MASTER

**USER'S
GUIDE**

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**SOLCOST -
PASSIVE
Solar Energy
Design
Program**

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FOREWORD

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This User's Guide documents the capabilities and data inputs for the SOLCOST-PASSIVE Solar Energy Design Program. SOLCOST-PASSIVE is intended for use by architects, building contractors, engineers, and passive solar designers. The coupled thermal and economic analyses within a single interactive computer program provides a useful tool for the passive design process. The input data requirements have been simplified so non-computer specialists can easily use the program to rapidly generate thermal performance estimates for a range of design variables.

The thermal performance methodology in SOLCOST-PASSIVE is based on the solar load ratio method developed by Los Alamos Scientific Laboratory. The computer implementation of the passive SLR method in the interactive SOLCOST framework was performed by Martin Marietta Aerospace for the U.S. Department of Energy, Education and Communications Branch.

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I. INTRODUCTION

The SOLCOST-PASSIVE solar energy design program is a public domain interactive computer design tool intended for use by non-thermal specialists to size passive solar systems with a methodology based on the Los Alamos Solar Load Ratio method. A life cycle savings analysis is included in the program. The intended user group includes architects, housing developers, lenders, engineers, and contractors. Although most of these users are not computer oriented, it is expected that engineering users of SOLCOST-PASSIVE will provide the above users with access to the SOLCOST-PASSIVE analysis on a design service basis.

Section II of this guide contains an overview of SOLCOST-PASSIVE capabilities and the Solar Load Ratio method which it is based on. For more detail, the user is referred to the Passive Solar Design Handbook, Volume 2, which was prepared for the Department of Energy by the Los Alamos Solar Group.* Section III is a detailed guide to the SOLCOST-PASSIVE input parameters. Section IV contains sample problems showing typical execution sessions and the resulting SOLCOST-PASSIVE output. Appendices A through D provide details on the SLR method and the life cycle savings methodology of SOLCOST-PASSIVE.

*Balcomb, J. Douglas, Dennis Barley, Robert McFarland, Joseph Perry, Jr., William Wray and Scott Noll, Passive Solar Handbook, Volume II, Passive Solar Design Analysis, prepared by LASL for the US DOE, DOE/CS-0127-2.

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II. SOLCOST-PASSIVE OVERVIEW

Passive Systems Analysis Capability

The passive solar heating capability in SOLCOST uses the Solar Load Ratio (SLR) method, which was developed at the Los Alamos Scientific Laboratory. The methodology is documented in Volume 2 of the Passive Solar Design Handbook by Bruce Anderson and Doug Balcomb. The SLR correlations were derived from hour-by-hour simulations made with the PASOLE and SUNSPOT computer programs developed by the Los Alamos Solar Group. The thermal network models in these computer programs were validated with data and experiments from fourteen test rooms, several instrumented test boxes, and fifteen actual buildings located near Los Alamos.

The SOLCOST-PASSIVE implementation of the SLR method predicts the solar savings fraction and required auxiliary heat for Trombe and water wall mass storage systems and direct gain buildings. Combinations of these approaches can be evaluated by simply specifying the parameters for each feature. The program also includes a powerful economic analysis, which accounts for federal and state solar tax incentives.

Key inputs to the analysis include:

- o Building Load Coefficient or building data to compute BLC, i.e. window, floor areas, R-values, etc.,
- o Passive system parameters including type, glazing area, orientation, and night insulation R-values,
- o Optional features including overhangs and reflectors,
- o Financial parameters if the economic analysis is desired.

Combinations of the three passive approaches can be analyzed in a single run, with each passive feature specified in detail, i.e., glazing area, tilt, azimuth, night insulation R-value, storage absorptance, overhang geometry, and reflector parameters. The solar savings fractions for each system type are computed and weighted by the glazing area to estimate the mixed system performance.

It is also possible to step through different sizes of glazing areas (up to four) in one run. This allows the user to investigate a range of system sizes with a minimum of computer input effort.

It is important that SOLCOST users understand the limits of applicability of the SLR method. For that reason, the following section has been taken directly from Volume 2 of the Passive Solar Design Handbook.

Applicability of the Thermal Design Aids

The SLR procedure is appropriate to the design of smaller passive solar buildings for which the heating requirement is determined primarily by energy losses through the exterior surfaces of the building, with only a small contribution from sources of heat inside the building, such as people, lights, and equipment. Thus the procedure is suitable for residences, small commercial buildings, warehouses, and livestock shelters, since internal sources of heat within these structures represent a small fraction of the total requirement, especially in colder climates. For example, in an occupied residence it is normally expected that the heat generated by people, lights, and other equipment will effect a temperature rise of about 5 F to 7 F. Of course, this depends on the living patterns of the residents and how well the house is insulated. Normally it is anticipated that the building occupant will wish to maintain the building at 70 F to 72 F. Thus the sun, or the auxiliary heater, must supply heat if the average outside temperature is less than about 65 F.

This is not to say that passive heat cannot be used effectively in other buildings, but a large commercial building (or even a small building with substantial heat-generating equipment) presents an entirely different heating situation than a small building. Much or all of the heat required is internally generated, and cooling becomes the dominant consideration in design for comfort control. Such structures require very special considerations by the designer in the application of passive solar gains, and improper design may create major overheating problems. Design tools appropriate to such buildings are being developed, but are not available at the time of writing of the Passive Solar Design Handbook.

Design tools for thermal storage wall approaches are at the most advanced stage of development, and the designer can use these techniques with the greatest confidence. The greatest number of experiments and analyses have been done for Trombe walls and water walls, and their performance is now very well characterized.

Design aids for the use of direct gain are not as fully developed as for thermal storage walls. This is principally because the situation is more complex, especially for the distribution and apportioning of the solar heat between lightweight, non-storage elements and massive heat storing elements of the internal building environment. Up to a point, the use of direct gain is fairly straightforward. If the heat from direct gain can be used in the building immediately, then there is no need for storage. Thus direct gain can be used to supply up to 30 or 40 percent of the building requirements without special concern for thermal storage. As the glazing area is increased beyond this, then it is essential to consider how the heat will be stored in the building materials and what temperature swings will result. If very large glazed areas are required, as would be the case of a design for a high solar fraction in a cold climate, then the designer must use thermal storage very judiciously and carefully or overheating will occur.

Correlation curves which have been developed for estimating solar contribution can be used with confidence if the assumptions used in the analysis match the actual operation of the building. The thermostat setting of 65 F (in the absence of internal heat) is of particular importance. The upper air temperature limit of 75 F, at which point heat is presumed to be vented to avoid overheating, is less important. Various sensitivity studies have been made, varying one design parameter at a time, and these results are useful in assessing the implications of changing the various design variables.

Performance Measures for Passive Solar Systems*

The definition of terms used to describe passive solar buildings has been a subject of ambiguity and concern among both designers and evaluators from the very start, beginning with the definition of what is meant by passive solar and extending through to the definition of various performance measures. There has not been a consensus of opinion on these issues, and various writers have chosen to define terms in various ways.

*This section is condensed from Appendix "D" of the Passive Solar Design Handbook, Vol. 2.

The key problems come up in defining what one means by the terms "solar heating fraction", "solar contribution", "thermal load", and "solar savings". All of these terms have different meanings, and an understanding of the differences is an essential part of understanding the significance of numbers used to describe passive solar performance.

Thermal Load

In the most literal sense, the term thermal load refers to the total amount of energy from all internal and external sources required to maintain the building at a temperature different than its environment. In a building heating application the heating load would refer simply to the total amount of energy input to the building, resulting in the building operating at a temperature higher than that of the outside temperature.

One can immediately think of two different heating loads which might be of value. The first is the actual thermal load that the building experiences, which might include a substantial amount of energy required to maintain the building at some level above a normal comfort situation. This might come about, for example, in a direct gain solar building when the solar input greatly exceeds the building heating requirements during a portion of the day and thermal storage is inadequate to absorb the excess. The building, therefore, achieves high temperatures - perhaps to the discomfort of the building occupants. The thermal load is nonetheless equal to the total energy input. The actual thermal load can also depend on occupant behavior and controller operation.

The second definition of thermal load might be referred to as reference thermal load. This would be the total amount of energy which would be required to maintain the building at a reference temperature level or schedule of temperature levels deemed desirable. Such a reference load might be greater or less than the actual building load, depending on whether the temperature inside was momentarily less than or greater than the desired reference temperature. The two only become equal if the building temperature control is accurate. Note that the distinction between these two types of loads may come about in a non-solar building or in an active solar building, as well as in a passive building.

Yet a third definition of thermal load would refer to a non-solar house, which is defined to be the same functionally and thermally as the solar house, except with the passive solar elements removed and replaced by "normal construction". To many this is felt to be the fairest way of defining a reference thermal load, but there are two problems with its use. The first, of course, is to define what is meant by "normal construction". One simple procedure would be to replace the passive solar elements which define a portion of the exterior of the building with elements which are similar to the rest of the building, in terms of insulating value and window type and window area. The second problem pertains to the difficulty of analyzing the reference, non-solar building, greatly increasing the computational time required in the analysis. It is more convenient to base the calculation on an adiabatic south wall, i.e., one with a neutral thermal effect. A "normal" wall which might replace the passive solar wall would have both solar gains and heat losses. For a well-insulated south wall these might well cancel. Rather than impose on the designer a separate calculation for such a wall, it is much simpler to assume the wall is neutral - that is, that the solar wall is replaced by a wall with absolutely no heat flow. This would normally not result in a large error.

Still another question which arises involves heat from internal sources, such as lights, appliances, and the occupants of a building. In one sense, this heat is part of the thermal load, since it is included in the heat loss from the building. Yet, in another sense, it is not part of the load presented to the heating system.

With the SLR approach, this ambiguity is resolved by defining distinctions between various meanings of the term "load". "Actual" load refers to the solar and auxiliary heat added to a solar heated building where temperatures may or may not be equal to the desired temperature; "reference" load, on the other hand, refers to the amount of heat required to maintain a building at the desired temperature. The other distinction involves the inclusion of the solar aperture. A "gross" load includes heat losses through the aperture, while a "net" load is the heat loss which would occur with the solar aperture replaced by an adiabatic (i.e., thermally neutral) wall. In all cases, heat supplied by internal sources is not included in the "load".

Summary of Loads

Gross:	Includes solar aperture
Net:	Excludes solar aperture
Actual:	Corresponds to actual temperatures
Reference:	Corresponds to set-point temperature

With the SLR method, the net reference load is used as the primary basis of performance evaluation. Put simply, it is the auxiliary heating requirement for a comparable non-solar building. More specifically, the net reference load:

- 1) is based on the desired temperature, or thermostat setting;
- 2) in a building with the solar aperture replaced with an adiabatic (thermally neutral) wall; and
- 3) does not include heat which is supplied by internal sources.

Solar Contribution

Solar energy which is absorbed in a building ultimately leaves the building by three routes. That which is effective in maintaining the "net" load at the "actual" temperature is referred to as "net solar contribution". Likewise, that which maintains the "gross" load at the actual temperature is referred to as the "gross solar contribution". This includes heat which is lost through the solar aperture. The third possible destiny of solar heat gains is venting to the ambient for the purpose of limiting over-heating. When this portion is included, the term "total solar input" is used.

Solar Savings

Solar savings is the reduction in backup heating requirements resulting from the presence of the solar collection element. It only has meaning with respect to a reference temperature setting in a non-solar building (the net reference load).

Solar Savings Fraction

Solar Savings Fraction is the performance measure of primary interest to the SLR approach.

$$SSF = \frac{\text{solar savings}}{\text{reference net load}}$$

or, equivalently:

$$SSF = 1 - \frac{\text{auxiliary heat supplied}}{\text{auxiliary heat in non-solar building}}$$

Thus the SSF is simply the solar savings referenced to a thermal load, which excludes both the heating and loading effects of the passive solar wall.

Reference Systems for the Solar Load Ratio Method

The SOLCOST-PASSIVE SLR correlations estimate the thermal performance of 1) direct gain spaces, and 2) thermal storage walls of either the Trombe wall type or the water wall type. Combinations of these configurations can also be evaluated. The SLR approach allows a rapid calculation of the solar savings fraction, which the passive system will achieve. This predicted savings is in close agreement with the results from the hour-by-hour simulations on which the SLR correlations are based. These simulations were based on a set of assumptions and a range of parameter values which defined the reference system designs. The assumptions for the Trombe wall and water wall systems are given in Table 1. The direct gain reference conditions are also given in Table 1. The direct gain SLR correlation was modified slightly by LASL after the Passive Solar Design Handbook was published, mainly to account for a change in the glazing spacing from 0.25 inch to 0.50 inch.* SOLCOST-PASSIVE contains the updated direct gain SLR correlation.

*Wray, W.O., "Additional Solar Load Ratio Correlations for Direct Gain Buildings," Proceedings of the 1980 AS/ISES Meeting, Phoenix, Arizona.

Table 1. Reference Passive System Designs

General

Thermal storage capacity = 45 Btu/F ft^2 of glazing

Other thermal mass of building is negligible

Double glazing, with normal transmittance = .747

Room temperature control range = 65 F to 75 F

Night insulation (when used) is R9

In place 5 pm to 8 am (Trombe and water walls)

In place 5 pm to 7 am (Direct gain)

Thermal mass-to-room air conductance = $1.0 \text{ Btu/F hr ft}^2$

Masonry properties (Trombe walls and direct gain)

$k = 1.0 \text{ Btu/ft hr F}$ (thermal conductivity)

$\rho = 150 \text{ lb/ft}^3$ (density)

$C = 0.2 \text{ Btu/lb F}$ (specific heat)

Infrared emittance of mass surface = 0.9

No internal heat generation (from appliances, etc.)

