Economics

WORKSHOP IN

THE PRACTICAL ASPECTS OF

SOLAR SPACE AND DOMESTIC WATER HEATING SYSTEMS

FOR

RESIDENTIAL BUILDINGS

MODULE 12

ECONOMIC CONSIDERATIONS

SOLAR ENERGY APPLICATIONS LABORATORY

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INTRODUCTION

Solar heating systems involve higher capital costs than conventional systems and economic evaluations invariably involve cost comparisons between the two systems. Comparisons which do not account for future fuel cost savings for heating are both misleading and unfavorable to solar systems. By accounting for capital and operating costs of heating alternatives over a period of time, deemed to be the "life" of the systems, the relative economic merits of "paying for hardware" or "paying for energy" can be determined. Thus life-cycle costing methods have generally been used to make economic comparisons although speculative assumptions for the rate of increases in the energy prices, discount rates, costs for goods and services, property tax, insurance and income tax deductions are used in the analysis. While life-cycle cost analysis is a fair method for comparing solar and non-solar systems, homeowners may also consider annual cash flow differences between the two types of heating systems. Explanations for both methods are included in this module.

OBJECTIVES

The objectives of this module are to describe methods for life-cycle cost and cash flow analyses to compare solar and non-solar systems. The participant of this workshop should be able to:

1. Estimate the installed cost of a solar system,
2. Establish the economic feasibility of a solar system.

FACTORS IN ANALYSES

The total cost of a solar heating system, over the life of the system, includes (1) capital and installation costs or mortgage payments for money borrowed to pay for the installed system, (2) fuel cost for the auxiliary unit, and (3) operating and maintenance (O and M) costs. With a non-solar heating system the capital and O and M costs are small but fuel costs are high (and rising steadily). A solar system has large capital costs, lower fuel costs, and non-negligible O and M costs. A comparison is necessary to determine whether a solar system is economical compared to a non-solar system and the comparison is usually made for a selected number of years which is estimated to be the "life" of a system. A life-cycle cost analysis is first explained followed by an annual cash flow analysis.

The yearly cash flow for a residential solar heating system is:

$$\begin{aligned}\text{Yearly cost with solar} = {} & \text{Mortgage payment} + \text{Auxiliary fuel cost} + \text{Property tax increase} + \text{Insurance premium} \\ & + \text{Operating costs} + \text{Maintenance cost} - \text{Income tax savings for interest and taxes paid}\end{aligned} \tag{12-1}$$

whereas for a non-solar system,

$$\text{Yearly cost for non-solar} = \text{Fuel cost} + \text{Operating and maintenance costs} \tag{12-2}$$

In commercial buildings there are other factors such as depreciation of equipment and salvage value to be considered.

The sum of the yearly cash flows over the "life" of the system can be construed as the life-cycle cost of the system, and the costs of the solar and non-solar systems can be compared over an equal life-time of n years, to determine which system would be more expensive.

Cash flow calculations should include inflation, with fuel costs perhaps increasing more rapidly than costs of general goods and services (at least in the near term). The use of different inflation factors for the items in Equation (12-1) or (12-2) in effect gives more weight to some cost items over others, say fuel costs over mortgage payments as an example, particularly if mortgage payment is fixed and fuel cost rises.

Because the sum of annual cash flows for both solar and non-solar systems would in effect add different value dollars each year as a consequence of inflation, a more appropriate economic comparison is made on the basis of present worth which discounts future expenditures to the value of first year dollars. Hence, when the present worth of future annual expenditures are added, equivalent value dollars are being added. When the inflation and discount factors are taken into consideration in a life-cycle cost analysis, Equations (12-1) and (12-2) may be rewritten as follows:

$$C_T(\text{solar}) = (AC_a)E_1 + C_oE_o + C_mE_m + (1-F)Lc_fE_f \qquad (12\text{-}3)$$

and

$$C_{TC}(\text{non-solar}) = C_{oc}E_o + C_{mc}E_m + Lc_fE_f \qquad (12\text{-}4)$$

where A is the collector area, ft^2

C_T is the total life-cycle cost of the solar system, \$

C_{TC} is the total life-cycle cost of the non-solar system, \$

C_a is the installed cost of the solar system per unit collector area, $\$/ft^2$

C_o is the first year operating cost for the solar system, \$/yr

C_{oc} is the first year operating cost for the non-solar system, \$/yr

C_m is the first year maintenance cost for the solar system, \$/yr

c_{mc} is the first year maintenance cost for the non-solar system, $/yr

c_f is the first year fuel cost per unit of delivered heat, $/MMBtu

E_l is an economic factor which accounts for downpayment, mortgage interest rate, insurance rate, property tax rate, income tax saving, inflation rate, and market discount rate

E_o is an economic factor which accounts for inflation rate of operating cost and market discount rate

E_m is an economic factor which accounts for inflation rate of maintenance cost and market discount rate

E_f is an economic factor which accounts for fuel inflation rate and market discount rate

F is the fraction of annual heat provided by the solar system

L is an annual heating load for the building, MMBtu

The economic factors, E_o, E_m, and E_f are the sums of annual compounded inflation factors discounted annually to present worth. The present worth of the sum of an annuity over a life time of n years inflated at a constant rate and discounted at a constant rate can be written as:

$$P/X(d,r,n) = \frac{(1+d)^n-(1+r)^n}{(1+d)^n(d-r)} \text{ for } d \neq r \qquad (12\text{-}5)$$

and

$$P/X(d,r,n) = n/(1+r) \text{ for } d = r \qquad (12\text{-}6)$$

where P is the present value of an annuity over n years

X is the first year cost

d is the discount rate

r is the inflation rate

n is the years of analysis or life of the system

The notation (d,r,n) after P/X indicates that the value of P/X refers to values of d, r, and n, placed in the appropriate terms in

Equations (12-5) and (12-6). Tables of P/X values are provided in this module for an appropriate range of d, r, and n in Tables 12-1 through 12-6.

The economic factors can now be expressed as:

$$E_o = P/X(d,r_o,n) \text{ years} \quad (12\text{-}7)$$

$$E_m = P/X(d,r_m,n) \text{ years} \quad (12\text{-}8)$$

$$E_f = P/X(d,r_f,n) \text{ years} \quad (12\text{-}9)$$

The economic factor E_1 is slightly more involved and is expressed as:

$$E_1 = \alpha + [(1 - t)p + h)]P/X(d,g,n) + (1 - \alpha)[(1 - t)\frac{P/X\ (d,0,m)}{P/X\ (i,0,m)} + (t)\frac{P/X\ (d,i,m)}{P/X\ (0,i,m)}] \quad (12\text{-}10)$$

where

α is the downpayment rate in the terms of the loan and fixed mortgage payment is assumed

t is the effective income tax rate of the owner,

p is the property tax rate based on initial capital cost (first year market value),

h is the insurance premium rate,

g is the inflation rate for general cost of goods and services (general inflation rate),

i is the interest rate of the loan,

m is the term (years) of the loan

Values of P/X (a,b,c) may be determined from Tables 12-1 through 12-6 by referring to the appropriate values in the tables as indicated by the terms in the parentheses following P/X. For example, P/X (d,0,m) may be determined by consulting the appropriate discount rate d, rate of annual increase 0, (zero), and years m.

Table 12-1

Values of P/X (d, r, n) for Discount Rate of 0 Percent

Years	Annual Rate of Increase					
	0	3	6	8	10	12
10	10.0	11.464	13.181	14.487	15.937	17.549
11	11.0	12.808	14.972	16.645	18.531	20.655
12	12.0	14.192	16.870	18.977	21.384	24.133
13	13.0	15.618	18.882	21.495	24.523	28.029
14	14.0	17.086	21.015	24.215	27.975	32.393
15	15.0	18.599	23.276	27.152	31.772	37.280
16	16.0	20.157	25.673	30.324	35.950	42.753
17	17.0	21.762	28.213	33.750	40.545	48.884
18	18.0	23.414	30.906	37.450	45.599	55.750
19	19.0	25.117	33.760	41.446	51.159	63.440
20	20.0	26.870	36.786	45.762	57.275	72.052
21	21.0	28.676	39.993	50.423	64.002	81.669
22	22.0	30.537	43.392	55.457	71.403	92.503
23	23.0	32.453	46.996	60.893	79.543	104.603
24	24.0	34.426	50.816	66.765	88.497	188.155
25	25.0	36.459	54.865	73.106	98.347	133.334
26	26.0	38.553	59.156	79.954	109.182	150.334
27	27.0	40.710	63.706	87.351	121.100	169.374
28	28.0	42.931	68.528	95.339	134.210	190.699
29	29.0	45.219	73.640	103.966	148.631	214.583
30	30.0	47.575	79.058	113.283	164.494	241.333

Table 12-2

Values of P/X (d, r, n) for Discount Rate of 4 Percent

Years	Annual Rate of Increase					
	0	3	6	8	10	12
10	8.111	9.210	10.492	11.462	12.537	13.727
11	8.760	10.083	11.655	12.865	14.222	15.845
12	9.385	10.947	12.841	14.321	16.004	17.918
13	9.986	11.804	14.049	15.833	17.889	20.258
14	10.563	12.652	15.281	17.404	19.883	22.777
15	11.118	13.492	16.536	19.035	21.991	25.491
16	11.652	14.323	17.816	20.728	24.222	28.413
17	12.166	15.147	19.120	22.487	26.580	31.561
18	12.659	15.963	20.449	24.314	29.076	34.950
19	13.134	16.771	21.804	26.210	31.714	38.600
20	13.590	17.571	23.185	28.180	34.506	42.531
21	14.029	18.364	24.592	30.225	37.458	46.764
22	14.451	19.149	26.027	32.349	40.581	51.322
23	14.857	19.926	27.489	34.555	43.883	56.232
24	15.247	20.696	28.979	36.846	47.377	61.519
25	15.622	21.459	30.498	39.224	51.071	67.213
26	15.983	22.214	32.046	41.695	54.979	73.344
27	16.330	22.962	33.623	44.260	59.113	79.448
28	16.663	23.703	35.232	46.924	63.485	87.059
29	16.984	24.436	36.871	49.690	69.109	94.718
30	17.292	25.163	38.541	52.563	73.000	102.965

Table 12-3

Values of P/X (d, r, n) for Discount Rate of 6 Percent

Years	Annual Rate of Increase					
	0	3	6	8	10	12
10	7.360	8.319	9.434	10.277	11.208	12.238
11	7.887	9.027	10.377	11.414	12.575	13.874
12	8.384	9.715	11.321	12.573	13.993	15.603
13	8.853	10.383	12.264	13.753	15.464	17.430
14	9.295	11.033	13.208	14.956	16.991	19.360
15	9.712	11.664	14.151	16.182	18.575	21.399
16	10.106	12.277	15.094	17.430	20.220	23.553
17	10.477	12.873	16.038	18.703	21.926	25.830
18	10.828	13.452	16.981	19.999	23.697	28.236
19	11.158	14.015	17.925	21.320	25.535	30.777
20	11.470	14.562	18.868	22.665	27.442	33.463
21	11.764	15.093	19.811	24.036	29.421	36.300
22	12.042	15.609	20.755	25.433	31.474	39.298
23	12.303	16.111	21.698	26.857	33.605	42.466
24	12.550	16.598	22.642	28.307	35.817	45.813
25	12.783	17.072	23.585	29.784	38.112	49.350
26	13.003	17.532	24.528	31.290	40.493	53.087
27	13.211	17.979	25.472	32.823	42.965	57.035
28	13.406	18.414	26.415	34.386	45.530	61.207
29	13.591	18.836	27.358	35.978	48.191	65.615
30	13.765	19.246	28.302	37.601	50.953	70.272

