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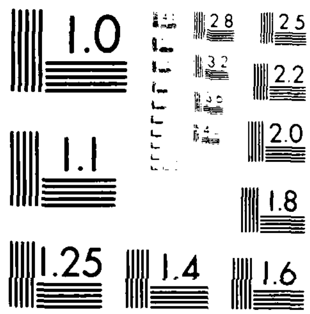
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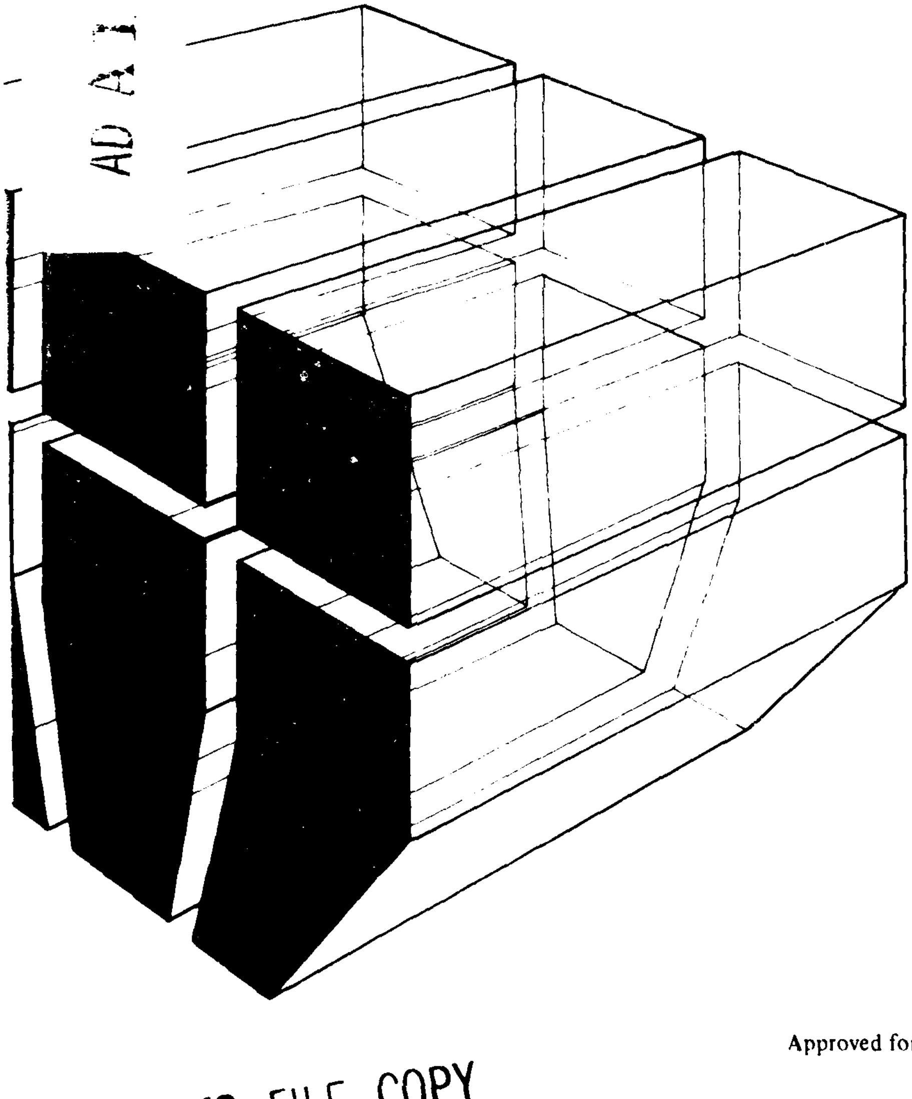
(Solar Energy Implementation Techniques)

SOLFEAS: AN INTERACTIVE PROGRAM FOR ESTIMATING THE ECONOMIC FEASIBILITY OF AN ACTIVE SOLAR THERMAL ENERGY SYSTEM

by
D. M. Joncich
C. W. Sohn



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SOLFEAS is an interactive computer program developed to provide Corps of Engineers Field Operating Agencies (FOAs) with a simple, inexpensive means of estimating the economic feasibility of an active solar thermal energy system. SOLFEAS can project paybacks for each of four solar system types: (1) service water heating/preheating (domestic hot water and/or process hot water), (2) space heating only, (3) combined space - service water heating, and (4) combined space - service water heating/space cooling.