Trombe Walls

Wall has vents at top and bottom, with backdraft dampers

Vent area = 3% of wall area (each of 2 vents)

Glazing Spacing = $1/4$ inch

Direct Gain

Mass is 6-inch thick masonry

Mass area is 3 times glazing area

Transmitted solar radiation is uniformly distributed on mass

Non-mass absorption fraction = 0.2

(heats air directly)

Glazing Spacing = $1/2$ inch

Additional Assumptions for LCR Method

Vertical, south-facing glass

Ground reflectance = 0.3

No shading of solar aperture

Mass absorptance = 1.0 (thermal storage walls)

= 0.8 (direct gain)

Additional SLR correlations for attached sunspaces have recently been published by LASL; unfortunately these have not been incorporated in the initial release of SOLCOST-PASSIVE. Users should refer to Reference 3 for detailed information on the attached sunspace correlations.

The current SLR correlations do not allow determination of optimum storage masses for passive systems. The Los Alamos researchers have studied this effect extensively with detailed simulations and have not been able to distill this effect into a universal correlation. Users are referred to Appendix C for additional discussion on storage effects.

Building Load Coefficient for Space Heating

The first step in the design development stage for a building project is the estimation of the space heating load. In the process of calculating a heating load, a Building Load Coefficient is determined. This quantity is useful for estimating the solar savings of small buildings with skin-dominated heating loads.

The Building Load Coefficient (BLC) has been defined by LASL as the additional heating required to maintain a one degree Fahrenheit increase in the building inside temperature if the solar collection glazing were covered with a perfect insulator. For example, if the heat required to maintain the building at 70°F were determined to be 400,000 Btu/day, and the heat required to maintain the building at 71°F were determined to be 420,000 Btu/day, then the BLC is equal to the difference or 20,000 Btu/day-F.

The solar glazing is not included in the calculation of the Building Load Coefficient. This is done for three reasons:

- o The solar glazing would not be present in a non-solar building, which is the principal basis for comparison.
- o The solar glazing is a net energy gainer, not a loser, and to represent it as part of the load would be misleading.
- o The Solar Load Ratio method is based on BLC's defined without the solar wall included.

Users can calculate their BLC separately using the methodology of Appendix A and input it directly to SOLCOST-PASSIVE, or they can input the building description and allow the program to compute the BLC.