Table 12-4

Values of P/X (d, r, n) for Discount Rate of 8 Percent

Years	Annual Rate of Increase					
	0	3	6	8	10	12
10	6.710	7.550	8.525	9.259	10.070	10.965
11	7.139	8.127	9.293	10.185	11.183	12.297
12	7.536	8.676	10.046	11.111	12.316	13.679
13	7.904	9.200	10.786	12.037	13.470	15.111
14	8.244	9.700	11.513	12.963	14.645	16.597
15	8.559	10.177	12.225	13.889	15.842	18.137
16	8.851	10.632	12.926	14.815	17.061	19.735
17	9.122	11.066	13.611	15.741	18.303	21.392
18	9.372	11.479	14.285	16.667	19.568	23.110
19	9.604	11.874	14.947	17.593	20.856	24.892
20	9.818	12.250	15.596	18.519	22.169	26.740
21	10.017	12.609	16.233	19.444	23.505	28.656
22	10.201	12.951	16.858	20.370	24.866	30.643
23	10.371	13.277	17.472	21.296	26.253	32.704
24	10.529	13.589	18.074	22.222	27.665	34.841
25	10.675	13.885	18.666	23.148	29.103	37.058
26	10.810	14.169	19.246	24.074	30.568	39.356
27	10.935	14.438	19.815	25.000	32.060	41.740
28	11.051	14.696	20.374	35.926	33.580	44.212
29	11.158	14.942	20.923	26.852	35.127	46.775
30	11.258	15.176	21.461	27.778	36.704	49.433

Table 12-5

Values of P/X (d, r, n) for Discount Rate of 10 Percent

Years	Annual Rate of Increase					
	0	3	6	8	10	12
10	6.145	6.884	7.739	8.382	9.091	9.872
11	6.495	7.355	8.366	9.139	10.000	10.961
12	6.814	7.796	8.971	9.882	10.909	12.069
13	7.103	8.209	9.554	10.611	11.818	13.197
14	7.367	8.596	10.116	11.377	12.727	14.346
15	7.606	8.958	10.657	12.030	13.636	15.516
16	7.824	9.297	11.179	12.721	14.545	16.708
17	8.022	9.614	11.681	13.399	15.455	17.920
18	8.201	9.911	12.166	14.064	16.365	19.155
19	8.365	10.190	12.632	14.717	17.273	20.413
20	8.514	10.450	13.082	15.359	18.182	21.693
21	8.649	10.695	13.515	15.989	19.091	22.997
22	8.772	10.923	13.933	16.607	20.000	24.324
23	8.883	11.137	14.335	17.214	20.909	25.675
24	8.985	11.337	14.723	17.810	21.818	27.051
25	9.077	11.525	15.097	18.396	22.727	28.452
26	9.161	11.701	15.457	18.970	23.636	29.878
27	9.237	11.865	15.804	19.534	24.545	31.331
28	9.307	12.019	16.138	20.088	25.455	32.809
29	9.370	12.613	16.461	20.632	26.364	34.315
30	9.427	12.299	16.771	21.166	27.273	35.848

Table 12-6

Values of P/X (d, r, n) for Discount Rate of 12 Percent

Years	Annual Rate of Increase					
	0	3	6	8	10	12
10	5.650	6.303	7.057	7.822	8.244	8.929
11	5.938	6.690	7.571	8.243	8.990	9.821
12	5.194	7.045	8.059	8.841	9.722	10.714
13	6.424	7.372	8.520	9.418	10.441	11.607
14	6.628	7.672	8.956	9.975	11.148	12.500
15	6.811	7.949	9.369	10.511	11.842	13.393
16	6.974	8.203	9.760	11.029	12.523	14.286
17	7.120	8.436	10.130	11.528	13.192	15.179
18	7.250	8.651	10.480	12.009	13.850	16.071
19	7.366	8.849	10.812	12.473	14.495	16.964
20	7.469	9.031	11.125	12.920	15.129	17.857
21	7.562	9.198	11.422	13.352	15.752	18.758
22	7.645	9.352	11.703	13.768	16.363	19.643
23	7.718	9.493	11.969	14.169	16.964	20.536
24	7.784	9.623	12.221	14.556	17.554	21.429
25	7.843	9.743	12.459	14.929	18.133	22.321
26	7.896	9.853	12.684	15.288	18.702	23.214
27	7.943	9.954	12.898	15.635	19.261	24.107
28	7.984	10.047	13.100	15.970	19.810	25.00
29	8.022	10.132	13.291	16.292	20.349	25.893
30	8.055	10.211	13.472	16.603	20.879	26.786

EXAMPLE 12-1

Determine the economic factors E_o, E_m, and E_f if the manual rate of increase for operating cost, r_o, is 10 percent, annual rate of increase for maintenance, r_m, is 6 percent, annual rate of increase for fuel, r_f, is 12 percent, and the discount rate is 8 percent for a life span of 20 years.

Solution:

E_o = P/X (8,10,20) = 22.169 (from Table 12-4)

E_m = P/X (8,6,20) = 15.596 (from Table 12-4)

E_f = P/X (8,12,20) = 26.740 (from Table 12-4)

EXAMPLE 12-2

Determine the economic factor E_1 if the terms of the loan are m = 25 years, i = 10 percent, and α = 20 percent downpayment. The property tax rate, p, is 3 percent and insurance rate, h, is 0.3 percent of market value, general inflation, g, is 6 percent, and the effective income tax rate is 35 percent. The market discount rate, d, is 8 percent.

Solution:

For Equation (12-10), find appropriate P/X values from the tables.

P/X (d,g,n) = P/X (8,6,20) = 15.596

P/X (d,0,m) = P/X (8,0,25) = 10.675

P/X (i,0,m) = P/X (10,0,25) = 9.077

P/X (d,i,m) = P/X (8,10,35) = 29.103

P/X (0,i,m) = P/X (0,10,25) = 98.347

$\alpha = 0.20$

$t = 0.35$

$p = 0.03$

$h = 0.003$

Thus,

$$E_1 = 0.20 + [(1-.35)(0.03)+0.003](15.596)$$
$$+ (1-0.2)[(1-.35)\frac{10.675}{9.077} + (0.35)\frac{29.103}{98.347}]$$
$$E_1 = 1.245 \qquad \text{(ans)}$$

EXAMPLE 12-3

Determine the present values of life-cycle costs of a solar system, a non-solar system and the savings with a solar system, given the following information:

$A = 500\ ft^2$	$r_m = 6\%$
$C_a = 26\ \$/ft^2$	$r_f = 12\%$
$C_o = 87\ \$/yr$	$m = 25$ years
$C_{oc} = 20\ \$/yr$	$i = 10\%$
$C_m = 100\ \$/yr$	$\alpha = 20\%$ down
$C_{mc} = 10\ \$/yr$	$p = 3\%$ of market value
$F = 0.68$	$h = 0.3\%$ of market value
$c_f = 10.25$ R/MMBtu	$g = 6\%$
$L = 130$ MMBtu	$t = 35\%$
$r_o = 10\%$	$d = 8\%$

Solution:

The equation to apply for the solar system is Equation (12-13).

From Example 12-1, $E_o = 22.169$, $E_m = 15.596$, $E_f = 26.740$.

From Example 12-2, $E_1 = 1.245$

Therefore,

$$C_T = (500)(26)(1.245) + (87)(22.169) + (100)(15.596) + (1 - .68)(130)(10.25)(26.740)$$

C_T = \$31,075 present value over 20 years of life

The equation to apply to the non-solar system is Equation (12-4).

$$C_{TC} = (20)(22.169) + (20)(15.596) + (130)(10.25)(26.740)$$

C_{TC} = \$36,230 present value over 20 years of life

The cost of the non-solar is clearly larger than the cost of the solar system. The difference, or savings realizable with the solar system, is:

$$\text{Present value of savings} = C_{TC} - C_T = 36,230 - 31,075 = \$5155$$

While in Example 12-3 the present values of the total costs for systems and life time savings are determinable, the calculations are restricted to fixed annual increases, fixed discount rates, fixed property tax and insurance rates, and fixed income tax rates for the owner. These rates are, of course, uncertain in future years and highly variable. If variable rates are to be applied, a detailed year by year analysis of cash flow and present worth discounting must be carried out, using the basic form of Equations (12-1) and (12-2).

Annual cash flows are calculated for a system and the annual cost may be discounted to present value. The cost in a future year may be discounted to present worth by multiplying the cost by the present worth factor, P, in:

$$P = \frac{1}{(1+d)^q} \qquad (12\text{-}11)$$

where

q is any year in the analysis period from 1 to n

d is the market discount rate

Values of P for practical ranges of d an q are tabulated in Table 12-7.

ENERGY COSTS

The conversion of unit costs of energy to dollars per million Btu ($/MMBtu) with various furnace efficiencies are shown on Figure 12-1 for natural gas, propane, and No. 2 fuel oil. The conversion of electric energy costs to dollars per million Btu for resistance heating and heat pumps with various coefficients of performance are shown on Figure 12-2. To determine the cost per million Btu of heat generated from furnaces, electric resistance heaters, or heat pumps, follow the unit cost of energy, found on the horizontal axis of the graphs, vertically to the appropriate line on the graph and read the cost in dollars along the vertical axis. For example, if No. 2 fuel oil cost fifty cents per gallon, and the furnace efficiency is 60 percent, the energy cost is $6.00/mBtu or 60 cents per therm (¢/therm). If the furnace is more efficient, say 70 percent, the energy cost is $5.10/MMBtu or 51 ¢/therm. Similarly, if electricity costs three cents per kilowatt-hour (C/kWh), and resistance heating is used, the energy cost is $8.80/MMBtu. If a heat pump is used, and the COP of the heat pump is 2, the energy cost is $4.40/MMBtu.

The cost of energy will increase in future years and an estimate of the rate of increase is subject not only to inflation rates of goods and services, but also to economic and political decisions of the federal government and the governments of other nations. One expects, however, the rate of fuel cost increases to be different from "normal" inflation rates and higher by a few percent, at least for the immediate future.

Table 12-7

Present Worth Factors (P)

(use for Worksheet LCA-4)

Year of Analysis	6	7	8	9	10	11	12	13	14	15	16
1	.943	.935	.926	.917	.909	.901	.893	.885	.877	.870	.862
2	.890	.873	.857	.842	.826	.812	.797	.783	.769	.756	.743
3	.840	.816	.794	.772	.751	.731	.712	.693	.675	.658	.641
4	.792	.763	.735	.708	.683	.659	.636	.613	.592	.572	.552
5	.747	.713	.681	.650	.621	.593	.567	.543	.519	.497	.476
6	.705	.666	.630	.596	.564	.535	.507	.480	.456	.432	.410
7	.665	.623	.583	.547	.513	.482	.452	.425	.400	.376	.354
8	.627	.582	.540	.502	.467	.434	.404	.376	.351	.327	.305
9	.592	.544	.500	.460	.424	.391	.361	.333	.308	.284	.263
10	.558	.508	.463	.422	.386	.352	.322	.295	.270	.247	.227
11	.527	.475	.429	.388	.350	.317	.287	.261	.237	.215	.195
12	.497	.444	.397	.356	.319	.286	.257	.231	.208	.187	.168
13	.469	.415	.368	.326	.290	.258	.229	.204	.182	.163	.145
14	.442	.388	.340	.299	.263	.232	.205	.181	.160	.141	.125
15	.417	.362	.315	.275	.239	.209	.183	.160	.140	.123	.108
16	.394	.339	.292	.252	.218	.188	.163	.141	.123	.107	.093
17	.371	.317	.270	.231	.198	.170	.146	.125	.108	.093	.080
18	.350	.296	.250	.212	.180	.153	.130	.111	.095	.081	.069
19	.331	.277	.232	.194	.164	.138	.116	.098	.083	.070	.060
20	.312	.258	.215	.178	.149	.124	.104	.087	.073	.061	.051
21	.294	.242	.199	.164	.135	.112	.093	.077	.064	.053	.044
22	.278	.226	.184	.150	.123	.101	.083	.068	.056	.046	.038
23	.262	.211	.170	.138	.112	.091	.074	.060	.049	.040	.033
24	.247	.197	.158	.126	.102	.082	.066	.053	.043	.035	.028
25	.233	.184	.146	.116	.092	.074	.059	.047	.038	.030	.024