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SOLFEAS contains integral weather data for 248 Weather Service stations; these may be accessed by specifying the appropriate SOLMET station number. For each SOLMET station, default values for the auxiliary fuel costs and escalation rates have been integrated into the program. Other economic factors, such as the discount rate, the system maintenance and repair (M R) costs, and the investment credit have been set in accordance with current guidance. Any of these values may be modified if this guidance is revised in the future. The only user inputs the program requires are monthly values for the total building space heating, cooling, and service hot water loads, and the SOLMET station number for the installation where the building is being considered.

For each of the four system types, the program uses a "universal curve" approach developed by the U.S. Army Construction Engineering Research Laboratory to compute the collector area needed to produce solar contributions ranging from 10 percent to 90 percent of the total load in 10 percent increments. The user need not input cost information for any of the solar components. For each system type, the necessary components have been defined within the program and sized as a function of the collector area in accordance with published "rules of thumb." An equation for computing the installed cost of each component as a function of its size has also been developed from data contained within a recognized cost-estimating guide. Thus, the program can automatically compute the system installed cost as a function of collector area for each of the four system types. Based on this information, SOLFEAS computes the net life-cycle cost for each candidate system and outputs this parameter for user inspection.

This report documents the development of SOLFEAS. Instructions for running the program and a sample problem are also provided.

FOREWORD

This work was performed for the Assistant Chief of Engineers (ACE) under Project 4A762781AT45, "Energy and Energy Conservation"; Task C, "Installation Energy Systems Strategy"; Work Unit 001, "Solar Energy Implementation Techniques." This study was prepared by the Energy Systems Division (ES) of the U.S. Army Construction Engineering Research Laboratory (CERL). Mr. E. Zulkofske, DAEN-ECE-E, was the Technical Monitor.

Appreciation is expressed to Mr. D. Ellis of the Corps of Engineers' Fort Worth District for producing an initial version of the program, and to Mr. B. Salimi of CERL-ES for his contributions to the development of the cost-estimating routines and to the analysis of the weather data.

Mr. R. G. Donaghy is Chief of CERL-ES. COL Louis J. Circeo is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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1 INTRODUCTION

Background

Title 10 United States Code (10 USC 2857) requires that solar energy systems be evaluated in the design of any new military construction where the use of solar energy can save fossil fuel. Each year, the Corps of Engineers' volume of new construction is large; as a result, several Field Operating Agencies (FOAs) have expressed their concern about the high costs associated with performing solar feasibility studies for MCA projects, since many of these solar energy systems are ultimately found to be cost-ineffective.[1] In a summary document issued by the Office of the Chief of Engineers (OCE), dated March 1980, costs of these studies were estimated to range from $500 to $20,000; $5000 was a typical value.[2]

To reduce both the effort and the costs associated with performing solar feasibility studies, personnel from the Fort Worth District Engineer Office developed an automated procedure for estimating the cost-effectiveness of a prospective solar thermal application. This procedure was the basis for the development of SOLFEAS.

Purpose

The purpose of this research was to provide FOA personnel with a quick, simple, and inexpensive procedure for initially assessing the cost-effectiveness of using a solar system in a prospective building; this procedure must be flexible enough to account for future variations in the solar system costs, the discount rate, fuel costs and escalation rates, and assumed system maintenance and repair (M&R) costs.