Figure 1 shows the program output summary for a BLC calculation from building description data.

```

PROJECT  MOUNTAIN HEAT LOAD EXAMPLE
LOCATION  GRAND LAKE,CO
LATITUDE 40.3
DIRECT GAIN SYSTEM    GLAZING AREA = 180. SQ FT    NIGHT INSUL. R-VALUE = 5.0

THERMOSTAT SETTING    65.0 DEG F
INTERNAL HEAT RATE      0.0 BTU/DAY

BUILDING PARAMETERS FOR LOAD CALCULATION
      AREA      R-VALUE      CONDUCTANCE
      (SQ FT)              (BTU/HR-F)
NON-SOLAR WALLS      1310.      25.      52.
ROOF OR CEILING      834.      30.      28.
NON-SOUTH WINDOWS      40.      3.      13.
FLOOR      484.      20.      23.
BASEMENT WALLS      64.      11.      36.
BUILDING VOLUME = 13200. CU FT
AIR CHANGES/HR = .75      120.
ELEVATION = 9960. FEET
                                TOTAL = 272.

CALCULATED VALUES
BUILDING LOAD COEFFICIENT 6535. BTU/DEGREE-DAY
LOAD COLLECTOR RATIO, BLC/AC 36.3 BTU/DEGREE-DAY-SQ-FT

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Figure 1. Sample SOLCOST-PASSIVE BLC Calculation

Effects of Thermostat Setting and Internal Heat Sources

The SLR approach uses an effective base temperature, T_{bs} , to compute the degree days for the solar building. This base temperature is given by the thermostat setting minus the building temperature increase associated with internal sources of heat from people, lights, appliances, water heater losses, etc., except the auxiliary heater or the sun. Unless other information is available, these sources can be taken equal to 20,000 Btu/day per person. The internal sources affect the solar building in a different way than they would affect a non-solar building, so another base temperature, T_{bns} , is also calculated for the reference non-solar building:

$$T_{bns} = T_{set} - Q_{int}/BLC$$

$$T_{bs} = T_{set} - Q_{int}/(BLC + 24 A_c U_c)$$

where A_c is the glazing area and U_c is the steady state conduction coefficient for the glazing. Details of this effective base temperature concept are given in Reference 1. SOLCOST-PASSIVE internally accounts for night insulation effects on U_c for the passive elements.

Using T_{bs} , a set of degree days, DDs, are calculated for the solar building in order to determine the monthly solar savings fractions. These are printed in the performance summary table for each run. An additional set of degree days, DDns, are calculated for the non-solar building and used to compute the annual non-solar (reference) building load from:

$$LOAD = BLC * DDNS$$

The monthly auxiliary energy terms for the solar building are given by:

$$Q_{auxs,i} = (1 - SSF_i) * (DD_{si}) * (BLC)$$

The annual solar savings fraction, SSF, is given by:

$$SSF = 1. - \frac{\sum Q_{auxs,i}}{BLC * DDns}$$

Users are cautioned that when internal heat is present, the "monthly SSF_i" terms printed in the performance table are only intermediate calculations (not true SSF's). In this case only the annual SSF has meaning. Obviously when there is no internal heating, the base temperatures for the solar and reference non-solar building are identical, and the monthly SSF's are meaningful performance measures.

Figure 2 shows a typical base temperature summary and performance summary output by the program.

PROJECT EXAMPLE DIRECT GAIN CABIN IN COLORADO

LOCATION GRAND LAKE, CO

LATITUDE 40.3

DIRECT GAIN SYSTEM GLAZING AREA = 210. SQ FT NIGHT INSUL. R-VALUE = 5.0

THERMOSTAT SETTING 65.0 DEG F

INTERNAL HEAT RATE 0.0 BTU/DAY

USER INPUT BUILDING LOAD COEFFICIENT 6430. BTU/DEGREE DAY

CALCULATED VALUES

LOAD COLLECTOR RATIO, BLC/AC 30.6 BTU/DEGREE-DAY-SQ-FT
DEGREE DAY BASE TEMPERATURE FOR NON-SOLAR BUILDING 65.0 DEG F
DEGREE DAY BASE TEMPERATURE FOR SOLAR BUILDING 65.0 DEG F
ANNUAL DEGREE-DAYS FOR NON-SOLAR BUILDING 10800. F-DAYS
ANNUAL DEGREE-DAYS FOR SOLAR BUILDING 10800. F-DAYS

PERFORMANCE SUMMARY FOR 210. SQ FT SYSTEM

MONTH	DEGREE DAYS (F-DAY)	SOLAR RADIATION ABSORBED (MMBTU/MON)	SOLAR LOAD RATIO	AUXILIARY ENERGY (MMBTU/MON)	USEFUL SOLAR ENERGY (MMBTU/MON)	SOLAR SAVINGS FRACTION
JAN	1555.2	4.04	.40	8.84	1.16	.116
FEB	1321.2	4.37	.51	7.03	1.47	.173
MAR	1296.0	4.64	.56	6.71	1.62	.195
APR	945.0	3.67	.60	4.74	1.33	.220
MAY	685.8	2.51	.57	3.52	.89	.202
JUN	450.0	2.40	.83	1.92	.97	.336
JUL	275.4	2.49	1.40	.73	1.04	.590
AUG	313.2	2.71	1.35	.87	1.15	.570
SEP	504.0	3.75	1.16	1.64	1.60	.494
OCT	802.8	4.82	.93	3.15	2.01	.389
NOV	1175.4	3.99	.53	6.19	1.36	.180
DEC	1476.0	3.68	.39	8.47	1.02	.108
YR	10800.0	43.07		53.80	15.64	.225

Figure 2. SOLCOST-PASSIVE Performance Summary

Solar Radiation Calculations

The technique used to obtain solar energy absorbed is to determine first the energy incident on a square foot of vertical south facing double glazing; then to modify this as required by several multiplicative factors which take into account orientation and tilt, ground reflectivity, reflectors, shading by overhangs, transmissivity of the glazing, building or storage wall absorptance and site shading. In SOLCOST-PASSIVE, all of these factors except site shading are computed internally for the given inputs of azimuth, tilt, ground reflectance, absorptance, and geometry for the overhang and/or reflector, if present.

A table of "Absorbed Solar Radiation Factors" which lists monthly values of all the radiation factors is output with each execution of SOLCOST-PASSIVE. For mixed systems, this table is printed for each system type input. Figure 3 shows an example Absorbed Solar Radiation Factors table.

Details for the radiation factor inputs are given in Appendix B. Tables of suggested ground reflectance and wall absorptance are given there, along with geometry definitions for the overhang and reflector inputs.

ABSORBED SOLAR RADIATION FACTORS PASSIVE SYSTEM TYPEDG										ABSORBED RADIATION (BTU/SQ FT-MON)
	HTV	AZF	TILT	GRF	OHANG	REFL	TRANS	ABSOR	SHADE	
JAN	1.75	1.00	1.00	1.07	1.000	1.000	.710	1.000	.600	19250.
FEB	1.43	1.00	1.00	1.08	1.000	1.000	.699	1.000	.600	20797.
MAR	1.04	1.00	1.00	1.11	1.000	1.000	.659	1.000	.600	22089.
APR	.74	1.00	1.00	1.15	1.000	1.000	.608	1.000	.600	17493.
MAY	.55	1.00	1.00	1.00	1.000	1.000	.575	1.000	.600	11962.
JUN	.48	1.00	1.00	1.00	1.000	1.000	.566	1.000	.600	11448.
JUL	.51	1.00	1.00	1.00	1.000	1.000	.569	1.000	.600	11837.
AUG	.63	1.00	1.00	1.00	1.000	1.000	.589	1.000	.600	12917.
SEP	.89	1.00	1.00	1.00	1.000	1.000	.635	1.000	.600	17836.
OCT	1.25	1.00	1.00	1.09	1.000	1.000	.684	1.000	.600	22938.
NOV	1.62	1.00	1.00	1.07	1.000	1.000	.708	1.000	.600	19017.
DEC	1.83	1.00	1.00	1.06	1.000	1.000	.711	1.000	.600	17502.

NOTES	1.HTV ..	HOR. TO VER. FACTOR	6.REFL ..	REFLECTOR FACTOR (IF PRESENT)
	2.AZF ..	AZIMUTH FACTOR	7.TRANS ..	GLAZING TRANSMISSION FACTOR
	3.TILT ..	TILT FACTOR	8.ABSOR ..	ABSORPTANCE OF PASSIVE FEATURE
	4.GRF ..	GROUND REFL. FACTOR		(DEFAULTED OR INPUT BY USER)
	5.OHANG	OVERHANG FACTOR	9.SHADE ..	SITE SHADING (DEF = 1.0 UNLESS INPUT BY USER)
	10. GLAZING TRANSMISSION BASED ON 2 LAYERS 1/8 INCH STD. GLASS			

Figure 3. Absorbed Solar Radiation Table from
SOLCOST-PASSIVE

Economics

The economic analysis in SOLCOST-PASSIVE is similar to the SOLCOST economics. Some changes have been made to simplify the inputs with the major one being that fuel cost tables are not used. Instead, the user simply inputs the cost of delivered auxiliary energy directly to the program. Other features include the provision for separate state and federal income tax incentives, which can be summed together (as in Colorado), or the state incentive can be reduced by the federal incentive (as in California). As of this writing, the federal solar tax incentives do not apply to passive buildings; however, the SOLCOST-PASSIVE software is designed to include the federal incentive if it ever becomes applicable.

Appendix D contains the details of the life cycle cost methodology. Key inputs to the analysis are shown in Figure 4, which is output by the program before the economic analysis.

LISTING OF ECONOMIC PARAMETERS	
COST DATA	
INITIAL FIXED COST	0. \$
INITIAL VARIABLE COST	15.00 \$/SQ FT
OPER. MAINT. AND INSUR RATE	1.0 %
FINANCIAL DATA	
LOAN DOWN PAYMENT	15.0 % OF INITIAL COST
LOAN INTEREST RATE	10.0 %
LOAN TERM	30. YEARS
DISCOUNT RATE	7.0 %
PERIOD OF OWNERSHIP	10. YEARS
GENERAL INFLATION RATE	6.0 % PER YEAR
PROPERTY APPRECIATION RATE	6.0 % PER YEAR
APPRECIATION VALUE FACTOR	.75
TAX DATA	
FED. STATE INCOME TAX RATE	25.0 %
PROPERTY TAX RATE	2.0 %
STATE SOLAR INCENTIVE	30.0 % UP TO A MAXIMUM OF 2000. \$
ENERGY COST DATA	
FUEL PRICE IN YEAR 1	14.65 \$/MILLION BTUS
ESCALATION RATE	8.0 % PER YEAR

Figure 4. Listing of SOLCOST-PASSIVE Economic Parameters

The analysis only considers the case of the homeowner, i.e., tax savings accrue for interest and property tax payments. Default values are provided for all of the economic parameters, including initial costs. Users are obviously encouraged to compute their own cost values, since the default values in the program are there only to demonstrate the economic capability.

Since the analysis is directed towards residential applications, the period of home ownership is used for the term of the economic analysis. Obviously the expected life of the passive building will be many times the average period of ownership. Resale value is a key factor in the current housing market, and passive homes may experience significant appreciation as the cost for conventional fuels continues to rise. For this reason, resale value can be included in the analysis by simply specifying a rate of appreciation and assigning a weighting factor to the increased value of the building. This latter factor requires some judgement by the user in estimating the future worth of the passive building.

Several output options are available for the economic analysis, including 1) a life cycle savings summary and 2) a detailed cash flow for the period of ownership. Examples of these two options are shown in Figures 5 and 6 for a sample economic analysis. Options are also available to suppress most of the data listing so that only bottom lines values are printed.

LIFE CYCLE SAVINGS ANALYSIS SUMMARY					
PASSIVE SYSTEM AREA,	SQ FT	175.	200.	225.	250.
SOLAR SAVINGS FRACTION		.399	.444	.487	.527
TOTAL COST,	\$	2705.	2920.	3135.	3350.
ANNUALIZED PASSIVE HEAT COST, \$/MIL. BTUS		15.10	14.63	14.32	14.14
DELIVERED HEAT COST (PAS+AUX), \$/MIL. BTUS		19.23	18.70	18.24	17.84
NET PRESENT VALUE OF SOLAR SAVINGS,	\$	719.	856.	978.	1084.

Figure 5. Sample SOLCOST-PASSIVE Life Cycle Savings Summary

\$\$\$ CASH FLOW SUMMARY \$\$\$
FOR
210. SQ. FT. PASSIVE SYSTEM

YR	(A) FUEL SAVINGS	(B) MAINT. +INS.	(C) PROP. TAX	(D) LOAN PAYMENT	(E) ANNUAL INTEREST	(F) TAX SAVINGS	(G) NET CASH FLOW	(H) DISCOUNTED CASH FLOW
0					DOWN PAYMENT =	-473.	-473.	
1	247.	33.	67.	284.	266.	1031.	895.	836.
2	267.	35.	71.	284.	264.	84.	-39.	-34.
3	289.	38.	75.	284.	262.	84.	-24.	-19.
4	312.	40.	80.	284.	260.	85.	-7.	-5.
5	337.	42.	84.	284.	258.	86.	12.	8.
6	364.	45.	89.	284.	255.	86.	32.	21.
7	393.	47.	95.	284.	252.	87.	53.	33.
8	424.	50.	100.	284.	249.	87.	77.	45.
9	458.	53.	106.	284.	246.	88.	102.	56.
10	495.	56.	113.	284.	242.	89.	130.	66.
10					YEAR 10 RESALE VALUE =	1813.		922.
							1456.	

NET PRESENT VALUE OF SOLAR SAVINGS 1456. DOLLARS
 PAYBACK TIMES FOR -
 NET CASH FLOW TO EQUAL TOTAL COST 0.0 YEARS
 DISCOUNTED CASH FLOW TO EQUAL TOTAL COST 0.0 YEARS
 NET CASH FLOW TO EQUAL DOWN PAYMENT5 YEARS
 DISCOUNTED CASH FLOW TO EQUAL DOWN PAYMENT .. .6 YEARS
 ANNUAL ENERGY SAVINGS WITH PASSIVE SYSTEM 15.6 MILLION BTUS

NOTES

NET CASH FLOW... $G = A - B - C - D + F$
 DIS. CASH FLOW... $H = G / (1 + \text{DIS. RATE})^{\text{YEAR I}}$
 TAX SAVINGS $F = \text{TAX RATE} \times (C + E)$
 RESALE VALUE = APPRECIATION - REMAINING LOAN BALANCE
 YEAR 1 TAX SAVINGS INCLUDES STATE CREDIT = 945.

Figure 6. Sample SOLCOST-PASSIVE Cash
Flow Summary

III. GUIDE TO SOLCOST-PASSIVE INPUT DATA

SOLCOST-PASSIVE is an interactive program which interrogates the user for the input data set needed to execute the analysis. Section IV explains the mechanics of the program operation.