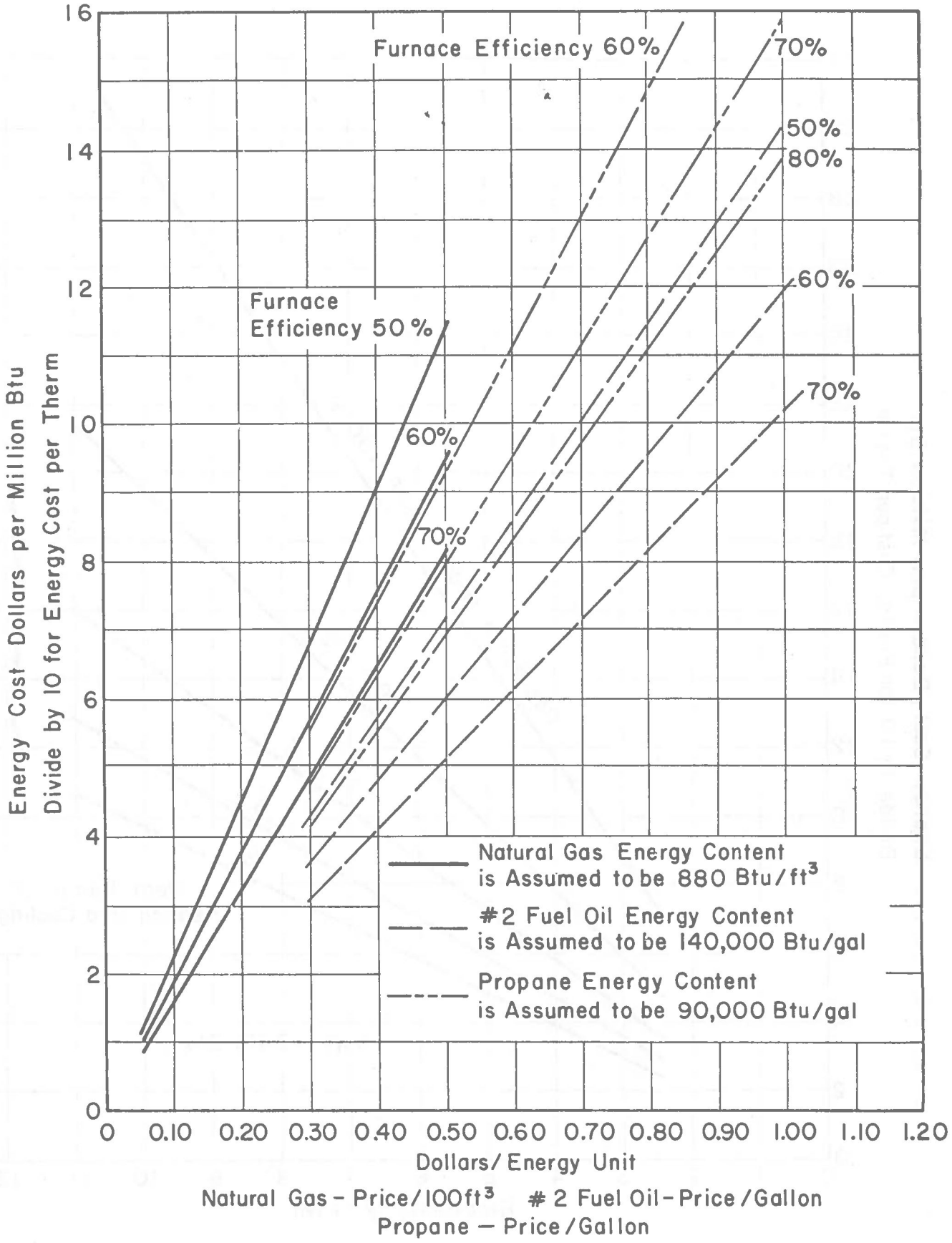

Figure 12-1. Energy Cost per Million Btu for Natural Gas, Propane and No. 2 Fuel Oil

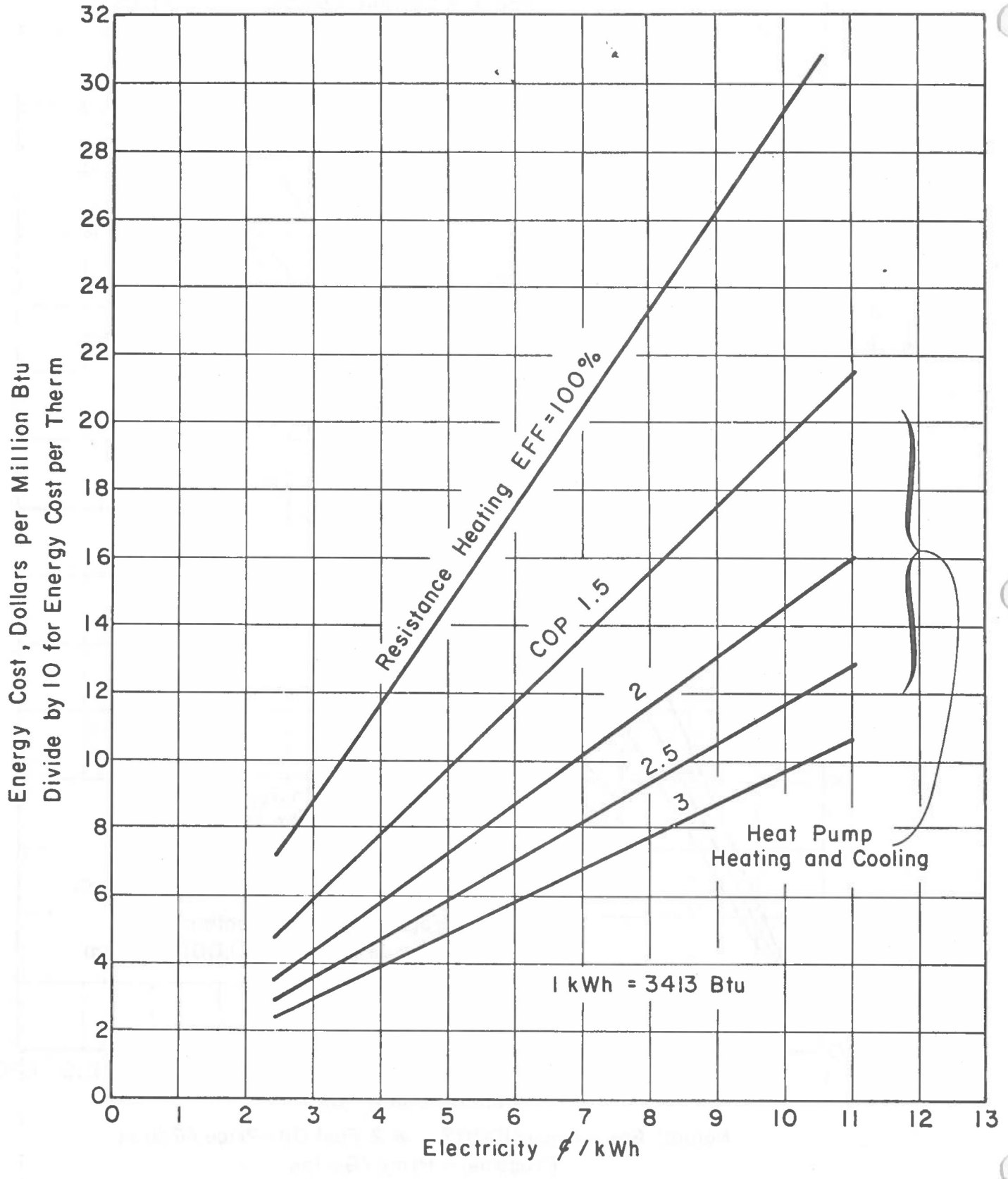

Figure 12-2. Energy Cost per Million Btu for Electricity

INFLATION RATES

The increases in costs per unit of energy, several years in the future in terms of cents per gallon, cents per kilowatt-hour, cents per hundred cubic feet of natural gas, or dollars per therm, can be estimated on the basis of annual percentage of increases over current costs. The multiplying factors for current energy costs to determine future costs is shown on Figure 12-3. The horizontal axis is the years beyond the current year. The vertical axis gives the multiplying factor over current costs, and is simply the interest compounded annually, $(1 + i)^n$.

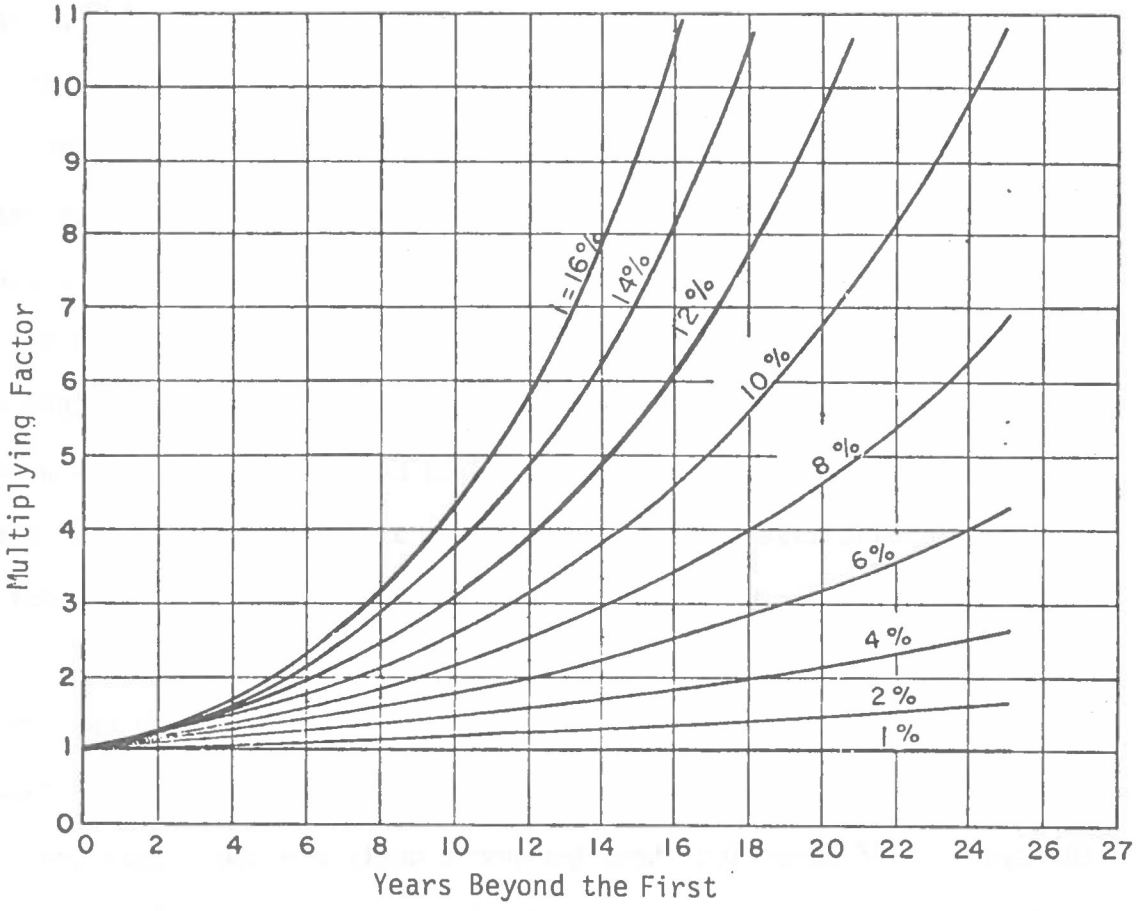

Figure 12-3. Inflation Factors

For example, if the current cost of electricity is expected to increase at a rate of 6 percent each year for the next 12 years, at the end of 12 years the electricity cost will double. If 3 cent per kilowatt-hour is the current cost and heating cost is $8.80 per million Btu, at the end of 12 years the electricity will cost 6 cents per kilowatt-hour and $17.80 per million Btu.

SOLAR SYSTEM COSTS

There is much speculation about the installed costs of solar systems and there is little information available to substantiate published information on costs. System costs based on research projects and demonstration projects funded by the federal government are misleading because the total costs of such projects include considerable engineering design costs and research staff costs. In some instances instrument costs for monitoring the performance of experimental systems, and often development costs of several alternative components in the systems are also included. The costs reported in popular magazines and newspaper accounts are likewise misleading because often systems which are designed and assembled by the owner on a do-it-yourself basis are cited and costs for the owners's time is seldom included in the cost quotations.

Guidelines are provided below to estimate the installed cost of a solar system including equipment costs and the cost of labor to install the system. Of these two items equipment costs are the largest and easiest to estimate, largely by consulting manufacturer's literature and price lists. Estimating labor costs is more difficult because it

depends upon the type of installation, location of the house and experience of the installer. Some ranges in prices for equipment and estimates in terms of man-hours for installation of systems in new buildings are listed below to provide cost estimating guidelines.

EQUIPMENT AND INSTALLATION TIME ESTIMATES

Liquid-Heating Systems

Typical equipment and material prices (in 1978) are listed below.