Approach

Development of this program consisted of the following tasks:

1. Evaluating the automated method developed by the Fort Worth District and identifying areas for potential simplification.

2. Locating sources of weather data required by the method.

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[1] Letter, DAEN-MPE-E, Office of the Chief of Engineers, to Corps Districts and Divisions, dated 26 March 1981, subject: Evaluation of Solar Energy Studies.

[2] <u>DOD Solar Energy Project Summaries</u> (Office of the Chief of Engineers, DAEN-MPE-E, March 1980).

3. Developing a procedure for estimating the installed cost of a solar energy system.

4. Determining the economic factors impacting the solar system cost-effectiveness.

5. Collecting data for each factor defined in step 4.

6. Combining the results of steps 1 through 5 into a user-oriented computer program.

7. Distributing the program to Corps FOAs.

Scope

SOLFEAS can project several measures of economic performance for each of the four solar system types. It is applicable to any active solar thermal system that has liquid collectors and employs sensible heat storage; however, it does not consider passive solar techniques at this time.

Mode of Technology Transfer

The information in this report will be included as part of the new Engineer Technical Letter (scheduled for publication early in FY83) which describes how solar energy systems are to be evaluated. It is intended that the program be included in Technical Manual 5-804-2 on solar system design, and the procedure incorporated into the pre-concept version of the Computer-Aided Engineering and Architectural Design System (CAEADS).

2 SOLAR SYSTEM THERMAL ANALYSIS

Solar Applications Treated

The statutory requirement which directs that solar energy be considered for military construction projects is contained within Title 10 of the United States Code (10 USC 2857). Specific guidance for meeting this requirement is normally communicated to Corps FOAs by means of Engineer Technical Letters (ETLs), issued periodically by HQUSACE. In the case of solar energy, this guidance may be found in ETL 1110-3-332, and ETL 1110-3-302.[3]

Changes to ETL 1110-3-302 (scheduled to be superseded early in FY83) will require the preparation of documentation in the form of engineering/economic life-cycle cost (LCC) analyses for determining the cost-effectiveness of each of the following solar system types:

1. Service water heating/preheating (domestic hot water and/or process hot water)

2. Space heating only

3. Combined space - service water heating

4. Combined space - service water heating/space cooling.

SOLFEAS has been structured to perform the required economics analyses for each of these applications.

While the size of the system components varies among applications and sites, the collection and storage aspects of the system configuration are assumed to be identical for the four solar system types listed above. These systems (see Figure 1) typically consist of a collector array, a heat exchanger, a thermal storage tank, two circulating pumps, and a control device.[4]

Systems in the collection-storage mode operate as follows:

1. The collectors absorb part of the solar energy incident on them, thereby raising their temperature.

2. When the collector temperature is sufficiently higher than the tank temperature, the controls activate the two pumps.

3. The collector pump circulates the collector fluid through the array of solar collectors and through one side of the heat exchanger. The storage pump simultaneously circulates fluid from the storage tank through the other

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[3] Economic Studies, ETL 1110-3-332 (Office of the Chief of Engineers [OCE], 22 March 1982); Evaluation of Solar Energy, ETL 1110-3-302 (OCE, 14 March 1979).

[4] D. M. Joncich and D. L. Johnson, Development of an Acceptance Test for Solar Energy Systems, Technical Report E-173/ADA089644 (U.S. Army Construction Engineering Research Laboratory [CERL], 1981).