This section presents additional information on the SOLCOST-PASSIVE inputs, which are listed on pages III-3 through III- . Sample problems for several input decks are explained in Section IV; the user should examine those examples to get acquainted with the parameters and data formats.

The SOLCOST-PASSIVE inputs consist of constants and arrays of data values. Each input is described in this guide under a Line Number, which ranges from Line 11 to Line 145. An input may be one of the following:

Floating Point Constant

112, 15. is the passive system installed cost per sq. ft.

117, .10 is a 10% loan interest rate

118, 20. is a 20 year term for the life cycle cost analysis

Integer Constant

11, 25 is a flag for site location number 25

41, 3 is a flag for the water wall system type

Floating Point Array

15, 32., 38., 45., 50., 60., 65., 68., 70., 62., 50., 40., 31.,*

is an array of monthly minimum average temperatures

Remember, the input parameters are listed by line numbers in this User's Guide. These line numbers agree with the SOLCOST-PASSIVE line numbers in the data input file.

SOLCOST-PASSIVE contains "built in" values for several of the inputs. If the user accepts these default values, he enters GO in the conversation and the program automatically uses the defaulted system. Therefore, it is critical that the user check each defaulted value to verify that it applies to his analysis. Values of the defaulted parameters are given on Pages III-3 through III-8.

Only two parameters have no defaulted value. These are:

Line 41	Passive System Type Flag
Line 51, 71, and 91	Area for Trombe wall, direct gain, and water wall apertures

Hence, the program can be run with all default values by only making an entry to the above lines. If Line 41 is entered with a 3 for a water wall system, and if Line 91 is entered as 390 sq. ft., the sample water wall problem in the Passive Solar Design Handbook will be output.

<u>Line No.</u>	<u>Parameter</u>	<u>Default Value</u>	<u>Description</u>
11	Site Location Number	104	See Table B-3 for listing of cities. Data bank supplies latitude, weather, and solar data for each site, lines 12 through 16. Use city nearest to installation. Data bank values can be overridden by direct entry of lines 12 through 16.
12	Site Latitude	0.	Degrees
13	Daily Horizontal Insolation Array	0.	Monthly values of average global horizontal insolation, Btu/day-sq.ft
14	Degree Days Array	0.	Monthly values of degree days, 65°F base
15	Min. Avg. Temperature Array	0.	Monthly min. avg. temperatures, °F
16	Max. Avg. Temperature Array	0.	Monthly max. avg. temperatures, °F
17	Ground Reflectance Array	0.3	Monthly ground reflectance values (see Appendix B)
18	Site Shading Fraction Array	1.0	Monthly site shading fractions
21	Building Load Coefficient	7420.	Building load coefficient, Btu/°F-day. See Appendix A. If input, lines 22-36 are skipped. Enter 0. to access lines 22-36.
22	Non-Solar Wall Area	0.	Wall area for building sq. ft.
23	R-Value for Non-Solar Wall	0.	
24	Roof or Ceiling Area	0.	Sq. Ft.
25	R-Value for Roof or Ceiling	0.	

<u>Line No.</u>	<u>Parameter</u>	<u>Default Value</u>	<u>Description</u>
26	Window Area	0.	Window area, excluding solar glazing, sq. ft.
27	R-Value for Windows	0.	
28	Floor Area Over Crawl Space	0.	Sq. Ft.
29	R-Value for Floor Over Crawl Space	0.	
30	Slab Perimeter	0.	Ft.
31	R-Value for Slab Perimeter Insulation	0.	
32	Building Volume	0.	Cu. Ft.
33	Infiltration Air Changes Per Hour	0.	
34	Elevation of Building Site	0.	Ft. above sea level
35	Basement Wall Length	0.	Ft.
36	R-Value for Basement Wall Insulation	0.	
41	Passive System Type	0.	1 = Trombe wall 2 = Direct gain 3 = Water wall 4 = Mix of above For mixed systems, enter the area of each type on line 51, 71, and 91.
42	Thermostat Setting	65.	Thermostat setting in passive building, °F
43	Internal Heat Generation	0.	Btu/day

<u>Line No.</u>	<u>Parameter</u>	<u>Default Value</u>	<u>Description</u>
	<u>Aperture Area</u>		
51	Trombe Wall	0.	Aperture area for solar glazing, sq. ft.
71	Direct Gain	0.	
91	Water Wall	0.	
	<u>Night Insulation R-Value</u>		
52	TW	9.	Night insulation R-Value
72	DG	9.	
92	WW	9.	
	<u>Tilt Angle</u>		
53	TW	90.	Tilt angle from horizontal degrees
73	DG	90.	
93	WW	90.	
	<u>Azimuth Angle</u>		
54	TW	0.	Azimuth angle from due South, degrees. (Note: SE and SW orientations give identical results with SLR method.)
74	DG	0.	
94	WW	0.	
	<u>Wall/Room Absorptance</u>		
55	TW	0.95	See Appendix B for typical absorptances.
75	DG	1.00	
95	WW	0.95	
	<u>Overhang Flag</u>		
56	TW	0	Enter integer 1 if an overhang is present. See Appendix B for details on overhang capability.
76	DG	0	
96	WW	0	
	<u>Glazing Height</u>		
57	TW	0.	Ft.
77	DG	0.	
97	WW	0.	
	<u>Hor. Projection of Overhang</u>		
58	TW	0.	Ft
78	DG	0.	
98	WW	0.	
	<u>Height of Overhang Over Glazing</u>		
59	TW	0.	Ft.
79	DG	0.	
99	WW	0.	
	<u>Reflector Flag</u>		
60	TW	0	Enter integer 1 if a reflector is present. See Appendix B for details on reflector analysis.
80	DG	0	
100	WW	0	

Line No.	Parameter	Default Value	Description
<u>Reflector Aspect Ratio</u>			
61	TW	0.	Aspect ratio is reflector E-W dimension divided by N-S dimension.
81	DG	0.	
101	WW	0.	
<u>Reflector Length</u>			
62	TW	0.	N-S length, ft.
82	DG	0.	
102	WW	0.	
<u>Reflector Specular Reflectance</u>			
63	TW	0.8	
83	DC	0.8	
103	WW	0.8	
84	Diurnal Heat Capacity (Direct Gain Systems Only)	0.	Btu/F-ft ² . See Appendix C for additional detail.
110	Economics Flag	0	Options: = 0 Do economics = 1 Skip economics
111	Initial Fixed Cost	0.	\$
112	Variable Cost	15.	\$/Sq.ft. of passive aperture
113	Oper., Maint., and Insur. Fraction	.01	Passive system OM+I
114	Backup System Cost	0.	Backup heating system cost
115	Backup System OM+I	.005	
116	Down Payment	0.15	Loan down payment fraction
117	Loan Interest Rate	0.10	Loan interest rate fraction
118	Loan Term	30.	Years
119	Discount Rate	.07	Discount rate fraction
120	Period of Ownership	10.	Period of home ownership, years. Term of cost analysis
121	General Inflation Rate	.06	Fraction per year
122	Property Appreciation Rate	.06	Fraction per year

<u>Line No.</u>	<u>Parameter</u>	<u>Default Value</u>	<u>Description</u>
123	Prop. Appreciation Value Factor	.75	Fraction, 0. to 1.0 If none of the passive cost is included in the resale price, this factor is zero. If all is included, then this factor = 1.0; values greater than 1.0 are possible.
124	Fed., State Income Tax Rate	.25	Fraction
125	Property Tax Rate	.02	Fraction
126	Fuel Price in Year 1	14.65	\$/Million Btu's delivered to the heating load
127	Fuel Escalation Rate	.08	Fraction, escalation rate per year. Enter a -1.0 if an escalation table of rates vs. years desired.
128	Fuel Escalation Table	0.	Enter two step schedule of escalation and years, i.e., .18, 5., .12, 10. will cause the year 1 price to be escalated 18% for the first 5 years, 12% for the next 10 years. Sum of years must be greater than or equal to the period of ownership.
129	Federal Solar Incentive Rate	0.	Current federal incentive is zero. Fraction
130	Max. Allowed Fed. Incentive	0.	\$
131	State Solar Incentive Rate	0.	Fraction
132	Max. Allowed State Incentive	0.	\$
133	Fed./State Incentives +/- Flag	0	Options = 0 Reduce state incentive by Federal incentive = 1 State incentive not reduced by federal incentive.

<u>Line No.</u>	<u>Parameter</u>	<u>Default Value</u>	<u>Description</u>
135	List Econ. Inputs Flag	0	Options: = 0 Print inputs = 1 Skip print of inputs
136	Compute Cash Flows Flag	0	Options = 0 Compute Cash Flow = 1 Skip Cash Flow
137	Print Cash Flow Flag	0	Options = 0 Print Cash Flow = 1 Print Summary Only
140	Print Project Sheet Flag	0	Options = 0 Print Project Sheet = 1 Skip
142	Print Abs. Rad. Table Flag	0	Options = 0 Print Abs. Rad. Table = 1 Skip
143	Print Monthly SSF	0	Options = 0 Print Monthly Solar Savings Fraction = 1 Skip
144	Multiple Area Run Flag	1	Enter number of candidate areas to be considered, up to 4 allowed.
145	Array of Candidate Areas	0.*	Enter up to 4 candidate areas, sq. ft.

IV. SOLCOST-PASSIVE INPUT DESCRIPTION WITH SAMPLE DESIGN CASES

The SOLCOST-PASSIVE solar energy design tool contains the following features:

- o Interactive conversational input mode,
- o Restart capability with an input file saved from a previous run (or created external to SOLCOST-PASSIVE),
- o Short form input mode,
- o Output printing at terminal or written to separate file for off-line printing.

Figure IV-1 shows the flow of data in the SOLCOLST-PASSIVE. System dependencies shown in Figure IV-1 are for a CDC host computer. Some minor changes in control statements are required for other host computers (see Appendix E).

The SOLCOST-PASSIVE inputs are free format in nature. Integers can be input for real values and vice-versa. Also, the position of the numeric values on the input line is not important; however, they must be separated by a comma or blank. Arrays must be terminated with an asterisk (*). Arrays can also be continued on additional cards, if necessary. A dollar sign (\$) is a special character designating comments. The input subroutine ignores everything after a dollar sign on each input image.

A shorthand feature is available for those arrays requiring 12 inputs. The program will fill the array with the last value encountered. Don't forget the * terminator. Project titles can only be entered at the start of the conversational session. Only one title per session is allowed. The title cannot be entered in the EDFILE data (as in SOLCOST).

Figure IV-1. SOLCOST-PASSIVE Data Schematic

Example No. 1 - Water Wall System in Dodge City

This example problem is taken from the Passive Solar Design Handbook. The project consists of a house located in Dodge City, Kansas, with a 390 Sq. Ft. water wall insulated with R9 night insulation. The solar glazing is oriented due south with no features such as overhangs or reflectors. The thermostat setting is 65°F, no internal heat sources are assumed, and the water wall absorptance is 1.00. The Building Load Coefficient is estimated to be 7420 Btu/degree day.

Economics were not included in the example.

Figure IV-2 shows the complete SOLCOST-PASSIVE session for this example. Figure IV-3 is the corresponding file OUTFIL, which was created by the Example 1 interactive session.

WELCOME TO THE SOLCOST-PASSIVE PROGRAM

NOTES --

TYPE HELP FOR A LIST OF USER COMMANDS

ENTER PROJECT TITLE (UP TO 60 CHARACTERS)
? SOLCOST-PASSIVE EXAMPLE NO. 1, WATER WALL
DO YOU WISH TO HAVE A LIST OF CITIES YES OR NO
? N
DO YOU HAVE AN OLD FILE TO START WITH YES OR NO.
? N
DO YOU WISH TO HAVE PROMPTS YES OR NO
? H

USER COMMANDS (MAY BE ENTERED AS SINGLE-CHARACTER)

HELP - LIST USER INPUT COMMANDS
DISPLAY - DISPLAY LINE INPUT OPTIONS AND/OR
DEFAULT VALUES
GO - TO TAKE THE DEFAULT VALUE AND GO TO NEXT LINE
DURING PROMPTS.
NEXT - STOP FILLING AN ARRAY BEFORE IT IS FILLED
LIST - LIST CURRENT USER FILE
LIST,NO. - LIST THE LINE NO. SPECIFIED
LIST,NO. - LIST THE SECTION SPECIFIED
PURGE - PURGE CURRENT LINE NUMBER FROM FILE
PURGE,NO. - PURGE LINE NUMBER SPECIFIED FROM FILE
RUN - TO SAVE THE INPUT FILE AND EXECUTE THE PROGRAM
EXIT - SAVE THE USER FILE AND END SESSION

WHERE: NO. IS A NUMBER,
1-8 ARE VALID SECTION NUMBERS
11-145 ARE VALID LINE NUMBERS

NOTES--

1. COMMANDS CAN BE ENTERED AT ANYTIME EXCEPT WHEN A "YES" OR "NO" RESPONSE IS EXPECTED. COMMAND "HELP" CAN BE ENTERED AT ANYTIME.
2. ALL PERCENTAGES ARE TO BE ENTERED AS DECIMAL FRACTIONS.
3. THE REPEAT OPTION FOR AN ARRAY IS "♦NO" WHERE "NO" IS THE NUMBER OF TIMES THAT THE LAST VALUE IS TO BE REPEATED. CAUTION ONLY ONE "♦" PER LINE.
(EXAMPLE: 16,0.65♦6)
4. A "NEXT" WILL END AN ARRAY BEFORE IT IS FILLED.
(EXAMPLE: 16,0.66♦4
NEXT)
5. TO FILL AN ARRAY WITH THE LAST VALUE INPUT SIMPLY END THE ARRAY WITH AN "♦".
(EXAMPLE: 16,0.72♦)

Figure IV-2. Example No. 1, Water
Wall in Dodge City