Item	Unit	Price Range (in dollars)		
		Low	Medium	High
Flat-plate collectors and mounting hardware	ft^2	10	15	24
Storage tank	750-1200 gal capacity	1000	1500	2500
Pumps and motor	10-20 gpm	80	180	350
Heat exchanger	each	200	300	400
Controls and sensors	each	500	750	1500
Piping (3/4 inch copper)	ft	.45	.60	.80-.85
Valves	each	20	30	45
Misc. fittings	-	200	250	350
Expansion tank	-	60	80	100
Insulation	-	500	750	1000
DHW Preheat tank	each	80	100	150

Installation time estimates for typical liquid-heating systems are listed below:

Item	Unit	Time (man-hours)		
		Low	Medium	High
Collectors and flashing	400-500 ft^2	40	60	80
Storage tank	each	8	10	12
Piping loops	all	40	60	80
DHW preheat subsystem	-	8	12	20
Insulation	all	16	20	30
Controls	-	8	12	16
Testing and balancing		10	15	20

Air-Heating Systems

Typical equipment and material prices (in 1978) are listed below

Item	Unit	Price Range (in dollars)		
		Low	Medium	High
Flat plate collectors and mounting hardware	ft^2	10	15	24
Storage containers	ft^3	0.5	1	1.5
Gravel	ton	3	4	5
Blower and motor	each	150	175	200
Control and sensors	set	500	750	1500
Motorized dampers	each	115	125	150
Heat Exchanger	each	45	60	80
DHW Preheat tank	each	80	100	150
Ducts	bulk	2000	2500	3500
Insulation	bulk	500	750	1000
Miscellaneous		200	300	400

Installation time estimates of typical air-heating systems are listed below

Item	Unit	Time (man-hours)		
		Low	Medium	High
Collectors	400-500 ft^2	40	60	80
Storage unit	each	20	25	30
Ducting	all	50	75	100
Controls	-	8	12	16
DHW preheat subsystem	-	8	12	20
Insulation		16	20	30
Testing and balancing	-	10	15	20

TYPICAL INSTALLED COSTS

Liquid-Heating System

An estimate for the installed cost of a typical liquid-heating system in a new building with 400 ft^2 of collectors is outlined below using the median values in the foregoing section.

1.	Collectors	equipment 400 ft^2/\$15/ft^2		\$6,000
		installation	60 hrs x \$15/hr	900
2.	Storage Tank	equipment		1,500
		installation	10 hrs x \$15/hr	150
3.	Pipe Loops	equipment		2,070
		installation	60 hrs x \$15/hr	900
4.	DHW Subsystem	equipment		280
		installation,	12 hrs x \$15/hr	180
5.	Controls	equipment		750
		installation	12 hrs x \$15/hr	180
6.	Insulation	materials		750
		installation	20 hrs x \$15/hr	300

7.	Testing and balancing		225
		Total Estimated Costs	14,185
		Breakdown of costs:	
		Equipment & materials	11,350
		Labor	2,835
		Installed cost/unit collector area	$35.46/ft^2

Air-Heating System

An estimate of the installed cost of a typical air-heating system in a new building with 400 ft^2 of collectors is outlined below using the median values in the foregoing section.

1.	Collectors	equipment	400 ft^2 X $15/ft^2	$6,000
		installation	60 hrs x $15/hr	900
2.	Pebble Bed	Container	300 ft^3 x $1/ft^3	300
		Gravel	15 tons x $4/ton	60
		Assembly	25 hrs x $15/hr	375
3.	Duct, Pumpers & blowers	Equipment		3,175
		installation	75 x $15/hr	1,125
4.	DHW Subsystem	equipment		385
		installation	12 x $15/hr	180
5.	Controls	equipment		750
		installation	12 hrs x $15/hr	180
6.	Insulation	materials		750
		installation	20 hrs x $15/hr	300
7.	Testing and balancing		15 hrs x $15/hr	225
		Total Estimated Costs		14,705
		Breakdown of costs:		
		Equipment & materials		11,420
		Labor		3,285
		Installed cost/unit collector area		$36.76/ft^2

MORTGAGE PAYMENTS

The largest portion of the annual cost of a solar system is the repayment of the loan obtained to install the system. The loan may be based on the total building costs or separately on the solar system alone. In either event, a downpayment ranging from 10 to 20 percent is required to secure the loan.

The annual mortgage payments can be calculated from the mortgage interest rate and term of the loan using the curves of Figure 12-4. To illustrate the use of Figure 12-4, suppose that a solar system with 400 square feet of collectors cost $12,500. A 20-year loan is obtained to purchase and install the system with interest at 9 percent, which requires a 20 percent downpayment. The annual mortgage payment on the loan is calculated as follows:

$$\text{Annual Mortgage} = (\text{System cost} - \text{downpayment}) \times (\text{Annual repayment factor (from Figure 12-4)})$$

or

$$\$1100 = (12{,}500 - 2500) \times (0.11)$$

PROPERTY TAX, INSURANCE, AND CREDIT ON INCOME TAXES

The annual cost of a solar system includes all the items contributing to the cash flow to operate a solar heating system. The costs include the mortgage payment and fuel costs, operating and maintenance costs, property tax, insurance on the solar system, income tax credits and savings on federal and state income taxes for property tax and interest paid on the loan.

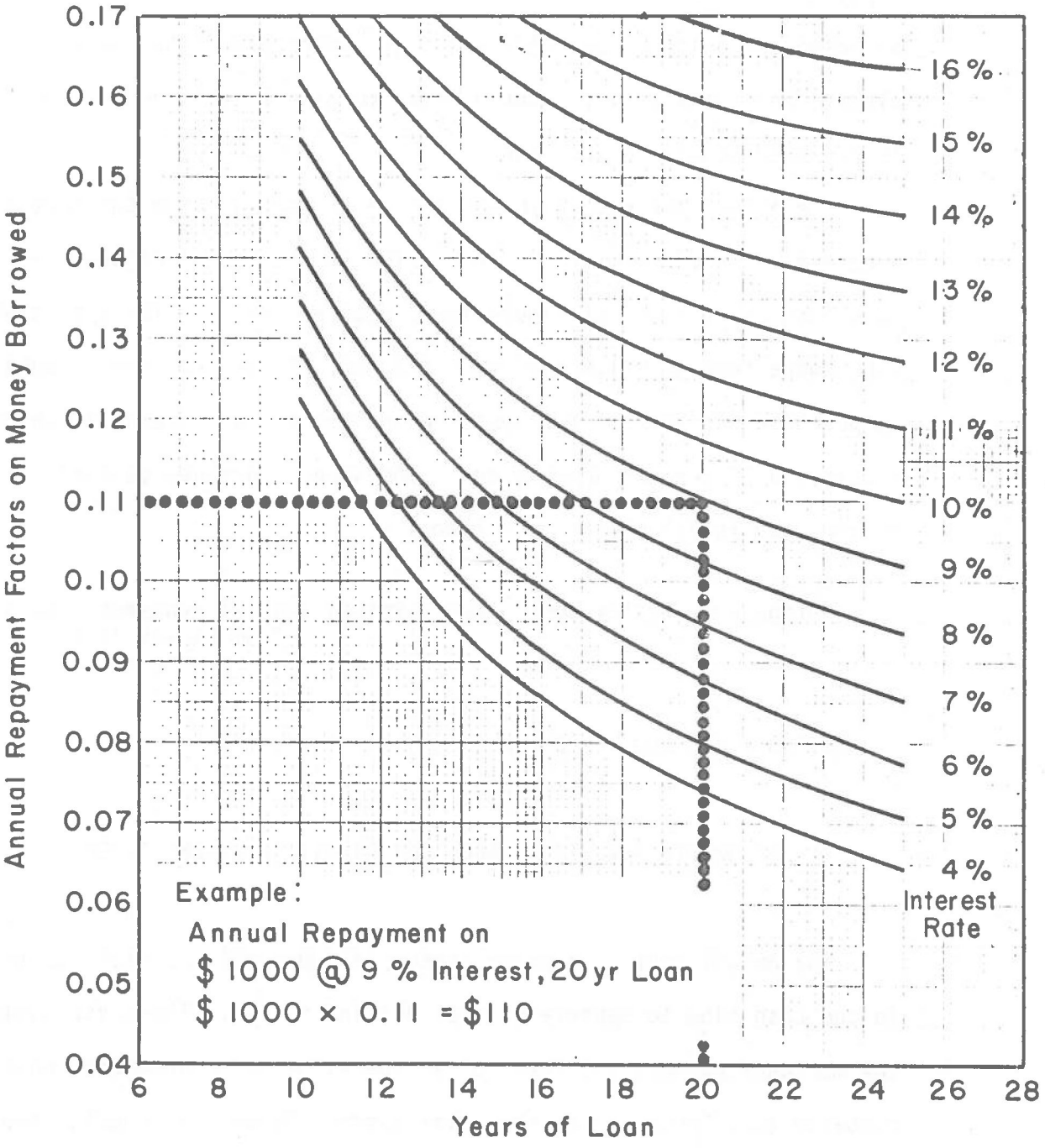

Figure 12-4. Repayment on Loan

A major item of income tax credit is the recently passed legislation by the federal government, which allows a maximum credit of $2200 from the owner's federal income tax liability. The credit allowance is 30 percent of the first $2000 and 20 percent of the next $8000 of the cost of the installed system. In some states there are additional credits provided to state income taxes for owners of solar systems.

Property taxes are based on a fraction of the assessed value of the solar system. The method of assessment, and the tax rate, varies from state to state and sometimes from county to county within the state. The office of the county treasurer can provide detailed information on method of assessed valuation on property and the tax rate. Usually, the assessed value is a fraction of the market value of the property and the tax rate is applied to the assessed value. In Colorado, the maximum assessed value of a solar system is 5 percent of market value. The amount of property tax on the solar system can be calculated as follows:

$$\text{Property tax} = (\text{System cost}) \times (\text{Fraction of assessed value}) \times (\text{tax rate})$$

Insurance rates on houses with a solar system, at present, are the same as for houses without solar systems. The basic insurance rate depends upon the type of house construction and location of the building within or outside a city or town. The insurance rate for a comprehensive homeowners policy differs from that for a straight fire insurance policy and the insurance rates for earthquake and flood damage (which is federally subsidized) are the only special insurances available for owners of buildings. The information on various insurance rates are available from local insurance agents. However, very few insurance companies have established insurance rates for solar systems. Damage to the contents

of a building resulting from leaks in piping or storage tanks or damage to the solar system resulting from flooding by natural causes is based on comprehensive or flood insurance rates. Although there are many factors to be considered, the annual premium on insurance for houses with solar systems is less than one percent of the value of the house and contents, and ranges from 0.3 to about 0.6 percent.

The "savings" on state and federal income taxes for property tax and interest paid on the mortgage can be substantial, depending upon the "tax bracket" of the homeowner. The amount of interest paid annually on the mortgage decreases with the number of years remaining on the mortgage. The portion of annual mortgage which is paid as interest can be determined from the graphs on Figure 12-5. The use of curves in the figure is illustrated in the following example.