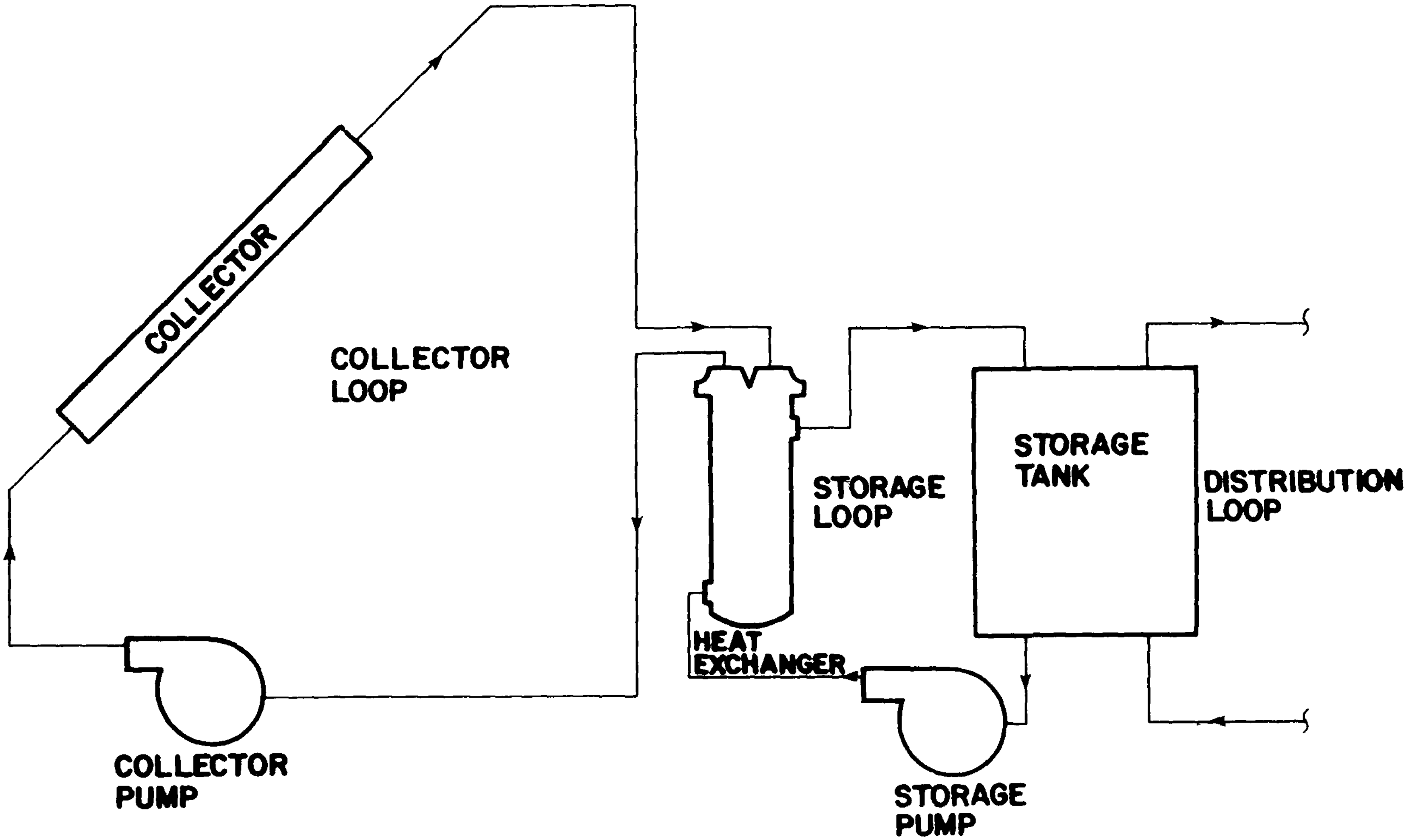

Figure 1. Solar system schematic.

side of the heat exchanger. The combined action of these two pumps transfers the collected energy to the storage tank. The heat exchanger is required because, in most cases, the collector loop must be freeze-protected.

The delivery point for the stored thermal energy differs in each of the four solar applications. For a service water heating system, this energy is ultimately transferred to another heat exchanger in contact with the building's hot water supply. For space heating applications, the solar-heated water is normally circulated through a duct-mounted coil in the building warm-air delivery system. In solar cooling applications, this water is delivered to the generator of an absorption chiller.