```

LINE:      110
           ECONOMICS FLAG  (IF =1 SKIP ECON)
? 1
LINE:      140
           PRINT PROJECT SHEET FLAG (=1 TO SKIP)
? G
LINE:      142
           PRINT ABS. RAD. TABLE FLAG (=1 TO SKIP)
? G
LINE:      143
           PRINT MONTHLY SSF FLAG      (=1 TO SKIP)
? G
LINE:      144
           MULTIPLE AREA RUN FLAG
? G
DO YOU WISH TO MAKE CHANGES TO THE FILE
YES OR NO
? N
DO YOU WISH TO HAVE THE INPUTS LISTED WITH THE OUTPUT YES OR NO
? N
DO YOU WISH TO HAVE THE OUTPUT WRITTEN ON FILE OUT YES OR NO
(A "NO" WILL CAUSE OUTPUT TO BE PRINTED AT THE TERMINAL)
? N

```

Figure IV-2. Example No. 1 (cont)

DO YOU WISH TO HAVE PROMPTS YES OR NO
? Y
DO YOU WISH TO HAVE PROMPTS FOR ALL THE SECTIONS.
IF YES ENTER "YES"
IF NO ENTER THE SECTION NUMBER
1=CITY/WEATHER 2=BLC/BLDG 3=SYSTEM DATA 4=TROMBE
5=DIRECT GAIN 6=WATER WALL 7=ECONOMICS 8=MISC
? Y
LINE: 11
LOCATION CODE
? 104
LINE: 17
GROUND REFLECTANCE BY MONTH
? 6
LINE: 18
SITE SHADING FRACTION BY MONTH (DEF = 1.0)
? 6
LINE: 21
BUILDING LOAD COEFFICIENT (BTU/F-DAY)
? 7420
LINE: 41
PASSIVE SYSTEM TYPE 1=TW, 2=DG, 3=WW, 4=MIXED
? 3
LINE: 42
THERMOSTAT SETTING (F)
? 65
LINE: 43
INTERNAL HEAT GENERATION (BTU/DAY)
? 0.
LINE: 91
APERTURE AREA: (SQ FT) WATER WALL
? 390
LINE: 92
NIGHT INSULATION R-VALUE WATER WALL
? 9.
LINE: 93
TILT ANGLE (DEG) WW
? 6
LINE: 94
AZIMUTH ANGLE (DEG) WW
? 6
LINE: 95
STORAGE MASS ABSORPTANCE WW
? 1.00
LINE: 96
OVERHANG FLAG WW
? 6
LINE: 100
REFLECTOR FLAG WW
? 6

Figure IV-2. Example No. 1 (cont)

SOLCOST-PASSIVE

DEVELOPED BY
MARTIN MARIETTA CORPORATION

BASED ON
LOS ALAMOS SOLAR LOAD RATIO METHOD

1

PROJECT SOLCOST-PASSIVE EXAMPLE NO. 1, WATER

LOCATION DODGE CITY, KS

LATITUDE 37.8

WATER WALL SYSTEM GLAZING AREA = 390. SQ FT NIGHT INSUL. R-VALUE = 9.0

THERMOSTAT SETTING 65.0 DEG F

INTERNAL HEAT RATE 0.0 BTU/DAY

USER INPUT BUILDING LOAD COEFFICIENT 7420. BTU/DEGREE DAY

CALCULATED VALUES

LOAD COLLECTOR RATIO, BLC/AG 19.0 BTU/DEGREE-DAY-SQ-FT

DEGREE DAY BASE TEMPERATURE FOR NON-SOLAR BUILDING 65.0 DEG-F

DEGREE DAY BASE TEMPERATURE FOR SOLAR BUILDING 65.0 DEG-F

ANNUAL DEGREE-DAYS FOR NON-SOLAR BUILDING 5046. F-DAYS

ANNUAL DEGREE-DAYS FOR SOLAR BUILDING 5046. F-DAYS

ABSORBED SOLAR RADIATION FACTORS PASSIVE SYSTEM TYPEWW

	HTV	AZF	TILT	GRF	OHANG	REFL	TRANS	ABSOR	SHADE	ABSORBED RADIATION (BTU/SQ FT-MON)
JAN	1.63	1.00	1.00	1.00	1.000	1.000	.708	1.000	1.000	29611.
FEB	1.33	1.00	1.00	1.00	1.000	1.000	.692	1.000	1.000	28912.
MAR	.97	1.00	1.00	1.00	1.000	1.000	.648	1.000	1.000	28877.
APR	.68	1.00	1.00	1.00	1.000	1.000	.598	1.000	1.000	23070.
MAY	.51	1.00	1.00	1.00	1.000	1.000	.569	1.000	1.000	18818.
JUN	.45	1.00	1.00	1.00	1.000	1.000	.563	1.000	1.000	18025.
JUL	.47	1.00	1.00	1.00	1.000	1.000	.565	1.000	1.000	18977.
AUG	.59	1.00	1.00	1.00	1.000	1.000	.581	1.000	1.000	21690.
SEP	.83	1.00	1.00	1.00	1.000	1.000	.624	1.000	1.000	26079.
OCT	1.16	1.00	1.00	1.00	1.000	1.000	.674	1.000	1.000	31610.
NOV	1.51	1.00	1.00	1.00	1.000	1.000	.703	1.000	1.000	28485.
DEC	1.71	1.00	1.00	1.00	1.000	1.000	.710	1.000	1.000	27555.

Figure IV-2. Example No. 1 (cont)

NOTES 1. HTV .. HOR. TO VER. FACTOR 6. REFL ... REFLECTOR FACTOR (IF PRESENT)
 2. AZF .. AZIMUTH FACTOR 7. TRANS ... GLAZING TRANSMISSION FACTOR
 3. TILT .. TILT FACTOR 8. ABSOR .. ABSORPTANCE OF PASSIVE FEATURE
 4. GRF .. GROUND REFL. FACTOR (DEFAULTED OR INPUT BY USER)
 5. OHANG OVERHANG FACTOR 9. SHADE ... SITE SHADING (DEF = 1.0 UNLESS
 INPUT BY USER)
 10. GLAZING TRANSMISSION BASED ON 2 LAYERS 1/8 INCH STD. GLASS

1

PERFORMANCE SUMMARY FOR 390. SQ FT SYSTEM

MONTH	DEGREE DAYS (F-DAY)	SOLAR RADIATION ABSORBED (MMBTU/MON)	SOLAR LOAD RATIO	AUXILIARY ENERGY (MMBTU/MON)	USEFUL SOLAR ENERGY (MMBTU/MON)	SOLAR SAVINGS FRACTION
JAN	1060.0	11.55	1.47	2.63	5.24	.666
FEB	834.0	11.28	1.82	1.38	4.81	.777
MAR	738.0	11.26	2.06	.94	4.53	.828
APR	344.0	9.00	3.52	.12	2.44	.954
MAY	115.0	7.34	8.60	.02	.84	.979
JUN	21.0	7.03	45.11	0.00	.16	1.000
JUL	0.0	7.40	0.00	0.00	0.00	1.000
AUG	0.0	8.46	0.00	0.00	0.00	1.000
SEP	41.0	10.17	33.43	0.00	.30	1.000
OCT	247.0	12.33	6.73	.04	1.79	.979
NOV	666.0	11.11	2.25	.69	4.25	.860
DEC	980.0	10.75	1.48	2.40	4.87	.670
YR	5046.0	117.67		8.22	29.22	.780

Figure IV-2. Example No. 1 (cont)

\$		LOCATION CODE
11,	104	
\$		BUILDING LOAD COEFFICIENT (BTU/F-DAY)
21,	7420.	
\$		PASSIVE SYSTEM TYPE 1=TW,2=DG,3=WW,4=MIXED
41,	3	
\$		THERMOSTAT SETTING (F)
42,	65.00	
\$		INTERNAL HEAT GENERATION (BTU/DAY)
43,	0.	
\$		APERTURE AREA, (SQ FT) WATER WALL
91,	390.0	
\$		NIGHT INSULATION R-VALUE WATER WALL
92,	9.000	
\$		STORAGE MASS ABSORPTANCE WW
95,	1.000	
\$		ECONOMICS FLAG (IF=1 SKIP ECON)
110,	1	

Figure IV-3. File OUTFIL Created
in Example No. 1

After the execution of Example No. 1, program control returns to the terminal for possible additional runs. To demonstrate the minimum output option, the session was continued as shown in Figure IV-4 for three additional candidate areas.

The session is terminated by the NO entry to the "Do you wish to make changes... " question, as shown at the end of Figure IV-4.

DO YOU WISH TO MAKE CHANGES AND EXECUTE THE PROGRAM AGAIN YES OR NO
(IF PROMPTS ARE DESIRED ENTER PROMPT)

? Y

ENTER LINE NO.

? 140

LINE: 140

PRINT PROJECT SHEET FLAG (=1 TO SKIP)

? 1

ENTER LINE NO.

? 142

LINE: 142

PRINT ABS. RAD. TABLE FLAG (=1 TO SKIP)

? 1

ENTER LINE NO.

? 143

LINE: 143

PRINT MONTHLY SSF FLAG (=1 TO SKIP)

? 1

ENTER LINE NO.

? 144

LINE: 144

MULTIPLE AREA RUN FLAG

? 3

ENTER LINE NO.

? 145

LINE: 145

ARRAY OF CANDIDATE AREAS (SQ FT)

? 100 125 150

ENTER LINE NO.

? R

DO YOU WISH TO HAVE THE INPUTS LISTED WITH THE OUTPUT YES OR NO

? N

DO YOU WISH TO HAVE THE OUTPUT WRITTEN ON FILE OUT YES OR NO

(A "NO" WILL CAUSE OUTPUT TO BE PRINTED AT THE TERMINAL)

? N

Figure IV-4. Example No. 1 Continuation for
Minimum Output Option with
Three Candidate Areas

SOLCOST - PASSIVE

DEVELOPED BY
MARTIN MARIETTA CORPORATION

BASED ON
LOS ALAMOS SOLAR LOAD RATIO METHOD

PERFORMANCE SUMMARY FOR 100. SQ FT SYSTEM

MONTH	DEGREE DAYS (F-DAY)	SOLAR RADIATION ABSORBED (MMBTU/MON)	SOLAR LOAD RATIO	AUXILIARY ENERGY (MMBTU/MON)	USEFUL SOLAR ENERGY (MMBTU/MON)	SOLAR SAVINGS FRACTION
YR	5046.0	30.17		27.09	10.36	.277

PERFORMANCE SUMMARY FOR 125. SQ FT SYSTEM

MONTH	DEGREE DAYS (F-DAY)	SOLAR RADIATION ABSORBED (MMBTU/MON)	SOLAR LOAD RATIO	AUXILIARY ENERGY (MMBTU/MON)	USEFUL SOLAR ENERGY (MMBTU/MON)	SOLAR SAVINGS FRACTION
YR	5046.0	37.71		24.94	12.50	.334

PERFORMANCE SUMMARY FOR 150. SQ FT SYSTEM

MONTH	DEGREE DAYS (F-DAY)	SOLAR RADIATION ABSORBED (MMBTU/MON)	SOLAR LOAD RATIO	AUXILIARY ENERGY (MMBTU/MON)	USEFUL SOLAR ENERGY (MMBTU/MON)	SOLAR SAVINGS FRACTION
YR	5046.0	45.26		22.89	14.55	.389

DO YOU WISH TO MAKE CHANGES AND EXECUTE THE PROGRAM AGAIN YES OR NO
(IF PROMPTS ARE DESIRED ENTER PROMPT)

N

2.848 CP SECONDS EXECUTION TIME

Example No. 2 - Mixed System (Trombe Wall and Direct Gain)

This example consists of a house in Denver having 180 sq. ft. of direct gain area and a 90 sq. ft. Trombe wall. The Trombe wall aperture faces due south; the direct gain windows face 25° from south and have an overhang with the geometry shown in Figure IV-5. Night insulation of R-5 is applied to the direct gain windows, the Trombe wall is uninsulated at night. The thermostat setting is 68°F , and internal heat sources total 60,000 Btu/day. The Building Load Coefficient is estimated to be 8370 Btu/degree day. No economics are included in this example.

Figure IV-5. Overhang Geometry for Example No. 2

Figure IV-6 presents the interactive session for this example.

WELCOME TO THE SOLCOST-PASSIVE PROGRAM

NOTES --

TYPE HELP FOR A LIST OF USER COMMANDS

ENTER PROJECT TITLE (UP TO 60 CHARACTERS)
? EXAMPLE NO. 2, MIXED SYSTEM (TROMBE + DIR. GAIN)
DO YOU WISH TO HAVE A LIST OF CITIES YES OR NO
? N
DO YOU HAVE AN OLD FILE TO START WITH YES OR NO.
? N
DO YOU WISH TO HAVE PROMPTS YES OR NO
? Y
DO YOU WISH TO HAVE PROMPTS FOR ALL THE SECTIONS.
IF YES ENTER "YES"
IF NO ENTER THE SECTION NUMBER
1=CITY/WEATHER 2=BLC/BLDG 3=SYSTEM DATA 4=TROMBE
5=DIRECT GAIN 6=WATER WALL 7=ECONOMICS 8=MISC
? 1
LINE: 11
LOCATION CODE
? 55
LINE: 17
GROUND REFLECTANCE BY MONTH
? 6
LINE: 18
SITE SHADING FRACTION BY MONTH (DEF = 1.0)
? 1. 1. .9 .9 .8 .65 .65 .65 .8 .85 .9 .9+
DO YOU WISH TO HAVE PROMPTS FOR OTHER SECTIONS?
IF NO ENTER "NO"
IF YES ENTER THE SECTION NUMBER (1,2,..... 8)
? 2
LINE: 21
BUILDING LOAD COEFFICIENT (BTU/F-DAY)
? 9320.
DO YOU WISH TO HAVE PROMPTS FOR OTHER SECTIONS.
IF NO ENTER "NO"
IF YES ENTER THE SECTION NUMBER (1,2,..... 8)
? 3
LINE: 41
PASSIVE SYSTEM TYPE 1=TW,2=DG,3=WW,4=MIXED
? 4
LINE: 42
THERMOSTAT SETTING (F)
? 68.
LINE: 43
INTERNAL HEAT GENERATION (BTU/DAY)
? 60000.

Figure IV-6. Example No. 2,
Mixed System - Direct Gain
and Trombe Wall

DO YOU WISH TO HAVE PROMPTS FOR OTHER SECTIONS.
 IF NO ENTER "NO"
 IF YES ENTER THE SECTION NUMBER (1,2,..... 8)

? 4
 LINE: 51
 APERTURE AREA, (SQ FT) TROMBE WALL

? 90.
 LINE: 52
 NIGHT INSULATION R-VALUE TROMBE WALL

? 0.
 LINE: 53
 TILT ANGLE (DEG) TW

? D
 ** DEFAULT VALUE **
 53, 90.00
 LINE: 53
 TILT ANGLE (DEG) TW

? 6
 LINE: 54
 AZIMUTH ANGLE (DEG) TW

? 6
 LINE: 55
 STORAGE MASS ABSORPTANCE TW

? 6
 LINE: 56
 OVERHANG FLAG TW

? 6
 LINE: 60
 REFLECTOR FLAG TW

? 6

Figure IV-6. Example No. 2 (Cont)

DO YOU WISH TO HAVE PROMPTS FOR OTHER SECTIONS.
 IF NO ENTER "NO"
 IF YES ENTER THE SECTION NUMBER (1,2,..... 8)

? 5
 LINE: 71
 APERTURE AREA, (SQ FT) DIRECT GAIN

? 180.
 LINE: 72
 NIGHT INSULATION R-VALUE DG

? 5.
 LINE: 73
 TILT ANGLE (DEG) DG

? 6
 LINE: 74
 AZIMUTH ANGLE (DEG) DG

? 25.
 LINE: 75
 STORAGE MASS ABSORPTANCE DG

? 6
 LINE: 76
 OVERHANG FLAG DG

? 1
 LINE: 77
 HEIGHT OF GLAZING (FT) DG

? 8.
 LINE: 78
 HDR. PROJECTION OF OVERHANG (FT) DG

? 2.75
 LINE: 79
 HEIGHT OF OVERHANG ABOVE GLAZING TOP (FT) DG

? 3.2
 LINE: 80
 REFLECTOR FLAG DG

? 6
 LINE: 84
 DIURNAL HEAT COEFFICIENT (BTU/F-SQ FT) DG

? 18000
 DO YOU WISH TO HAVE PROMPTS FOR OTHER SECTIONS.
 IF NO ENTER "NO"
 IF YES ENTER THE SECTION NUMBER (1,2,..... 8)

? 7
 LINE: 110
 ECONOMICS FLAG (IF =1 SKIP ECON)

? 1

Figure IV-6. Example No. 2 (Cont)

DO YOU WISH TO HAVE PROMPTS FOR OTHER SECTIONS.
 IF NO ENTER "NO"
 IF YES ENTER THE SECTION NUMBER (1,2,..... 8)
 ? N
 DO YOU WISH TO MAKE CHANGES TO THE FILE
 YES OR NO
 ? N
 DO YOU WISH TO HAVE THE INPUTS LISTED WITH THE OUTPUT YES OR NO
 ? Y
 DO YOU WISH TO HAVE THE OUTPUT WRITTEN ON FILE OUT YES OR NO
 (A "NO" WILL CAUSE OUTPUT TO BE PRINTED AT THE TERMINAL)
 ? N
 1
 \$ LOCATION CONF
 11, 55
 \$ SITE SHADING FRACTION BY MONTH (DEF = 1.0)
 18, 1.000 1.000 .9000 .9000 .8000 .6500
 .6500 .6500 .8000 .8500 .9000 .9000
 \$ BUILDING LOAD COEFFICIENT (BTU/F-DAY)
 21, 8370.
 \$ PASSIVE SYSTEM TYPE 1=TW,2=DG,3=WW,4=MIXED
 41, 4
 \$ THERMOSTAT SETTING (F)
 42, 68.00
 \$ INTERNAL HEAT GENERATION (BTU/DAY)
 43, .6000E+05
 \$ APERTURE AREA, (SQ FT) TROMBE WALL
 51, 90.00
 \$ NIGHT INSULATION R-VALUE TROMBE WALL
 52, 0.
 \$ APERTURE AREA, (SQ FT) DIRECT GAIN
 71, 180.0
 \$ NIGHT INSULATION R-VALUE DG
 72, 5.000
 \$ AZIMUTH ANGLE (DEG) DG
 74, 25.00
 \$ OVERHANG FLAG DG
 76, 1
 \$ HEIGHT OF GLAZING (FT) DG
 77, 8.000