Let us assume that a loan of $10,000 has been secured at a term of 20 years and 9 percent interest. The annual mortgage payment was computed in the previous section to be $1100. Of that mortgage payment, 82 percent, or $900, is for interest in the first year. As this is the first year of payment, 20 years remain on the mortgage at the beginning of the year. By following the vertical line corresponding to 20 years in Figure 12-5 to the 9 percent curve, it is seen that the fraction of mortgage payment, which is interest, during the first year is 0.82. In the eleventh year, with ten years remaining on the mortgage at the beginning of the year, the interest paid during the year is (0.575) x ($1100), or $632. The income tax savings on a federal or state return for interest and taxes would be:

$$\left(\begin{matrix}\text{Income}\\ \text{tax credit}\end{matrix}\right) = \left(\begin{matrix}\text{Interest and}\\ \text{taxes}\end{matrix}\right) \times \left(\begin{matrix}\text{Tax rate based}\\ \text{on net income}\end{matrix}\right)$$

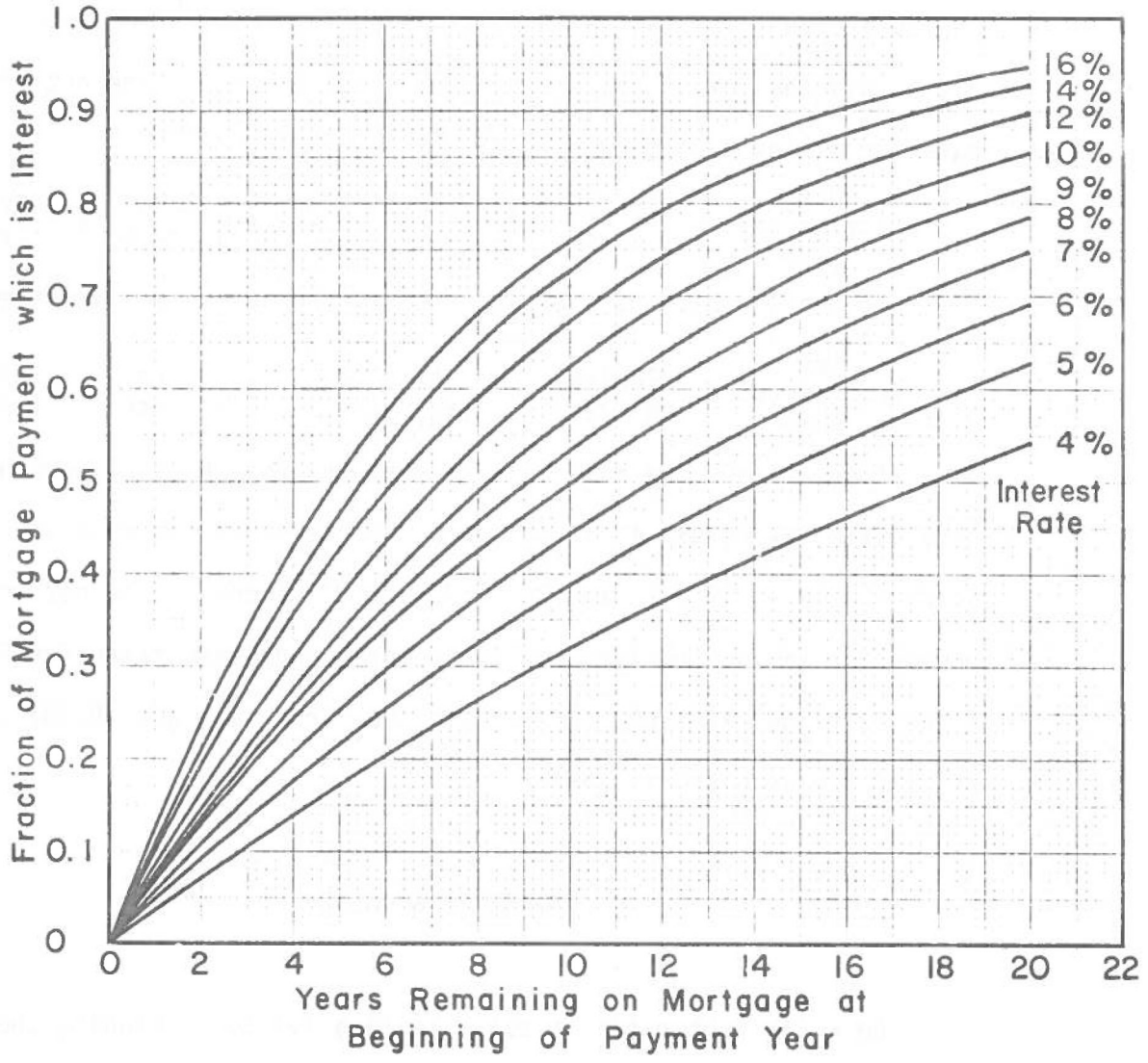

Figure 12-5. Fraction of Mortgage Payment which is Interest

The federal income tax return provides credit for state income taxes paid and many states give credit for federal income taxes. Thus the full credit for tax savings resulting from payment of interest is not simply the sum of state and federal tax savings. The net effective rate for states giving credit is:

$$\begin{pmatrix}\text{Net}\\ \text{Effective}\\ \text{Rate}\end{pmatrix} = \begin{pmatrix}\text{Federal}\\ \text{tax rate}\end{pmatrix} + \begin{pmatrix}\text{State}\\ \text{tax rate}\end{pmatrix} - 2 \begin{pmatrix}\text{Federal}\\ \text{tax rate}\end{pmatrix} \times \begin{pmatrix}\text{State}\\ \text{tax rate}\end{pmatrix}$$

For states which do not give credit, the net effective rate is:

$$\begin{pmatrix}\text{Net}\\ \text{Effective}\\ \text{Rate}\end{pmatrix} = \begin{pmatrix}\text{Federal}\\ \text{tax rate}\end{pmatrix} + \begin{pmatrix}\text{State}\\ \text{tax rate}\end{pmatrix} - 1 \begin{pmatrix}\text{Federal}\\ \text{tax rate}\end{pmatrix} \times \begin{pmatrix}\text{State}\\ \text{tax rate}\end{pmatrix}$$

If the income tax rate on a federal tax return is 25 percent and on a state tax return is 10 percent, the net effective rate is (0.25 + 0.10 - 2 x 0.25 x 0.10) 0.30, or 30 percent. The net annual income tax savings realized on the federal and state taxes for interest alone is (0.30) x ($900), or $270 in the first year and (0.30) x ($632) or $190 in the eleventh year.

OPERATING COSTS

The cost of operating a solar heating system, including the cost for operating the auxiliary unit in the system, is the cost of electric energy required to operate the pumps, central heat distribution fan, valves, and controller in a hydronic system, and the blowers, motorized dampers, and controller in an air system. The amount of energy used to collect, store, and distribute solar energy varies from system to system in the range from 5 to 10 percent of the total solar energy collected. The lower values in the range apply to low-heat systems with small pressure drops, and air systems with single blowers with small pressure

drops. The higher values in the range apply to high-head systems with large pressure drops, small systems with large pumps, and air systems with two blowers.

The operating cost for a non-solar system is much less than for a solar system. Although the blower size for distributing air to the rooms is the same, the power requirement is less for a non-solar system because the pressure drop in the system is lower. As an approximation, the energy required to operate a non-solar system is two to three percent of the total annual heating load.

MAINTENANCE COSTS

The maintenance costs for solar systems is unknown; there is insufficient long-term experience with various systems to indicate an appropriate maintenance cost. While there is one air system that has been operated continuously for 19 years, on which the maintenance cost was zero, it can be expected that all solar systems will require some amount of maintenance during the life of the system. For the purpose of economic analysis, maintenance costs can be included each year for a nominal amount, say one hundred dollars, escalated annually at a selected inflation rate.

ECONOMIC ANALYSIS WORKSHEETS

There are included in this section "short" forms and a "long" forms for calculating annual cash flow and life cycle costs of a system. The short form enables calculation of the present worth

of cummulative system and heating costs over the life of the system. The long method provides a year-by-year analysis of system cost, either in terms of present worth or cash flow, where the annual rates of increase can be changed for any item for any year. The steps for the calculations are outlined and explained on the worksheets. Sheets 1 and 2 of Worksheet LCA-1 are data sheets common to both the short and long forms.

WORKSHEET LCA-1

Worksheets LCA-1 (2 sheets) are data sheets to facilitate the computations. Technical, economic, and cost data are listed on the worksheets.

WORKSHEET LCA-2

Worksheet LCA-2 outlines step by step procedure for calculating life-cycle costs of both the solar and non-solar system. The economic factors, E values, are determined from Tables 12-1 through 12-6.

Worksheet LCA-1
Sheet 1 of 2

DATA SHEET FOR ECONOMIC ANALYSIS

Project_____

Building Data (see Worksheet B)

1.	Annual space heating load	_____ MMBtu/yr
2.	Annual DHW heating load	_____ MMBtu/yr
3.	Total H and DHW load (add lines 1 & 2)	_____ MMBtu/yr

Solar System Data

4.	Collector area	_____ ft^2
5.	Fraction of annual heating load supplied from solar	_____ decimal

Energy Prices

6.	c_e, current energy cost for electricity (use Figure 12-2) _____¢/kWhr	_____ $/MMBtu
7.	c_f, c_{fc}, current cost of fuel (use Figure 12-1 or 12-2)	_____ $/MMBtu

Terms of Loan

8.	m, term of the loan for solar system	_____ yrs
9.	α, downpayment _____%	_____ decimal
10.	i, interest rate on loan _____%	_____ decimal

Economic Data

11.	C_a, installed cost of solar system per unit area	_____ $/$ft^2$
12.	r_f, estimated auxiliary fuel inflation rate	_____ %
13.	r_e, r_o, estimated electric energy inflation	_____ %
14.	g, r_m, estimated general inflation rate	_____ %
15.	p, property tax rate (based on market value)	_____ decimal
16.	h, insurance premium rate	_____ decimal
17.	Federal income tax rate for owner	_____ decimal
18.	State income tax rate for owner	_____ decimal
19.	t, effective income tax rate {i.e., (line 17) + (line 18) - [2 x (line 17) x (line 18)]}	_____ decimal
20.	d, market discount rate	_____ decimal

Worksheet LCA-1
Sheet 2 of 2

Solar System Cost Items

21. Installed cost (line 4 x line 11) _____$

22. Federal tax credit for solar (30% of first $2000 plus 20% of next $8000 on to total cost of system) _____$

23. Downpayment (line 21 x line 9) _____$

24. Amount of loan (line 21 - line 23) _____$

25. Annual mortgage payment (multiply line 24 by annual mortgage rate from Figure 12-4) _____$/yr

26. C_f, first year cost of auxiliary heating (line 3 x (1-line 5) x line 7) _____$/yr

27. First year property tax (line 21 x line 15) _____$/yr

28. First year insurance premium (line 21 x line 16) _____$/yr

29. C_o, first year cost of operating the solar system (line 3 x (a value between .05 and .10) x line 6 _____$/yr

30. C_m, first year maintenance cost (estimate) _____$/yr

Non-Solar System Cost Items

31. C_{fc}, first year cost of fuel for non-solar system (line 3 x line 7) _____$/yr

32. C_{oc}, first year cost of operating non-solar system (line 3 x .01 x line 6) _____$/yr

Worksheet LCA-2
Sheet 1 of 2

LIFE-CYCLE COST ANALYSIS

Total Cost for Solar System

33. n, total years of analysis _____ yrs
34. A, collector area (line 4 of LCA-1) _____ ft^2
35. L, annual heat load (line 3 of LCA-1) _____ MMBtu
36. F, fraction of annual heat provided by the solar system (line 5 of LCA-1) _____ decimal
37. P/X (d,g,n) (See Tables 12-1 through 12-6) _____
38. P/X (d,0,m) (See Tables 12-1 through 12-6) _____
39. P/X (i,0,m) (See Tables 12-1 through 12-6) _____
40. P/X (d,i,m) (See Tables 12-1 through 12-6) _____
41. P/X (0,i,m) (see Tables 12-1 through 12-6) _____
42. $(t)[\frac{P/X\ (d,i,m)}{P/X\ (0,i,m)}] = (\frac{\text{line 12 x line 40}}{\text{line 41}})$ _____
43. $(1 - t)[\frac{P/X\ (d,0,m)}{P/X\ (i,0,m)}] = [\frac{(1\text{-line 19}) \times (\text{line 38})}{\text{line 41}}]$ _____
44. Add line 42 and line 43 _____
45. $1 - \alpha$ (1 - line 9) _____
46. Multiply: line 44 x line 45 _____
47. $(1-t)(p) + h$
    (1 - line 19)(line 15) + (line 16) _____
48. Multiply: line 47 x line 37 _____
49. E_1 = (line 9) + (line 48) + (line 46) _____
50. $E_o = P/X\ (d,r_o,n)$ = (see Tables 12-1 through 12-6) _____
51. $E_m = P/X\ (d,r_m,n)$ (see Tables 12-1 through 12-6) _____

52. E_f = P/X (d,r_f,n) (See Tables 12-1 through 12-6) _____

53. (A)(C_a)(E_1) = (line 34 x line 11 x line 49) _____$

54. ($C_o E_o$ = (line 29 x line 50) _____$

55. $C_m E_m$ = (line 30 x line 51) _____$

56. (1-F)(L)(c_f)(E_f) = (____)(____)(____)(____) _____$
(1 - line 36) x line 35 x line 7 x line 52

57. C_T = line 53 + line 54 + line 55 + line 56 - line 22

_____$

Total Cost for Non-Solar System

58. $C_{oc} E_o$ = line 32 x line 50 _____$

59. $Lc_{fc} E_f$ = line 35 x line 7 x line 52 (maintenance cost neglected) _____$

60. C_{TC} = line 58 + line 59 _____$

Present Value of Life-Cycle Cost Savings With Solar System

61. Savings = (line 60 - line 57) _____$

WORKSHEET LCA-3

In Worksheet LCA-3, column [1] is the year into the future for which the analysis may be made. A reasonable economic analysis can be made for 15 to 20 years into the future.

