% cd total) |
|--|--------------------------------|---------------------------------------|---------------------------|
| Net Electricity (bought-sold) (MWh/unit)..... | 43.8 | 42.0 | 4.2 |
| Fuel consumed onsite (MMBtu/unit)..... | 0. | 0. | 0. |
| Total energy requirement (bbl crude equiv.) ^f | 107. | 103. | 4.2 |
| Electricity sold to grid annually (MWh, entire building)..... | | | 0. |
| Annual peak electricity demand (kW, entire building)..... | | | 27.3 |

Note:

From this point onward, this report consists of approximately 500 pages of tables in very small fonts that were unsuitable for conversion using optical character recognition. The pages may be posted to the version of the report stored on the OTA websites, but they will inevitably contain many recognition errors, and users that wish to consult these tables should consider obtaining a paper or microfilm copy through NTIS or through a library.