 \$ HOR. PROJECTION OF OVERHANG (FT) DG
 78, 2.750
 \$ HEIGHT OF OVERHANG ABOVE GLAZING TOP (FT) DG
 79, 3.200
 \$ DIURNAL HEAT COEFFICIENT (BTU/F-SQ FT) DG
 84, .1800E+05
 \$ ECONOMICS FLAG (IF =1 SKIP ECON)
 110, 1

Figure IV-6. Example No. 2 (Cont)

SOLCOST-PASSIVE

DEVELOPED BY
MARTIN MARIETTA CORPORATION

BASED ON
LOS ALAMOS SOLAR LOAD RATIO METHOD

1

PROJECT EXAMPLE NO. 2, MIXED SYSTEM (TROMBE + DIR. GAIN)

LOCATION DENVER, CO

LATITUDE 39.8

MIXED SYSTEM TYPE	GLAZING AREAS, SQ FT	NIGHT INSULATION R-VALUE
TROMBE WALL	90.	0.
DIRECT GAIN	180.	5.
TOTAL	270.	

THERMOSTAT SETTING 68.0 DEG F

INTERNAL HEAT RATE 60000.0 BTU/DAY

USER INPUT BUILDING LOAD COEFFICIENT 8370. BTU/DEGREE DAY

CALCULATED VALUES

LOAD COLLECTOR RATIO, BLC/AC	31.0 BTU/DEGREE-DAY-SQ-FT
DEGREE DAY BASE TEMPERATURE FOR NON-SOLAR BUILDING	60.8 DEG-F
DEGREE DAY BASE TEMPERATURE FOR SOLAR BUILDING	62.0 DEG-F
ANNUAL DEGREE-DAYS FOR NON-SOLAR BUILDING	4946. F-DAYS
ANNUAL DEGREE-DAYS FOR SOLAR BUILDING	5251. F-DAYS

ABSORBED SOLAR RADIATION FACTORS
PASSIVE SYSTEM TYPETW

	HTV	AZF	TILT	GRF	OHANG	REFL	TRANS	ABSOR	SHADE	ABSORBED RADIATION (BTU/SQ FT-MON)
JAN	1.73	1.00	1.00	1.00	1.000	1.000	.710	.950	1.000	30309.
FEB	1.41	1.00	1.00	1.00	1.000	1.000	.697	.950	1.000	29391.
MAR	1.03	1.00	1.00	1.00	1.000	1.000	.657	.950	.900	27455.
APR	.73	1.00	1.00	1.00	1.000	1.000	.606	.950	.900	21180.
MAY	.54	1.00	1.00	1.00	1.000	1.000	.574	.950	.800	15622.
JUN	.48	1.00	1.00	1.00	1.000	1.000	.565	.950	.650	11713.
JUL	.50	1.00	1.00	1.00	1.000	1.000	.568	.950	.650	12319.
AUG	.62	1.00	1.00	1.00	1.000	1.000	.587	.950	.650	14328.
SEP	.88	1.00	1.00	1.00	1.000	1.000	.633	.950	.800	21831.
OCT	1.23	1.00	1.00	1.00	1.000	1.000	.682	.950	.850	27272.
NOV	1.60	1.00	1.00	1.00	1.000	1.000	.707	.950	.900	25573.
DEC	1.81	1.00	1.00	1.00	1.000	1.000	.711	.950	.900	24943.

- NOTES
- 1.HTV .. HOR. TO VER. FACTOR
 - 2.AZF .. AZIMUTH FACTOR
 - 3.TILT .. TILT FACTOR
 - 4.GRF .. GROUND REFL. FACTOR
 - 5.OHANG .. OVERHANG FACTOR
 - 6.REFL ... REFLECTOR FACTOR (IF PRESENT)
 - 7.TRANS .. GLAZING TRANSMISSION FACTOR
 - 8.ABSOR .. ABSORPTANCE OF PASSIVE FEATURE
(DEFAULTED OR INPUT BY USER)
 - 9.SHADE .. SITE SHADING (DEF = 1.0 UNLESS
INPUT BY USER)
 10. GLAZING TRANSMISSION BASED ON 2 LAYERS 1/8 INCH STD. GLASS

ABSORBED SOLAR RADIATION FACTORS
PASSIVE SYSTEM TYPEDG

	HTV	AZF	TILT	GRF	OHANG	REFL	TRANS	ABSOR	SHADE	ABSORBED RADIATION (BTU/SQ FT-MON)
JAN	1.73	.96	1.00	1.00	.994	1.000	.693	1.000	1.000	29591.
FEB	1.41	.96	1.00	1.00	.999	1.000	.686	1.000	1.000	29246.
MAR	1.03	.98	1.00	1.00	.979	1.000	.667	1.000	.900	28199.
APR	.73	1.01	1.00	1.00	.861	1.000	.639	1.000	.900	20524.
MAY	.54	1.05	1.00	1.00	.750	1.000	.613	1.000	.800	13833.
JUN	.48	1.06	1.00	1.00	.735	1.000	.599	1.000	.650	10216.
JUL	.50	1.06	1.00	1.00	.737	1.000	.604	1.000	.650	10755.
AUG	.62	1.03	1.00	1.00	.800	1.000	.626	1.000	.650	13228.
SEP	.88	1.00	1.00	1.00	.934	1.000	.655	1.000	.800	22114.
OCT	1.23	.97	1.00	1.00	1.000	1.000	.679	1.000	.850	27699.
NOV	1.60	.96	1.00	1.00	.995	1.000	.691	1.000	.900	25056.
DEC	1.81	.96	1.00	1.00	.995	1.000	.694	1.000	.900	24357.

Figure IV-6. Example No. 2 (Cont)

1. HTV ... HORIZ. TO VERT. FACTOR
 2. AZF ... AZIMUTH FACTOR
 3. TILT ... TILT FACTOR
 4. GRF ... GROUND REFL. FACTOR
 5. OHANG ... OVERHANG FACTOR
 6. REFL ... REFLECTOR FACTOR (IF PRESENT)
 7. TRANS ... GLAZING TRANSMISSION FACTOR
 8. ABSOR ... ABSORPTANCE OF PASSIVE FEATURE (DEFAULTED OR INPUT BY USER)
 9. SHADE ... SITE SHADING (DEF = 1.0 UNLESS INPUT BY USER)
 10. GLAZING TRANSMISSION BASED ON 2 LAYERS 1/8 INCH STD. GLASS

1

PERFORMANCE SUMMARY FOR 270. SQ FT SYSTEM

MONTH	DEGREE DAYS (F-DAY)	SOLAR RADIATION ABSORBED (MMBTU/MON)	SOLAR LOAD RATIO	AUXILIARY ENERGY (MMBTU/MON)	USEFUL SOLAR ENERGY (MMBTU/MON)	SOLAR SAVINGS FRACTION
JAN	997.8	7.99	.96	5.43	2.92	.349
FEB	818.6	7.90	1.15	3.91	2.94	.429
MAR	777.7	7.61	1.16	3.70	2.80	.431
APR	439.4	5.54	1.52	1.64	2.04	.554
MAY	187.1	3.73	2.49	.38	1.19	.759
JUN	38.1	2.76	9.07	.00	.32	1.000
JUL	0.0	2.90	0.00	0.00	0.00	1.000
AUG	0.0	3.57	0.00	0.00	0.00	1.000
SEP	78.7	5.97	9.02	.00	.66	.996
OCT	318.5	7.48	2.79	.53	2.13	.800
NOV	680.7	6.77	1.20	3.16	2.53	.445
DEC	914.1	6.58	.87	5.32	2.33	.305
YR	5250.8	69.44		24.09	17.31	.418

DO YOU WISH TO MAKE CHANGES AND EXECUTE THE PROGRAM AGAIN YES OR NO
 (IF PROMPTS ARE DESIRED ENTER PROMPT)
 ? N

1.232 CP SECONDS EXECUTION TIME
 SAVE,OUTFIL=PEXAMP2
 BYE

Figure IV-6. Example No. 2 (Cont)

APPENDIX A. Building Load Coefficient Calculation Procedure*

The procedure consists of calculating several components of the Building Load Coefficient. This coefficient is the additional heating which would be required to maintain a one degree Fahrenheit increase in the building inside temperature if the solar collection wall were covered with a perfect insulator. For example, if the heat required to maintain the building at 70 F were determined to be 400,000 Btu/day, and the heat required to maintain the building at 71F were determined to be 420,000 Btu/day, then the Building Load Coefficient is equal to the difference or 20,000 Btu/day F.

The procedure consists of adding together several estimated contributions of heat loss. Start by making rough estimates of the combined area of all floors (sq ft) and the "perimeter" (the combined length of all external walls of all floors (ft)). Then, either estimate the combined area of all east, west, and north windows, or use:

$$\begin{aligned} \text{Non-south window area} &= (2/3) \times (\text{perimeter}) \times (\text{ceiling height}) \\ &\quad \times (\text{non-south window fraction}) \end{aligned}$$

The non-south window fraction will normally be between 0.05 for a situation with minimum window area, and 0.10 for a case with ample window area.

Next, carefully estimate the south (solar) window area being careful to only include net exposed portion of the window.

Then, compute the following:**

Walls

$$L_w = 24 \times \frac{\text{wall area}}{\text{R value of walls}}$$

where wall area = (perimeter) x (ceiling height)
- (non-south window area) - (south window area)

*This Appendix is taken from the Passive Solar Design Handbook.

**The derivation of these formulas is based on a simplified use of the ASHRAE-type heat loss approach. All terms contain a factor of 24 to convert from Btu/hr F to Btu/day F. The terms L_w , L_g , L_f , and L_r are simply $24 \times U \times A$, where U is the U-value of the element (which is equal to $1/R$) and A is the area of the element. For glazings, the approximation is made that $U = 1.1/(\text{number of glazings})$. For the perimeter and basement and basement loss terms, the form is an approximation to tabular data where the constants are chosen to give a good fit.

Non-South Window

$$L_g = 26 \times \frac{\text{non-south window area}}{\text{number of glazings}}$$

Perimeter (slab on grade)

$$L_p = 100 \times \frac{\text{length of perimeter foundation}}{\text{R value of perimeter insulation} + 5}$$

Floor (over vented crawl space)

$$L_f = 24 \times \frac{\text{area of ground floor}}{\text{R value of floor}}$$

Basement (heated basement or other fully-bermed wall, including floor losses)

$$L_b = 256 \times \frac{\text{length of wall}}{\text{R value of wall insulation} + 8}$$

Note: normally only one of L_p , L_f , or L_b will apply.

Roof

$$L_r = 24 \times \frac{\text{roof area}}{\text{R value of roof}}$$

Infiltration:

$$L_i = (0.432) \times (\text{average air changes per hour}) \times (\text{ADR}) \\ \times (\text{ceiling height}) \times (\text{combined area of all floors})$$

where ADR is the Air Density Ratio shown in Fig. A-1 to account for other than sea level locations.

Add the appropriate components to obtain the final BLC estimate, for example:

$$\text{BLC} = L_w + L_g + L_r + L_p + L_i$$

Note that the solar glazing is not included in the calculation of the Building Load Coefficient.

Fig. A-1. The Air Density Ratio (ADR) for different elevations. The sea level air density is 0.075 lb/ft³.

APPENDIX B. Absorbed Radiation Calculation Parameters

SOLCOST-PASSIVE uses the LASL developed correlations for monthly insolation sums as functions of the mid-month noon zenith angle, i.e., latitude minus declination angle. Their base case to which all other results are related is the following:

- o Vertical, south-facing glazing
- o No overhang or reflector
- o Ground reflectance of 0.3 (totally diffuse)

Starting with the base case, the parameters were varied one at a time to determine their effect on the monthly insolation incident on the vertical, south facing glazing. The tilt and azimuth angles were also varied simultaneously to determine their combined effect.

Ground Reflectance

Table B-1 contains some ground reflectance values from the work of Hunn and Calafell*. SOLCOST-PASSIVE users can input their respective monthly values of the ground reflectance in the Line 17 array.

Table B-1. Average Reflectance Values for Representative Winter Landscapes

<u>Rural Areas</u>	<u>Reflectance</u>
<u>Fields with snow cover</u>	
1. Field with wooded area in background	0.66,0.73
2. Open field (soil and dry grass) near road	0.61,0.70
3. Trees dispersed in field	0.62
<u>Wooded areas</u>	
4. Conifer forest (with heavy snow cover)	0.61
5. Deciduous forest (with heavy snow cover)	0.72
<u>Water</u>	
6. Open water	0.16
7. Ice/snow-covered water	0.68
8. Partially open waterway (trees and houses in background)	0.43,0.66
<u>Urban Areas</u>	
9. Urban areas (commercial, institutional)	0.16,0.38
10. Residential areas (dwellings and roadway)	0.21,0.35,0.45
11. Educational institution	0.36,0.42
12. Recreational area (park)	0.49

*B.D. Hunn and D.O. Calafell, "Determination of Average Ground Reflectivity for Solar Collectors," Solar Energy, Vol. 19, pp 87-89 (1977).

Overhang's

Figure B-1 defines the overhang geometry used by LASL in correlating the effect of an overhang on solar insolation. The "Line No's" shown in the figure are the SOLCOST-PASSIVE input line numbers. The range of values over which the correlation applies is the following:

$$Y/H = 0.0 \text{ to } 0.5$$

$$X/H = 0.125 \text{ to } 0.5$$

NOTE: Line numbers shown for Trombe wall system.

Figure B-1. Overhang Geometry

Reflectors

Figure B-2 defines the reflector geometry input parameters required by SOLCOST-PASSIVE. The nominal reflector analysis included the following conditions:

- o Reflector positioned horizontally in front of vertical south glazing with reflector edge against base of glazing,
- o Reflector size = glazing size,
- o Solar glazing is south facing,
- o Specular reflector with reflectance = 0.8,
- o Aspect ratio = 5, i.e., reflector E-W dimension divided by N-S dimension.

Figure B-2. Reflector Geometry

Absorptance of Storage Mass

Table B-2 lists the solar absorptance for various building materials. The Los Alamos researchers used a reference value of 0.8 for the area weighted solar absorptance in their SLR simulations. They also suggest that the minimum absorptance in passive applications be 0.5 or greater.

Weather Data Bank