Column [2] is the annual mortgage payment (see Worksheet LCA-1, line 25). If the mortgage payment is a fixed annual amount, the payment for all future years would be the same as the first year,

Column [3] is the years remaining on the mortgage at the beginning of the year. The worksheet is for a 20-year mortgage.

Column [4] is the fraction of the mortgage payment which is paid as interest. The fraction decreases with increasing years and may be determined from Figure 12-5 for the particular interest rate of the mortgage.

Column [5] is the portion of the mortgage which is paid as interest and is the product of column [2] times column [4].

Column [6] is auxiliary fuel cost. Because fuel cost is expected to increase, the first year fuel cost should be increased in subsequent years. The first year fuel cost is the amount on line 26, Worksheet LCA-1. The second year fuel cost is determined by multiplying the first year cost by $(1 + r_f)$, (for r_f see line 12 of Worksheet LCA-1). For example, if the first year fuel cost is $400 and the fuel inflation rate is 7 percent, the second year cost is ($400 x 1.07 =) $428. The fuel cost for each succeeding year is determined by multiplying the previous year by (1 + fuel inflation rate). Note that the inflation rate may be changed for each year.

Column [7] is the annual property tax. The first year tax is calculated on line 27 on Worksheet LCA-1 and succeeding years can be escalated by the general inflation rate, g.

Column [11] is the income tax savings calculated by the product of the effective tax rate (on line 19 of Worksheet of LCA-1) and the sum of annual interest paid, in column [5], plus property taxes, column [7].

Column [12] is the annual expense of solar system and is determined by: Column [2] + column [6] + column [7] - column [8] + column [9] + column [10] - column [11]. The first year cash flow is calculated by adding the down payment and subtracting the federal tax credit. .

LIFE CYCLE COST ANALYSIS
CASH FLOW

A. Mortgage interest rate _____ decimal
B. Auxiliary fuel inflation rate ___ decimal
C. General inflation rate _____ decimal

Collector area _____ ft^2
Solar fraction of total load ____ decimal
(see Worksheet LCA-1, line 5)

System Cost $_____
Down Payment $_____
Federal Tax Credit $_____

[1] Year	[2] Annual Mortgage Payment	[3] Years Left on Mortgage	[4] Frac. of Mortgage as Interest	[5] Interest Paid	[6] Auxiliary Fuel Cost	[7] Property Tax	[8] Insurance	[9] Operating Cost	[10] Maintenance Cost	[11] Income Tax Savings	[12] Expense with Solar
1		20									*
2		19									
3		18									
4		17									
5		16									
6		15									
7		14									
8		13									
9		12									
10		11									
11		10									
12		9									
13		8									
14		7									
15		6									
16		5									
17		4									
18		3									
19		2									
20		1									

[2] Annual mortgage payment from LCA-1, line 25
[4] See Figure 12-5
[5] Column [2] x column [4]
[6] First year cost from LCA-1, line 26
Second and future years:
(previous year cost) x (1 + fuel inflation rate)
[7] See line 27, LCA-1
Second and future years:
(previous year cost) x (1 + general inflation rate)
[8] See line 28, LCA-1 (and use general inflation rate)
[9] First year cost see Line 29, LCA-1
Second and future years:
(previous year cost) x (1 + fuel inflation rate)
[10] First year cost see line 30, LCA-1
Second and future years:
(previous year cost) x (1 + general inflation rate)
[11] {Column [5] + Column [7]} x line 19, LCA-1
[12] [2]+[6]+[7]+[8]+[9]+[10]-[11]
*[12] For first year, add down payment and subtract federal tax credit

WORKSHEET LCA-4

Worksheet LCA-4 is used to compare life cycle and cash flow analyses for solar and non-solar systems.

Column [1] is the year of analysis.

Column [2] is the total fuel and operating cost for the non-solar system. The first year cost is the total of lines 31 and 32 on Worksheet LCA-1. The costs in succeeding years are determined by multiplying the cost of fuel for the previous year $(1 + r_f)$ and the cost for operation for the previous year by $(1 + r_e)$.

Column [3] is the cumulative annual cash flow for the non-solar system.

Column [4] is the present worth factor, determined from Table 12-7.

Column [5] is the present worth of the annual cost for a non-solar system.

Column [6] is the annual cost of the solar system, transferred from column [12] of Worksheet LCA-3.

Column [7] is the cumulative annual cash flow for the solar system.

Column [8] is the present value of the annual cost of the solar system determined by multiplying column [6] by column [4].

Column [9] is the present worth of savings with a solar system and is determined by column [5] - column [8].

Column [10] is the cumulative present worth of savings with a solar system and is the running sum of column [9].

Column [11] is the cumulative savings in cash flow and is determined by column [3] - column [7].

LIFE-CYCLE COST ANALYSIS
CASH FLOW AND PRESENT WORTH SUMMARIES

[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
	NON-SOLAR SYSTEM				SOLAR SYSTEM					
		d = ____			Collector Area ____ ft^2					
Year	Fuel plus Operating Expenses	Cumulative Expenses	Present Worth Factor	Present Worth of Annual Cost	Expense with Solar System	Cumulative Expenses	Present Worth of Annual Cost	Present Worth of Savings	Cumulative Present Worth of Savings	Cumulative Savings (cash flow)
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										

[2] First year cost, add lines 31 and 32 of LCA-1
Second and future years:
(previous year cost) x (1 + fuel inflation rate)
[3] Accumulate column [2]
[4] See Table 12-7
[5] Column [2] x column [4]

[6] Column [12], Worksheet LCA-3
[7] Accumulate column [6]
[8] Column [6] x column [4]
[9] Column [5] x column [8]
[10] Running sum of column [9]
[11] Column [3] - column [7]

EXAMPLE 12-4

Determine the life-cycle cost of the liquid-heating solar system of Example 12-1 with 500 square feet of collectors. Assume the following data apply:

1. F, annual solar fraction is 0.68
2. Seven percent of the solar energy collected is required to operate the pumps and control the system
3. c_e, current electricity cost is 3.5 ¢/kWh
4. A 20-year loan at 9 percent is obtainable with 20 percent down
5. Cost of solar system is \$20/ft^2 for collector-related costs plus \$3,000 for costs not related to collector area. In terms of collector area, the cost is 20 + (3000/500) or 26 \$/ft^2 of collector
6. r_f, fuel inflation rate is 10 percent
7. g, general inflation rate is 6 percent
8. Homeowners insurance is available for a premium of 0.3 percent of insured value
9. Property tax is levied on an assessed value which is 30 percent of market and the mil levy is 100. This is the equivalent of a property tax levied as (0.30 x 0.1), or 3 percent of market value
10. The owner's federal income tax rate is 32 percent and the solar tax is 8 percent
11. Maintenance cost is \$100 for first year
12. Use a market discount rate of 10 percent

DATA SHEET FOR ECONOMIC ANALYSIS

Project Sunbody Residence

Building Data (see Worksheet B)		
1.	Annual space heating load	108.3 MMBtu/yr
2.	Annual DHW heating load	21.0 MMBtu/yr
3.	Total H and DHW load (add lines 1 & 2)	129.3 MMBtu/yr
Solar System Data		
4.	Collector area	500 ft^2
5.	Fraction of annual heating load supplied from solar	0.68 decimal
Energy Prices		
6.	c_e, current energy cost for electricity (use Figure 12-2) 3.5 ¢/kWhr	10.25 $/MMBtu
7.	c_f, c_{fc}, current cost of fuel (use Figure 12-1 or 12-2)	10.25 $/MMBtu
Terms of Loan		
8.	m, term of the loan for solar system	20 yrs
9.	α, downpayment 20 %	0.20 decimal
10.	i, interest rate on loan 9 %	0.09 decimal
Economic Data		
11.	C_a, installed cost of solar system per unit area	26 $/$ft^2$
12.	r_f, estimated auxiliary fuel inflation rate	10 %
13.	r_e, r_o, estimated electric energy inflation	10 %
14.	g, r_m, estimated general inflation rate	6 %
15.	p, property tax rate (based on market value)	0.03 decimal
16.	h, insurance premium rate	0.003 decimal
17.	Federal income tax rate for owner	0.32 decimal
18.	State income tax rate for owner	0.08 decimal
19.	t, effective income tax rate {i.e., (line 17) + (line 18) - [2 x (line 17) x (line 18)]}	0.35 decimal
20.	d, market discount rate	0.10 decimal

Solar System Cost Items

21.	Installed cost (line 4 x line 11)	13,000	$
22.	Federal tax credit for solar (30% of first $2000 plus 20% of next $8000 on to total cost of system)	2,200	$
23.	Downpayment (line 21 x line 9)	2,600	$
24.	Amount of loan (line 21 - line 23)	10,400	$
25.	Annual mortgage payment (multiply line 24 by annual mortgage rate from Figure 12-4)	1,144	$/yr
26.	C_f, first year cost of auxiliary heating (line 3 x (1-line 5) x line 7)	424	$/yr
27.	First year property tax (line 21 x line 15)	390	$/yr
28.	First year insurance premium (line 21 x line 16)	39	$/yr
29.	C_o, first year cost of operating the solar system (line 3 x (a value between .05 and .10) x line 6	64	$/yr
30.	C_m, first year maintenance cost (estimate)	100	$/yr

Non-Solar System Cost Items

31.	C_{fc}, first year cost of fuel for non-solar system (line 3 x line 7)	1,325	$/yr
32.	C_{oc}, first year cost of operating non-solar system (line 3 x .01 x line 6)	21	$/yr

LIFE-CYCLE COST ANALYSIS

Total Cost for Solar System

33.	n, total years of analysis	20 yrs
34.	A, collector area (line 4 of LCA-1)	500 ft^2
35.	L, annual heat load (line 3 of LCA-1)	129.3 MMBtu
36.	F, fraction of annual heat provided by the solar system (line 5 of LCA-1)	.68 decimal
37.	P/X (d,g,n) (See Tables 12-1 through 12-6)	13.082
38.	P/X (d,0,m) (See Tables 12-1 through 12-6)	8.514
39.	P/X (i,0,m) (See Tables 12-1 through 12-6)	9.176
40.	P/X (d,i,m) (See Tables 12-1 through 12-6)	16.770
41.	P/X (0,i,m) (see Tables 12-1 through 12-6)	51.518
42.	$(t)[\frac{P/X\ (d,i,m)}{P/X\ (0,i,m)}] = (\frac{\text{line 12 x line 40}}{\text{line 41}})$	0.114
43.	$(1 - t)[\frac{P/X\ (d,0,m)}{P/X\ (i,0,m)}] = [\frac{(1\text{-line 19}) \times (\text{line 38})}{\text{line 41}}]$	0.603
44.	Add line 42 and line 43	0.717
45.	$1 - \alpha$ (1 - line 9)	0.8
46.	Multiply: line 44 x line 45	0.574
47.	(1-t)(p) + h (1 - line 19)(line 15) + (line 16)	0.0225
48.	Multiply: line 47 x line 37	0.294
49.	E_1 = (line 9) + (line 48) + (line 46)	1.068
50.	E_o = P/X (d,r_o,n) = (see Tables 12-1 through 12-6)	18.182
51.	E_m = P/X (d,r_m,n) (see Tables 12-1 through 12-6)	13.082

52. E_f = P/X (d,r_f,n) (See Tables 12-1 through 12-6) 18,182

53. (A)(C_a)(E_1) = (line 34 x line 11 x line 49) 13,884 $

54. ($C_o E_o$ = (line 29 x line 50) 1,164 $

55. $C_m E_m$ = (line 30 x line 51) 1,308 $

56. (1-F)(L)(c_f)(E_f) = (.32)(129.3)(10.26)(18.182) 7,711 $
(1 - line 36) x line 35 x line 7 x line 52