Data for 248 U.S. locations were taken from the NOAA Report, "Input Data for Solar Systems".* In constructing the weather data base, NOAA used monthly normals (30-year mean values) of maximum, minimum, and average temperatures, and heating degree days extracted from Climatology of the United States No. 81 (By State) and Local Climatological Data Annual Summaries for 1977.

Average daily values of total hemispheric (global) solar radiation on a horizontal surface were based on rehabilitated data for 26 cities. The remaining 222 stations contain model generated data. Most of the average weather values, i.e., temperatures and degree days, are based on a 24-25 year period. SOLMET Volume 1 - User's Manual lists the exact period, as well as provides information on the rehabilitation of hourly solar radiation data.

Additional U.S. cities for which no radiation data was available are still in the SOLCOST-PASSIVE data bank. They are marked with an asterisk in Table B-3. For these cities the user must input his own radiation values on Line 13.

Several Canadian cities are also included in the data bank. The source for this data is not well documented, and Canadian users are cautioned to check this data with possibly more recent literature sources.

*V. Cinquemani, et al, Input Data for Solar Systems, Nov. 1978, prepared by NOAA for U.S. Department of Energy, Division of Solar Technology, under Interagency Agreement No. E(49-26)-1041.

Table B-2. Solar Absorptance of Various Materials*

Optical flat black paint	.98
Flat black paint	.95
Black lacquer	.92
Dark gray paint	.91
Black concrete	.91
Dark blue lacquer	.91
Black oil paint	.90
Stafford blue bricks	.89
Dark olive drab paint	.89
Dark brown paint	.88
Dark blue-gray paint	.88
Azure blue or dark green lacquer	.88
Brown concrete	.85
Medium brown paint	.84
Medium light brown paint	.80
Brown or green lacquer	.79
Medium rust paint	.78
Light gray oil paint	.75
Red oil paint	.74
Red bricks	.70
Uncolored concrete	.65
Moderately light buff bricks	.60
Medium dull green paint	.59
Medium orange paint	.58
Medium yellow paint	.57
Medium blue paint	.51
Medium kelly green paint	.51
Light green paint	.47
White semi-gloss paint	.30
White gloss paint	.25
Silver paint	.25
White lacquer	.21
Polished aluminum reflector sheet	.12
Aluminized mylar film	.10
Laboratory vapor deposited coatings	.02

NOTE: This table is meant to serve as a guide only. Variations in texture, tone, overcoats, pigments, binders, etc., can vary these values.

*G. G. Gubareff et al, Thermal Radiation Properties Survey, second edition, Honeywell Research Center, Minneapolis-Honeywell REGulator Company, Minneapolis, Minnesota, 1960.

**S. More, Los Alamos Scientific Laboratory, Solar Energy Group, Unpublished data.

Table B-3. Cities in SOLCOST-PASSIVE Data Bank

SITE CODE	CITY NAME, STATE	LATITUDE			
1	BIRMINGHAM, AL	33.6	48	SAN DIEGO, CA	32.7
2	MOBILE, AL	30.7	49	SAN FRANCISCO, CA	37.6
3	MONTGOMERY, AL	32.3	50	SAN JOSE, CA	37.3
4	ANNETTE, AK	55.0	51	SANTA MARIA, CA	34.9
5	BARROW, AK	71.3	52	SUNNYVALE, CA	37.4
6	BETHEL, AK	60.8	53	BOULDER, CO	40.0
7	BETTLES, AK	66.9	54	COLORADOSPRGS, CO	38.8
8	BIG DELTA, AK	64.0	55	DENVER, CO	39.8
9	FAIRBANKS, AK	64.8	56	EAGLE, CO	39.7
10	GULKANA, AK	62.2	57	GRANDJUNCTION, CO	39.1
11	HOMER, AK	59.6	58	GRAND LAKE, CO	40.3
12	JUNEAU, AK	58.4	59	PUEBLO, CO	38.3
13	KING SALMON, AK	58.7	60	HARTFORD, CT	41.9
14	KODIAK, AK	57.8	61	WILMINGTON, DE	39.7
15	KOTZEBUE, AK	66.9	62	WASHINGTON, DC	39.0
16	MATANUSKA, AK	61.6	63	APALACHICOLA, FL	29.7
17	MCGRATH, AK	63.0	64	DAYTONA BEACH, FL	29.2
18	NOME, AK	64.5	65	GAINESVILLE, FL	29.7
19	SUMMIT, AK	63.3	66	JACKSONVILLE, FL	30.5
20	YAKUTAT, AK	59.5	67	KEY WEST, FL	24.6
21	PAGE, AZ	36.6	68	MIAMI, FL	25.
22	PHOENIX, AZ	33.4	69	ORLANDO, FL	28.
23	PRESCOTT, AZ	34.7	70	PENSACOLA, FL	30.0
24	TUCSON, AZ	32.1	71	TALLAHASSEE, FL	30.4
25	WINSLOW, AZ	35.0	72	TAMPA, FL	28.0
26	YUMA, AZ	32.7	73	W. PALM BEACH, FL	26.7
27	FORT SMITH, AR	35.3	74	ATLANTA, GA	33.7
28	LITTLE ROCK, AR	34.7	75	AUGUSTA, GA	33.4
29	ARCATA, CA	41.0	76	GRIFFIN, GA	33.3
30	BAKERSFIELD, CA	35.4	77	MACON, GA	32.7
31	CHINA LAKE, CA	35.7	78	SAVANNAH, GA	32.1
32	DAGGETT, CA	34.9	79	BARBERS PT, HI	21.3
33	DAVIS, CA	38.6	80	HILO, HI	19.7
34	EL TORO, CA	33.7	81	HONOLULU, HI	21.3
*35	EURCKA, CA	40.8	82	LIHUE, HI	22.0
36	FRESNO, CA	36.8	83	BOISE, ID	43.6
37	INYOKERN, CA	35.7	84	LEWISTON, ID	46.4
38	LONG BEACH, CA	33.8	85	POCATELLO, ID	42.9
39	LOS ANGELES, CA	33.9	86	TWIN FALLS, ID	40.6
40	MT SHASTA, CA	41.3	*87	CAIRO, IL	37.1
41	NEEDLES, CA	34.8	88	CHICAGO, IL	41.8
42	OAKLAND, CA	37.7	89	LEMONT, IL	41.7
43	PASADENA, CA	34.2	90	MOLINE, IL	41.5
44	POINT MUGU, CA	34.1	91	PEORIA, IL	40.7
45	RED BLUFF, CA	40.2	92	SPRINGFIELD, IL	39.8
46	RIVERSIDE, CA	34.0	93	EVANSVILLE, IN	38.1
47	SACRAMENTO, CA	38.5	94	FORT WAYNE, IN	41.0
			95	INDIANAPOLIS, IN	39.0

Table B-3. Cities in SOLCOST-PASSIVE Data Bank (Cont)

96	SOUTH BEND, IN	41.7	144	JACKSON, MS	32.3
97	AMES, IA	42.0	145	MERIDIAN, MS	32.3
98	BURLINGTON, IA	40.8	*146	VICKSBURG, MS	32.2
99	DES MOINES, IA	41.5	147	COLUMBIA, MO	38.8
*100	DUBUQUE, IA	42.5	148	KANSAS CITY, MO	39.3
101	MASON CITY, IA	43.2	149	ST LOUIS, MO	38.8
102	SIOUX CITY, IA	42.4	150	SPRINGFIELD, MO	37.2
*103	CONCORDIA, KS	39.6	151	BILLINGS, MT	45.8
104	DODGE CITY, KS	37.8	152	CUT BANK, MT	48.6
105	GOODLAND, KS	39.4	153	DILLON, MT	45.3
106	MANHATTAN, KS	39.2	154	GLASGOW, MT	48.2
107	TOPEKA, KS	39.1	155	GREAT FALLS, MT	47.5
108	WICHITA, KS	37.7	*156	HAVER CITY, MT	48.5
109	COVINGTON, KY	39.1	157	HELENA, MT	46.6
110	LEXINGTON, KY	38.0	*158	KALISPELL, MT	48.2
111	LOUISVILLE, KY	38.2	159	LEWISTOWN, MT	47.1
112	BATON ROUGE, LA	30.5	160	MILESCITY, MT	46.4
113	LAKE CHARLES, LA	30.1	161	MISSOULA, MT	46.9
114	NEW ORLEANS, LA	30.0	162	SUMMIT, MT	48.3
115	SHREVEPORT, LA	32.5	163	GRAND ISLAND, NE	41.0
116	BANGOR, ME	44.8	164	LINCOLN, NE	40.9
117	CARIBOU, ME	46.9	165	NORTH OMAHA, NE	41.4
*118	EASTPORT, ME	44.9	166	NORTH PLATTE, NE	41.1
119	PORTLAND, ME	43.7	167	SCOTTS BLUFF, NE	41.9
120	ANNAPOLIS, MD	39.0	168	ELKO, NV	40.8
121	BALTIMORE, MD	39.2	169	ELY, NV	39.3
122	PATUXENT RIVER, MD	38.3	170	LAS VEGAS, NV	36.1
123	SILVER HILL, MD	38.8	171	LOVE LOCK, NV	40.1
124	AMHERST, MA	42.3	172	RENO, NV	39.5
125	BLUE HILL, MA	42.2	173	TONOPAH, NV	38.1
126	BOSTON, MA	42.4	174	WINNEMUCCA, NV	40.9
127	LYNN, MA	42.5	175	YUCCA FLATS, NV	37.0
128	NATICK, MA	42.3	176	CONCORD, NH	43.2
129	ALPENA, MI	45.1	177	ATLANTIC CITY, NJ	39.5
130	DETROIT, MI	42.4	178	LAKEHURST, NJ	40.0
131	EAST LANSING, MI	42.7	179	NEWARK, NJ	40.7
132	FLINT, MI	43.0	180	TRENTON, NJ	40.2
133	GRAND RAPIDS, MI	42.9	181	ALBUQUERQUE, NM	35.1
134	HOUGHTON, MI	47.2	182	CLAYTON, NM	36.5
135	LANSING, MI	42.8	183	FARMINGTON, NM	36.8
*136	MARQUETTE, MI	46.6	184	ROSWELL, NM	33.4
137	SAULT STE MARIE, MI	46.5	185	TRUTH OR CONSEQUENCE, NM	33.2
138	TRAVERSE CITY, MI	44.7	186	TUCUMCARI, NM	35.2
139	DULUTH, MN	46.8	187	ZUNI, NM	35.1
140	INTRNTAL FALLS, MN	48.6	188	ALBANY, NY	42.8
141	MINNEAPOLIS, MN	44.9	189	BINGHAMPTON, NY	42.2
142	ROCHESTER, MN	43.9	190	BUFFALO, NY	42.9
143	ST CLOUD, MN	45.6	*191	CANTON, NY	44.7

Table B-3. Cities in SOLCOST-PASSIVE Data Bank (Cont)

192	ITHACA, NY	42.5	*240	BLOCK ISLAND, RI	41.1
193	MASSENA, NY	44.9	241	NEWPORT, RI	41.5
194	NEW YORK, NY	40.8	242	PROVIDENCE, RI	41.7
195	NY, NY (LAGUARDIA)	40.8	243	CHARLESTON, SC	32.9
196	ROCHESTER, NY	43.1	244	COLUMBIA, SC	34.0
197	SCHENECTADY, NY	42.8	245	GREENVILLE, SC	34.9
198	SYRACUSE, NY	43.1	246	HURON, SD	44.4
199	ASHEVILLE, NC	35.4	247	PIERRE, SD	44.4
200	CAPE HATTERAS, NC	35.3	248	RAPID CITY, SD	44.1
201	CHARLOTTE, NC	35.2	249	SIOUX FALLS, SD	43.6
202	CHERRY POINT, NC	34.9	250	CHATTANOOGA, TN	35.0
203	GREENSBORO, NC	36.1	251	KNOXVILLE, TN	35.8
204	RALEIGH, NC	35.9	252	MEMPHIS, TN	35.1
205	BISMARCK, ND	46.8	253	NASHVILLE, TN	36.1
*206	DEVILS LAKE, ND	48.2	254	OAK RIDGE, TN	36.0
207	FARGO, ND	46.9	255	ABILENE, TX	32.4
208	MINOT, ND	48.3	256	AMARILLO, TX	35.2
*209	WILLISTON, ND	48.3	257	AUSTIN, TX	30.3
210	AKRON, OH	40.9	258	BIG SPRINGS, TX	32.3
211	CINCINNATI, OH	39.1	259	BROWNSVILLE, TX	25.9
212	CLEVELAND, OH	41.4	260	CORPUSCHRISTI, TX	27.8
213	COLUMBUS, OH	40.0	261	DALLAS, TX	32.9
214	DAYTON, OH	39.9	262	DEL RIO, TX	29.4
215	PUT-IN-BAY, OH	41.7	263	EL PASO, TX	31.8
216	TOLEDO, OH	41.6	264	FORT WORTH, TX	32.8
217	YOUNGSTOWN, OH	41.3	*265	GALVESTON, TX	29.2
218	OKLAHOMA CITY, OK	35.4	266	HOUSTON, TX	30.0
219	STILLWATER, OK	36.2	267	KINGSVILLE, TX	27.5
220	TULSA, OK	36.2	268	LAREDO, TX	27.5
221	ASTORIA, OR	46.2	269	LUBBOCK, TX	33.7
*222	BAKER, OR	44.8	270	LUFKIN, TX	31.2
223	BURNS, OR	43.6	271	MIDLAND, TX	31.9
224	CORVALLIS, OR	44.6	272	PORT ARTHUR, TX	30.0
225	MEDFORD, OR	42.4	273	SAN ANGELO, TX	31.4
226	NORTH BEND, OR	43.4	274	SAN ANTONIO, TX	29.5
227	PENDLETON, OR	45.7	275	SHERMAN, TX	33.7
228	PORTLAND, OR	45.6	276	WACO, TX	31.6
229	REDMOND, OR	44.3	277	WICHITA FALLS, TX	34.0
*230	ROSEBURG, OR	43.2	278	BRYCE CANYON, UT	37.7
231	SALEM, OR	44.9	279	CEDER CITY, UT	37.7
232	ALLENTOWN, PA	40.7	280	SALT LAKE CITY, UT	40.8
233	AVOCA, PA	41.3	281	BURLINGTON, VT	44.5
234	ERIE, PA	42.1	282	MT WEATHER, VA	39.1
235	HARRISBURG, PA	40.2	283	NORFOLK, VA	36.9
236	PHILADELPHIA, PA	39.9	284	RICHMOND, VA	37.5
237	PITTSBURGH, PA	40.5	285	ROANOKE, VA	37.3
238	SCRANTON, PA	41.3	286	OLYMPIA, WA	47.0
239	STATE COLLEGE, PA	40.8	287	PROSSER, WA	46.3

Table B-3. Cities in SOLCOST-PASSIVE Data Bank (Cont)

288	PULLMAN,WA	46.7	313	CALGARY,ALBERTA	51.0
289	RICHLAND,WA	46.3	314	EDMONTON,ALBERTA	53.6
290	SEATTLE,WA	47.5	315	LETHBRIDGE,ALBRT	49.6
291	SPOKANE,WA	47.6	316	VANCOUVER,BC	49.0
292	TACOMA,WA	47.3	317	VICTORIA,BC	48.0
*293	WALLA WALLA,WA	46.1	318	CHURCHILL,MANTBA	58.8
294	WHIDBEYISLAND,WA	48.4	319	WINNIPEG,MANITBA	49.9
295	YAKIMA,WA	46.6	320	MONCTON,NEW BRUN	46.1
296	CHARLESTON,WV	38.4	321	ST JOHN,NEW BRUN	45.0
*297	ELKINS,WV	38.9	322	ST JOHN,NEWFNDLD	47.5
298	HUNTINGTON,WV	38.4	323	AKLAVIK,NW TERR	68.2
299	PARKERSBURG,WV	39.3	324	HALIFAX,NOV SCOT	45.0
300	EAU CLAIRE,WI	44.9	325	HAMILTON,ONT	43.0
301	GREEN BAY,WI	44.5	326	KAPUSKASING,ONT	49.4
302	LA CROSSE,WI	43.9	327	LONDON,ONT	43.0
303	MADISON,WI	43.1	328	OTTAWA,ONT	45.5
304	MILWAUKEE,WI	43.0	329	TORONTO,ONT	43.7
305	CASPER,WY	42.9	330	WINDSOR,ONT	42.0
306	CHEYENNE,WY	41.2	331	MONTREAL,QUEBEC	45.5
307	LANDER,WY	42.8	332	QUEBEC CITY,QUEB	47.0
308	LARAMIE,WY	41.3	333	SASKATOON,SASK	52.0
309	ROCK SPRINGS,WY	41.6	334	KOROR ISLAND	7.3
310	SHERIDAN,WY	44.8	335	KWAJALEIN ISLAND	8.7
311	YELLOWSTNPARK,WY	44.7	336	WAKE ISLAND	19.3
312	SAN JUAN,PR	18.4			

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B-10

APPENDIX C. Effects of Thermal Storage Mass

Figures C-1 and C-2 present some LASL generated SSF's as a function of storage mass for six cities, which cover a range of locations and climate types. The following discussion from the Passive Solar Design Handbook summarizes the key LASL conclusions regarding thermal storage mass.

1. The effect of changing the thermal storage mass of a water wall is reduced by approximately 35% when R9 night insulation is used compared to the effect when no night insulation is used.
2. The optimum thickness of a Trombe wall is slightly greater when R9 night insulation is used than when no night insulation is used. The optimum is also less pronounced when night insulation is used.
3. The optimum thickness of a Trombe wall depends on the wall material thermal conductivity; the higher the conductivity the thicker the wall can be.
4. The presence of vents in the wall becomes important for either thick walls or walls of low thermal conductivity. This is so because the convective loop effect of thermocirculation becomes a major mechanism for heating the building in these cases. In one study the presence of the thermocirculation vents increased the value of optimum wall thickness from approximately 12 inches to approximately 18 inches.
5. The presence of vents is also more important at low values of Solar Savings Fraction than at high values.

The curves in Figures C-1 and C-2 show that the effect of thermal storage changes significantly from one locality to another. This is presumably caused by differences in weather patterns. No systematic study has been done to determine exactly what causes these differences. An attempt was made to compact the data on these curves into a single universal curve, but this was not successful.

EFFECT OF WALL THERMAL MASS

BOSTON

EFFECT OF WALL THERMAL MASS

ALBUQUERQUE

EFFECT OF WALL THERMAL MASS

NASHVILLE

Figure C-1. The Effect of Different Values of Thermal Storage Wall Mass on the Performance of Trombe Wall and Water Wall Passive Buildings. The Reference Value is 45 Btu/F Sq. Ft. - No Night Insulation

EFFECT OF WALL THERMAL MASS

MADISON

EFFECT OF WALL THERMAL MASS

MEDFORD

EFFECT OF WALL THERMAL MASS

SANTA MARIA

Figure C-2. The Effect of Thermal Storage Wall Mass on the Performance of Passive Buildings - No Night Insulation

Diurnal Heat Capacity for Direct Gain Spaces*

A simple technique has been devised for estimating the diurnal temperature swing to be expected in a direct gain building. The method is based on a "diurnal heat capacity" of the building determined from the thermal properties of each enclosing surface. The method is described in a 6-step procedure as follows:

Step 1 - Calculate the surface area, A, of all building interior mass walls, floors, and ceilings, and assign classification in accordance with the following criteria;

<u>Location</u>	
The surface of any massive material which receives some direct sun, except covered floor.	Class 1
Covered floor (or any covered surface)	Class 4
Walls which enclose a direct-gain room for which the solar gains exceed the room day-time losses.	Class 2
All ceilings, except in sealed rooms (such as closets).	Class 2
Walls which enclose other rooms which communicate by convection with direct gain rooms.	Class 3
Uncovered floor in direct-gain rooms (not directly sunlit)	Class 3
Floors other than in direct-gain rooms.	Class 4
All surfaces in closed-off rooms	Class 4

In this listing, include gypsum board surfaces and wood surfaces more than 1/2 inch thick. Do not include insulating materials such as fiberglass ceiling panels and walls covered with heavy fabric, rugs, or other insulation.

*This section is taken directly from the Passive Solar Design Handbook.

TABLE G-1

DIURNAL HEAT CAPACITY*
(Btu/ft² F)

		Material					
		Concrete	Limestone Rock	Brick	Pine Wood	Dry Sand	Adobe
density (lb/ft ³)		143	153	112	31	95	120
specific heat (Btu/lb F)		0.21	0.22	0.22	0.67	0.19	0.20
thermal conductivity (Btu/ft F hr)		1.0	0.54	0.40	0.097	0.19	0.332
<u>Class 1 & 2 (direct)</u>	1"	2.50	2.80	2.05	1.71	1.50	2.00
	2"	4.99	5.52	4.04	2.96	2.90	3.92
	3"	7.37	7.81	5.73	3.14	3.86	5.44
	<u>Daily Heat Stored</u>	9.47	9.17	6.74	2.93	4.14	6.20
	Surface ΔT	6"	11.94	9.30	6.86	2.76	3.82
		8"	12.14	8.63	6.36	2.77	3.62
		12"	10.99	8.29	6.10	2.77	3.61
<u>Class 3 (indirect)</u>	16"	10.65	8.33	6.13	2.77	3.62	5.52
	1"	2.28	2.48	1.91	1.58	1.43	1.86
	2"	3.63	3.71	3.10	2.26	2.39	3.00
	3"	4.21	4.05	3.54	2.21	2.70	3.39
	<u>Daily Heat Stored</u>	4"	4.40	4.06	3.60	2.07	2.67
	Room ΔT	6"	4.37	3.84	3.40	1.99	2.46
		8"	4.22	3.69	3.24	2.00	2.38
		12"	4.02	3.65	3.20	2.00	2.39
		16"	4.00	3.66	3.21	2.00	2.39
							3.04

*The wall is assumed to be insulated on the back side, or to be back-to-back with another wall of the same thickness having the same surface boundary condition.

Step 2 - For Class 1 surfaces, estimate the fraction of the solar day that the surface is sunlit, f , and the absorptance of the surface, α .

The estimate need not be very precise. Absorptance values can be estimated visually using the following guide:

Very dark surfaces $\alpha = 0.8$ to 0.9

Most surfaces $\alpha = 0.5$ to 0.6

Light colored surfaces $\alpha = 0.3$ to 0.4

(also refer to Table B-2)

Step 3 - Look up the diurnal heat capacity (dhc) of each Class 1, Class 2, and Class 3 surface in Table C-1. Note that there are two dhc tables, one for Class 1 and Class 2 surfaces (direct), and another for Class 3 surfaces (indirect). For interior mass walls the effective wall thickness is one-half the total thickness and both surfaces should be counted. (For a method of calculating the diurnal heat capacity for any material properties and thickness and a fuller explanation, consult the Passive Solar Design Handbook.)

Step 4 - Calculate the Diurnal Heat Capacity (DHC) of each surface from the formula:

$DHC = A \times (dhc) \times (1 + \alpha f)$ Class 1

$DHC = A \times (dhc)$ Class 2 and 3

$DHC = 0$ Class 4

Step 5 - Estimate the heat capacity of the building furnishings. In lieu of other information, use 2 Btu/F per sq ft of floor space.

$DHC = 2 \times A_{\text{floor}}$

Step 6 - Sum the DHC values to obtain the Total Diurnal Heat Capacity of the building interior. Entry of the total DHC on Line 84 will cause SOLCOST-PASSIVE to compute the January clear day temperature swing for the direct gain space.

APPENDIX D. Life Cycle Savings Analysis

SOLCOST-PASSIVE performs present worth analysis of the passive investment for the period of building ownership. Two levels of calculation detail are possible, including: 1) an economics summary; and 2) a detailed cash flow for the passive investment. Key parameters in the summary include:

- o Annualized Passive Heat Cost, AAC, \$/Million Btu's
- o Delivered Heat Cost, DHC, \$/Million Btu's
- o Net present value of solar savings, NPV, \$.

The annualized passive heat cost, AAC, is determined from:

$$AAC = FCR * TC / (HLOAD * F)$$

where

FCR = Fixed charge rate

TC = Total passive cost, \$

HLOAD = Annual heat load, million Btu's

F = Solar savings fraction.

The fixed charge rate, FCR, is based on the following:

$$FCR = CRFN(PT, r) * (X_1 - X_2 - X_3 + X_4)$$

CRFN(PT, r) is the nominal capital recovery factor based on PT years at discount rate r.

X_1 is a factor that accounts for the mortgage or loan downpayment, DPR, and principal and interest costs over the T years of the term.

$$X_1 = DPR + (1 - DPR) * \frac{CRFN(T, i)}{CRFN(PT, r)}$$

X_2 is a factor that accounts for mortgage interest tax deductions over the PT years of ownership.

$$X_2 = (1 - DPR) * FSLTX * \left[\frac{CRFN(T, i)}{CRFN(PT, r)} + i - CRFN(T, i) * DSPWF(PT, i, r) \right]$$

DSPW(PT, i, r) is the differential series present worth factor and FSLTX is the federal, state income tax rate.

*This appendix is condensed from the work of S. Noll who authored the economic analysis in the Passive Solar Design Handbook.

X_3 is a factor that accounts for the profit that is realized from the sale of the passive home at the end of the PTth year. X_3 is calculated based on the difference between the assessed market value of the passive elements in the home and the unpaid principal balance of the mortgage or home improvement loan.

$$X_3 = \text{FWF}(\text{PT}, \delta) * \text{PWF}(\text{PT}, r) * V - (1 - \text{DPR}) * \text{RBF}(\text{T}, i, \text{PT}) * \text{PWF}(\text{PT}, r)$$

$\text{FWF}(\text{PT}, \delta)$ is a future worth factor that converts the initial total cost TC of the passive addition into market value at PT year end. δ is the annual escalation rate of property values over the PT years (not necessarily equal to θ , the rate of inflation). $\text{PWF}(\text{PT}, r)$ is a present worth factor that brings the market value in year PT back into a first year discounted value.

$\text{RBF}(\text{T}, i, \text{PT})$ is simply a fraction that tells the portion of the initial loan principal that remains unpaid at the time of sale and is a function of PT and the loan term factors T and i ($0 < \text{RBF} < 1$).

X_4 is a factor that accounts for property taxes and operation, maintenance, and insurance expenditures over the PT years.

$$X_4 = \text{DSPWF}(\text{PT}, \theta, r) * (\text{PTXR} * (1 - \text{FSLTX}) + \text{OMI})$$

The property tax rate, PTXR, is adjusted to reflect federal, state, and local income tax deductions. $\text{DSPWF}(\text{PT}, \theta, r)$ is used as a correction factor for PTXR and OMI to account for the inflationary increases in these expenditures.

It is important to remember that the fixed charge rate, FCR, is quite sensitive to the parameter values that enter the calculation of X_1 , X_2 , X_3 , and X_4 . Care should be taken to analyze those parameters that are subject to the most uncertainty (e.g., V and r) so that sensitivities may be determined.

The delivered heat cost DHC is the annualized value of the delivered cost of passive and auxiliary heat to the building, computed as follows:

$$\text{DHC} = \text{AAC} * \text{F} + \text{P} * (1 - \text{F}) + \text{ABSC}$$

where

AAC = Annualized passive heat cost

F = Solar savings fraction

P = Annualized backup fuel cost

ABSC = Annualized backup system costs for capitol, operation, and maintenance

The annualized backup fuel cost P is given by:

$$\text{P} = \text{CRFN}(\text{PT}, \text{r}) * \text{DSPWF}(\text{PT}, \text{e}, \text{r},) * \text{P}_0$$

where

CRFN(PT,r) = Capital recovery factor for PT years of ownership and discount rate of r

DSPWF(PT,e,r,) = Differential series present worth factor for PT,r, and fuel escalation rate e.

P₀ = Fuel price in year zero.

The annualized backup system cost ABSC is given by:

$$\text{ABSC} = \frac{\text{BSC} * \text{X5} * \text{CRFN}(\text{PT}, \text{r})}{\text{HLOAD}}$$

where

BSC = Backup system cost, \$

X5 = Defined below

CRFN(PT,r) = Capitol recovery factor for PT,r

HLOAD = Annual heating load, million Btu's

The X5 term in ABSC is given by:

$$\text{X5} = \text{X1} + \text{DSPWF}(\text{PT}, \theta, \text{r}) * \text{OMB}$$

where

X1 = Defined above in FCR section

OMB = Operation, maintenance, insurance for backup system

DSPWF(PT,θ,r) = Differential series present worth factor for PT,r, and inflation rate θ

Finally, the net present value term, NPV, can be calculated as follows:

$$\text{NPV} = \left[(\text{P} + \text{ABSC} - \text{DHC}) * \text{HLOAD} \right] * \text{SPWF}(\text{PT}, \text{r})$$

where

P	= Annualized backup fuel cost, \$/million Btu's
ABSC	= Annualized backup system costs, \$/million Btu's
DHC	= Delivered heat cost, \$/million Btu's
HLOAD	= Annual heating load, million Btu's
SPWF(PT,r)	= Series present worth factor for period of ownership PT and discount rate r