57. C_T = line 53 + line 54 + line 55 + line 56 - line 22

21,867 $

Total Cost for Non-Solar System

58. $C_{oc}E_o$ = line 32 x line 50 491 $

59. $Lc_{fc}E_f$ = line 35 x line 7 x line 52 (maintenance cost neglected) 24,097 $

60. C_{TC} = line 58 + line 59 24,588 $

Present Value of Life-Cycle Cost Savings With Solar System

61. Savings = (line 60 - line 57) 2,721 $

LIFE CYCLE COST ANALYSIS
CASH FLOW

A. Mortgage interest rate 9 decimal
B. Auxiliary fuel inflation rate 10 decimal
C. General inflation rate 6 decimal

Collector area 500 ft²
Solar fraction of total load .68 decimal
(see Worksheet LCA-1, line 5)

System Cost $13,000
Down Payment $2,600
Federal Tax Credit $2,200

[1] Year	[2] Annual Mortgage Payment	[3] Years Left on Mortgage	[4] Frac. of Mortgage as Interest	[5] Interest Paid	[6] Auxiliary Fuel Cost	[7] Property Tax	[8] Insurance	[9] Operating Cost	[10] Maintenance Cost	[11] Income Tax Savings	[12] Expense with Solar
1	1144	20	.820	938	424	390	39	64	100	465	2096*
2	1144	19	.805	921	466	413	41	70	106	467	1773
3	1144	18	.785	898	513	438	44	77	112	468	1860
4	1144	17	.765	875	564	464	46	85	119	469	1953
5	1144	16	.745	852	621	492	49	94	126	470	2056
6	1144	15	.720	824	683	522	52	103	134	471	2167
7	1144	14	.700	801	751	553	55	113	142	474	2284
8	1144	13	.670	766	826	586	59	125	150	473	2417
9	1144	12	.640	732	909	622	62	137	159	474	2559
10	1144	11	.610	698	1000	659	66	151	169	475	2714
11	1144	10	.575	658	1100	698	70	166	179	475	2882
12	1144	9	.540	618	1210	740	74	183	190	475	3066
13	1144	8	.500	572	1331	785	78	201	201	475	3265
14	1144	7	.450	515	1464	832	83	221	213	471	3486
15	1144	6	.400	458	1610	882	88	243	226	469	3724
16	1144	5	.350	400	1771	935	93	267	240	467	3983
17	1144	4	.290	332	1948	991	99	294	254	463	4267
18	1144	3	.230	263	2143	1050	105	323	269	460	4574
19	1144	2	.160	183	2357	1113	111	356	285	454	4912
20	1144	1	.085	97	2593	1080	118	391	303	447	5282

[2] Annual mortgage payment from LCA-1, line 25
[4] See Figure 12-5
[5] Column [2] x column [4]
[6] First year cost from LCA-1, line 26
Second and future years:
(previous year cost) x (1 + fuel inflation rate)
[7] See line 27, LCA-1
Second and future years:
(previous year cost) x (1 + general inflation rate)
[8] See line 28, LCA-1 (and use general inflation rate)
[9] First year cost see Line 29, LCA-1
Second and future years:
(previous year cost) x (1 + fuel inflation rate)
[10] First year cost see line 30, LCA-1
Second and future years:
(previous year cost) x (1 + general inflation rate)
[11] {Column [5] + Column [7]} x line 19, LCA-1
[12] [2]+[6]+[7]+[8]+[9]+[10]-[11]
*[12] For first year, add down payment and subtract federal tax credit

LIFE-CYCLE COST ANALYSIS
CASH FLOW AND PRESENT WORTH SUMMARIES

[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
	NON-SOLAR SYSTEM				SOLAR SYSTEM					
		d = 0.10			Collector Area 500 ft²					
Year	Fuel plus Operating Expenses	Cumulative Expenses	Present Worth Factor	Present Worth of Annual Cost	Expense with Solar System	Cumulative Expenses	Present Worth of Annual Cost	Present Worth of Savings	Cumulative Present Worth of Savings	Cumulative Savings (cash flow)
1	1352	1352	.909	1229	2096	2096	1905	- 676	-676	- 744
2	1487	2839	.826	1228	1773	3869	1464	- 236	-912	-1030
3	1636	4475	.751	1229	1860	5729	1397	- 168	-1080	-1254
4	1800	6275	.683	1229	1953	7682	1334	- 105	-1185	-1407
5	1979	8254	.621	1229	2056	9738	1277	- 48	-1233	-1484
6	2177	10,431	.564	1228	2167	11,905	1222	6	-1227	-1474
7	2395	12,826	.513	1229	2284	14,189	1172	57	-1170	-1363
8	2635	15,461	.467	1231	2411	16,606	1129	102	-1068	-1145
9	2898	18,359	.424	1229	2559	19,165	1085	144	- 924	- 806
10	3188	21,547	.386	1231	2714	21,879	1048	183	-741	- 832
11	3507	25,054	.350	1227	2882	24,761	1009	218	-523	293
12	3857	28,911	.319	1230	3066	27,827	978	252	-271	1084
13	4243	33,154	.290	1230	3265	31,092	947	283	12	2062
14	4667	37,821	.263	1227	3486	34,578	917	310	322	3243
15	5134	42,955	.239	1227	3724	38,302	890	337	659	4653
16	5648	48,603	.218	1231	3983	42,285	868	363	1022	6318
17	6212	54,815	.198	1230	4267	46,552	845	385	1407	8263
18	6834	61,649	.180	1230	4574	51,126	823	407	1814	10523
19	7517	69,166	.164	1233	4912	56,038	806	427	2241	13128
20	8269	77,435	.149	1232	5282	61,320	787	445	2686	16115

[2] First year cost, add lines 31 and 32 of LCA-1
Second and future years:
(previous year cost) x (1 + fuel inflation rate)
[3] Accumulate column [2]
[4] See Table 12-7
[5] Column [2] x column [4]

[6] Column [12], Worksheet LCA-3
[7] Accumulate column [6]
[8] Column [6] x column [4]
[9] Column [5] x column [8]
[10] Running sum of column [9]
[11] Column [3] - column [7]

DATA SHEET FOR ECONOMIC ANALYSIS

Project_____

Building Data (see Worksheet B)

1.	Annual space heating load	_____MMBtu/yr
2.	Annual DHW heating load	_____MMBtu/yr
3.	Total H and DHW load (add lines 1 & 2)	_____MMBtu/yr

Solar System Data

4.	Collector area	_____ft^2
5.	Fraction of annual heating load supplied from solar	_____decimal

Energy Prices

6.	c_e, current energy cost for electricity (use Figure 12-2) _____¢/kWhr	_____$/MMBtu
7.	c_f, c_{fc}, current cost of fuel (use Figure 12-1 or 12-2)	_____$/MMBtu

Terms of Loan

8.	m, term of the loan for solar system	_____yrs
9.	α, downpayment _____%	_____decimal
10.	i, interest rate on loan _____%	_____decimal

Economic Data

11.	C_a, installed cost of solar system per unit area	_____$/$ft^2$
12.	r_f, estimated auxiliary fuel inflation rate	_____%
13.	r_e, r_o, estimated electric energy inflation	_____%
14.	g, r_m, estimated general inflation rate	_____%
15.	p, property tax rate (based on market value)	_____decimal
16.	h, insurance premium rate	_____decimal
17.	Federal income tax rate for owner	_____decimal
18.	State income tax rate for owner	_____decimal
19.	t, effective income tax rate {i.e., (line 17) + (line 18) - [2 x (line 17) x (line 18)]}	_____decimal
20.	d, market discount rate	_____decimal

Solar System Cost Items

21.	Installed cost (line 4 x line 11)	_____$
22.	Federal tax credit for solar (30% of first $2000 plus 20% of next $8000 on to total cost of system)	_____$
23.	Downpayment (line 21 x line 9)	_____$
24.	Amount of loan (line 21 - line 23)	_____$
25.	Annual mortgage payment (multiply line 24 by annual mortgage rate from Figure 12-4)	_____$/yr
26.	C_f, first year cost of auxiliary heating (line 3 x (1-line 5) x line 7)	_____$/yr
27.	First year property tax (line 21 x line 15)	_____$/yr
28.	First year insurance premium (line 21 x line 16)	_____$/yr
29.	C_o, first year cost of operating the solar system (line 3 x (a value between .05 and .10) x line 6	_____$/yr
30.	C_m, first year maintenance cost (estimate)	_____$/yr

Non-Solar System Cost Items

31.	C_{fc}, first year cost of fuel for non-solar system (line 3 x line 7)	_____$/yr
32.	C_{oc}, first year cost of operating non-solar system (line 3 x .01 x line 6)	_____$/yr

LIFE-CYCLE COST ANALYSIS

Total Cost for Solar System

33. n, total years of analysis _____ yrs
34. A, collector area (line 4 of LCA-1) _____ ft^2
35. L, annual heat load (line 3 of LCA-1) _____ MMBtu
36. F, fraction of annual heat provided by the solar system (line 5 of LCA-1) _____ decimal
37. P/X (d,g,n) (See Tables 12-1 through 12-6) _____
38. P/X (d,O,m) (See Tables 12-1 through 12-6) _____
39. P/X (i,O,m) (See Tables 12-1 through 12-6) _____
40. P/X (d,i,m) (See Tables 12-1 through 12-6) _____
41. P/X (O,i,m) (see Tables 12-1 through 12-6) _____
42. $(t)\left[\frac{P/X\ (d,i,m)}{P/X\ (O,i,m)}\right] = \left(\frac{\text{line 12 x line 40}}{\text{line 41}}\right)$ _____
43. $(1 - t)\left[\frac{P/X\ (d,O,m)}{P/X\ (i,O,m)}\right] = \left[\frac{(1\text{-line 19}) \times (\text{line 38})}{\text{line 41}}\right]$ _____
44. Add line 42 and line 43 _____
45. $1 - \alpha$ (1 - line 9) _____
46. Multiply: line 44 x line 45 _____
47. $(1-t)(p) + h$ $(1 - \text{line 19})(\text{line 15}) + (\text{line 16})$ _____
48. Multiply: line 47 x line 37 _____
49. E_1 = (line 9) + (line 48) + (line 46) _____
50. E_o = P/X (d,r_o,n) = (see Tables 12-1 through 12-6) _____
51. E_m = P/X (d,r_m,n) (see Tables 12-1 through 12-6) _____

52. $E_f = P/X\ (d, r_f, n)$ (See Tables 12-1 through 12-6) _____

53. $(A)(C_a)(E_1)$ = (line 34 x line 11 x line 49) _____$

54. $(C_o E_o$ = (line 29 x line 50) _____$

55. $C_m E_m$ = (line 30 x line 51) _____$

56. $(1-F)(L)(c_f)(E_f)$ = (____)(____)(____)(____) _____$
(1 - line 36) x line 35 x line 7 x line 52

57. C_T = line 53 + line 54 + line 55 + line 56 - line 22

_____$

Total Cost for Non-Solar System

58. $C_{oc} E_o$ = line 32 x line 50 _____$

59. $Lc_{fc} E_f$ = line 35 x line 7 x line 52 (maintenance cost neglected) _____$

60. C_{TC} = line 58 + line 59 _____$

Present Value of Life-Cycle Cost Savings With Solar System

61. Savings = (line 60 - line 57) _____$

LIFE CYCLE COST ANALYSIS
CASH FLOW

A. Mortgage interest rate _____decimal
B. Auxiliary fuel inflation rate____decimal
C. General inflation rate _____decimal

Collector area_____ft^2
Solar fraction of total load _____decimal
(see Worksheet LCA-1, line 5)

System Cost $_____
Down Payment $_____
Federal Tax Credit $_____

[1] Year	[2] Annual Mortgage Payment	[3] Years Left on Mortgage	[4] Frac. of Mortgage as Interest	[5] Interest Paid	[6] Auxiliary Fuel Cost	[7] Property Tax	[8] Insurance	[9] Operating Cost	[10] Maintenance Cost	[11] Income Tax Savings	[12] Expense with Solar
1		20									*
2		19									
3		18									
4		17									
5		16									
6		15									
7		14									
8		13									
9		12									
10		11									
11		10									
12		9									
13		8									
14		7									
15		6									
16		5									
17		4									
18		3									
19		2									
20		1									

[2] Annual mortgage payment from LCA-1, line 25
[4] See Figure 12-5
[5] Column [2] x column [4]
[6] First year cost from LCA-1, line 26
Second and future years:
(previous year cost) x (1 + fuel inflation rate)
[7] See line 27, LCA-1
Second and future years:
(previous year cost) x (1 + general inflation rate)
[8] See line 28, LCA-1 (and use general inflation rate)
[9] First year cost see Line 29, LCA-1
Second and future years:
(previous year cost) x (1 + fuel inflation rate)
[10] First year cost see line 30, LCA-1
Second and future years:
(previous year cost) x (1 + general inflation rate)
[11] {Column [5] + Column [7]} x line 19, LCA-1
[12] [2]+[6]+[7]+[8]+[9]+[10]-[11]
*[12] For first year, add down payment and subtract federal tax credit

LIFE-CYCLE COST ANALYSIS
CASH FLOW AND PRESENT WORTH SUMMARIES

[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
	NON-SOLAR SYSTEM				SOLAR SYSTEM					
		d = ___			Collector Area ___ ft^2					
Year	Fuel plus Operating Expenses	Cumulative Expenses	Present Worth Factor	Present Worth of Annual Cost	Expense with Solar System	Cumulative Expenses	Present Worth of Annual Cost	Present Worth of Savings	Cumulative Present Worth of Savings	Cumulative Savings (cash flow)
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										

[2] First year cost, add lines 31 and 32 of LCA-1
Second and future years:
(previous year cost) x (1 + fuel inflation rate)
[3] Accumulate column [2]
[4] See Table 12-7
[5] Column [2] x column [4]

[6] Column [12], Worksheet LCA-3
[7] Accumulate column [6]
[8] Column [6] x column [4]
[9] Column [5] x column [8]
[10] Running sum of column [9]
[11] Column [3] - column [7]

DATA SHEET FOR ECONOMIC ANALYSIS

Project_____

Building Data (see Worksheet B)

1.	Annual space heating load	_____MMBtu/yr
2.	Annual DHW heating load	_____MMBtu/yr
3.	Total H and DHW load (add lines 1 & 2)	_____MMBtu/yr

Solar System Data

4.	Collector area	_____ft^2
5.	Fraction of annual heating load supplied from solar	_____decimal

Energy Prices

6.	c_e, current energy cost for electricity (use Figure 12-2) _____¢/kWhr	_____$/MMBtu
7.	c_f, c_{fc}, current cost of fuel (use Figure 12-1 or 12-2)	_____$/MMBtu

Terms of Loan

8.	m, term of the loan for solar system	_____yrs
9.	α, downpayment _____%	_____decimal
10.	i, interest rate on loan _____%	_____decimal

Economic Data

11.	C_a, installed cost of solar system per unit area	_____$/$ft^2$
12.	r_f, estimated auxiliary fuel inflation rate	_____%
13.	r_e, r_o, estimated electric energy inflation	_____%
14.	g, r_m, estimated general inflation rate	_____%
15.	p, property tax rate (based on market value)	_____decimal
16.	h, insurance premium rate	_____decimal
17.	Federal income tax rate for owner	_____decimal
18.	State income tax rate for owner	_____decimal
19.	t, effective income tax rate {i.e., (line 17) + (line 18) - [2 x (line 17) x (line 18)]}	_____decimal
20.	d, market discount rate	_____decimal

Solar System Cost Items

21.	Installed cost (line 4 x line 11)	_____$
22.	Federal tax credit for solar (30% of first $2000 plus 20% of next $8000 on to total cost of system)	_____$
23.	Downpayment (line 21 x line 9)	_____$
24.	Amount of loan (line 21 - line 23)	_____$
25.	Annual mortgage payment (multiply line 24 by annual mortgage rate from Figure 12-4)	_____$/yr
26.	C_f, first year cost of auxiliary heating (line 3 x (1-line 5) x line 7)	_____$/yr
27.	First year property tax (line 21 x line 15)	_____$/yr
28.	First year insurance premium (line 21 x line 16)	_____$/yr
29.	C_o, first year cost of operating the solar system (line 3 x (a value between .05 and .10) x line 6	_____$/yr
30.	C_m, first year maintenance cost (estimate)	_____$/yr

Non-Solar System Cost Items

31.	C_{fc}, first year cost of fuel for non-solar system (line 3 x line 7)	_____$/yr
32.	C_{oc}, first year cost of operating non-solar system (line 3 x .01 x line 6)	_____$/yr

DATA SHEET FOR ECONOMIC ANALYSIS

Project_____

Building Data (see Worksheet B)

1.	Annual space heating load	_____MMBtu/yr
2.	Annual DHW heating load	_____MMBtu/yr
3.	Total H and DHW load (add lines 1 & 2)	_____MMBtu/yr

Solar System Data

4.	Collector area	_____ft^2
5.	Fraction of annual heating load supplied from solar	_____decimal

Energy Prices

6.	c_e, current energy cost for electricity (use Figure 12-2) _____¢/kWhr	_____$/MMBtu
7.	c_f, c_{fc}, current cost of fuel (use Figure 12-1 or 12-2)	_____$/MMBtu

Terms of Loan

8.	m, term of the loan for solar system	_____yrs
9.	α, downpayment _____%	_____decimal
10.	i, interest rate on loan _____%	_____decimal

Economic Data

11.	C_a, installed cost of solar system per unit area	_____$/$ft^2$
12.	r_f, estimated auxiliary fuel inflation rate	_____%
13.	r_e, r_o, estimated electric energy inflation	_____%
14.	g, r_m, estimated general inflation rate	_____%
15.	p, property tax rate (based on market value)	_____decimal
16.	h, insurance premium rate	_____decimal
17.	Federal income tax rate for owner	_____decimal
18.	State income tax rate for owner	_____decimal
19.	t, effective income tax rate {i.e., (line 17) + (line 18) - [2 x (line 17) x (line 18)]}	_____decimal
20.	d, market discount rate	_____decimal

Solar System Cost Items

21. Installed cost (line 4 x line 11) _____ $

22. Federal tax credit for solar (30% of first $2000 plus 20% of next $8000 on to total cost of system) _____ $

23. Downpayment (line 21 x line 9) _____ $

24. Amount of loan (line 21 - line 23) _____ $

25. Annual mortgage payment (multiply line 24 by annual mortgage rate from Figure 12-4) _____ $/yr

26. C_f, first year cost of auxiliary heating (line 3 x (1-line 5) x line 7) _____ $/yr

27. First year property tax (line 21 x line 15) _____ $/yr

28. First year insurance premium (line 21 x line 16) _____ $/yr

29. C_o, first year cost of operating the solar system (line 3 x (a value between .05 and .10) x line 6 _____ $/yr

30. C_m, first year maintenance cost (estimate) _____ $/yr

Non-Solar System Cost Items

31. C_{fc}, first year cost of fuel for non-solar system (line 3 x line 7) _____ $/yr

32. C_{oc}, first year cost of operating non-solar system (line 3 x .01 x line 6) _____ $/yr

LIFE-CYCLE COST ANALYSIS

Total Cost for Solar System

33. n, total years of analysis _____ yrs
34. A, collector area (line 4 of LCA-1) _____ ft^2
35. L, annual heat load (line 3 of LCA-1) _____ MMBtu
36. F, fraction of annual heat provided by the solar system (line 5 of LCA-1) _____ decimal
37. P/X (d,g,n) (See Tables 12-1 through 12-6) _____
38. P/X (d,0,m) (See Tables 12-1 through 12-6) _____
39. P/X (i,0,m) (See Tables 12-1 through 12-6) _____
40. P/X (d,i,m) (See Tables 12-1 through 12-6) _____
41. P/X (0,i,m) (see Tables 12-1 through 12-6) _____
42. $(t)\left[\frac{P/X\ (d,i,m)}{P/X\ (0,i,m)}\right] = \left(\frac{\text{line 12 x line 40}}{\text{line 41}}\right)$ _____
43. $(1 - t)\left[\frac{P/X\ (d,0,m)}{P/X\ (i,0,m)}\right] = \left[\frac{(1\text{-line 19}) \times (\text{line 38})}{\text{line 41}}\right]$ _____
44. Add line 42 and line 43 _____
45. $1 - \alpha$ (1 - line 9) _____
46. Multiply: line 44 x line 45 _____
47. $\frac{(1-t)(p) + h}{(1 - \text{line 19})(\text{line 15}) + (\text{line 16})}$ _____
48. Multiply: line 47 x line 37 _____
49. E_1 = (line 9) + (line 48) + (line 46) _____
50. E_o = P/X (d,r_o,n) = (see Tables 12-1 through 12-6) _____
51. E_m = P/X (d,r_m,n) (see Tables 12-1 through 12-6) _____

52. E_f = P/X (d,r_f,n) (See Tables 12-1 through 12-6) _____

53. $(A)(C_a)(E_1)$ = (line 34 x line 11 x line 49) _____$

54. $(C_oE_o$ = (line 29 x line 50) _____$

55. C_mE_m = (line 30 x line 51) _____$

56. $(1-F)(L)(c_f)(E_f)$ = (____)(____)(____)(____) _____$
(1 - line 36) x line 35 x line 7 x line 52

57. C_T = line 53 + line 54 + line 55 + line 56 - line 22

_____$

Total Cost for Non-Solar System

58. $C_{oc}E_o$ = line 32 x line 50 _____$

59. $Lc_{fc}E_f$ = line 35 x line 7 x line 52 (maintenance cost neglected) _____$

60. C_{TC} = line 58 + line 59

_____$

Present Value of Life-Cycle Cost Savings With Solar System

61. Savings = (line 60 - line 57)

_____$

LIFE CYCLE COST ANALYSIS
CASH FLOW

A. Mortgage interest rate _____decimal
B. Auxiliary fuel inflation rate____decimal
C. General inflation rate _____decimal

Collector area_____ft^2
Solar fraction of total load _____decimal
(see Worksheet LCA-1, line 5)

System Cost $_____
Down Payment $_____
Federal Tax Credit $_____

[1] Year	[2] Annual Mortgage Payment	[3] Years Left on Mortgage	[4] Frac. of Mortgage as Interest	[5] Interest Paid	[6] Auxiliary Fuel Cost	[7] Property Tax	[8] Insurance	[9] Operating Cost	[10] Maintenance Cost	[11] Income Tax Savings	[12] Expense with Solar
1		20									*
2		19									
3		18									
4		17									
5		16									
6		15									
7		14									
8		13									
9		12									
10		11									
11		10									
12		9									
13		8									
14		7									
15		6									
16		5									
17		4									
18		3									
19		2									
20		1									

[2] Annual mortgage payment from LCA-1, line 25
[4] See Figure 12-5
[5] Column [2] x column [4]
[6] First year cost from LCA-1, line 26
Second and future years:
(previous year cost) x (1 + fuel inflation rate)
[7] See line 27, LCA-1
Second and future years:
(previous year cost) x (1 + general inflation rate)
[8] See line 28, LCA-1 (and use general inflation rate)
[9] First year cost see Line 29, LCA-1
Second and future years:
(previous year cost) x (1 + fuel inflation rate)
[10] First year cost see line 30, LCA-1
Second and future years:
(previous year cost) x (1 + general inflation rate)
[11] {Column [5] + Column [7]} x line 19, LCA-1
[12] [2]+[6]+[7]+[8]+[9]+[10]-[11]
*[12] For first year, add down payment and subtract federal tax credit

LIFE-CYCLE COST ANALYSIS
CASH FLOW AND PRESENT WORTH SUMMARIES

[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
	NON-SOLAR SYSTEM				SOLAR SYSTEM					
		d = ____			Collector Area ____ ft^2					
Year	Fuel plus Operating Expenses	Cumulative Expenses	Present Worth Factor	Present Worth of Annual Cost	Expense with Solar System	Cumulative Expenses	Present Worth of Annual Cost	Present Worth of Savings	Cumulative Present Worth of Savings	Cumulative Savings (cash flow)
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										

[2] First year cost, add lines 31 and 32 of LCA-1
Second and future years:
(previous year cost) x (1 + fuel inflation rate)
[3] Accumulate column [2]
[4] See Table 12-7
[5] Column [2] x column [4]

[6] Column [12], Worksheet LCA-3
[7] Accumulate column [6]
[8] Column [6] x column [4]
[9] Column [5] x column [8]
[10] Running sum of column [9]
[11] Column [3] - column [7]