While individual project designs will vary and may not be completely represented by Figure 1, for the purpose of feasibility assessment, a methodology based on the assumption that a system contains these components is considered to be reasonably accurate.

Solar System Performance

In developing a solar energy system design methodology, the U.S. Army Construction Engineering Research Laboratory (CERL) performed several hundred solar system simulations for typical Army buildings in various parts of the country. An analysis of the performance curves for these systems indicated that with proper normalization, the performance of a given solar system could be represented by a single universal performance curve for all buildings in all locations.[5] This was also discovered at about the same time by researchers at the Los Alamos Scientific Laboratory.[6]

CERL produced three such universal curves: one for solar domestic hot water, one for solar heating, and one for solar domestic water heating combined with space heating and cooling. For each of these applications, the corresponding curve may be used to determine the overall performance of the system pictured in Figure 1. Development of this approach was based on several assumptions. First, a singly glazed, flat-plate collector with a plate emissivity of .10 and an absorptivity of .90 was taken as the reference collector. The tilt of these collectors from the horizontal depended on the particular application. For solar domestic hot water systems, this angle was assumed to be equal to the latitude; for solar space heating, it was taken as the latitude plus 10 degrees; for solar space heating and cooling, it was set as latitude minus 10 degrees. These tilt angles were found to be nearly optimal for each application, respectively. All collectors were modeled as being unshaded and facing south. The heat exchanger effectiveness was set at .8, and the storage tank volume was assumed to be roughly 16 lb (6.4 kg) of

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5 D. Hittle, D. Holshouser, and G. Walton, Interim Feasibility Assessment Method for Solar Heating and Cooling of Army Buildings, Technical Report E-91/ADA026588 (CERL, 1976); D. M. Joncich, D. J. Leverenz, D. C. Hittle, and G. Walton, Design of Solar Heating and Cooling Systems, Technical Report E-139/ADA062719 (CERL, 1978).

6 J. D. Balcomb, D. P. Grimmer, J. C. Hedstrom, and K. C. Herr, Pacific Regional Solar Heating Handbook, Informal Report/LA-6242-MS (Los Alamos Scientific Laboratory, 1976).

water per square foot of collector area. The tank insulation had an "R" value of 19 sq ft °F hr/Btu, but all line losses were considered to be negligible.

Using the universal curve requires a knowledge of the thermal energy demands for the facility under consideration and of the on-site solar availability. Once this information is determined, the curve can relate solar system performance to the total collector area. However, to apply the curves, an understanding of the following terms is required:

1. The annual or monthly solar radiation incident on the titled collector array, Q_C, in Btu/sq ft/yr or Btu/sq ft/month. Since solar insolation data are normally given in terms of horizontal radiation intensities, these numbers must be corrected for the tilt angle of the collector array. A correction procedure was developed when the universal curves were produced.

2. The annual or monthly building thermal energy requirements, Q_L. For applying the universal curve, these energy requirements are defined as the total thermal energy <u>in the form of hot water</u> required by the facility's domestic hot water system, space heating system, or absorption chiller.

3. The solar load ratio, SLR. This is defined as the ratio of the annual (or monthly) radiation incident on the collector array to the annual (or monthly) energy requirements of the building, as given in Eq 1:

$$SLR = \frac{Q_C A_C}{Q_L}, \qquad \text{[Eq 1]}$$

where A_C is the collector array area. The SLR essentially measures the solar energy available to the system collector array relative to the total facility energy requirement.

4. Percentage of the building thermal energy requirement provided by solar energy, η. This term, the fraction of Q_L provided by a collector array of area A_c, is related to SLR as shown in Eq 2.

$$\eta = 1 - e^{-a(SLR)^b} \qquad \text{[Eq 2]}$$

where a and b are constants. Values of a and b for the three universal curves are listed in Table 1. While the form of the expression for each curve is the same, the application of the curves varies somewhat, depending on the solar system being considered. For domestic hot water systems, or for systems involving domestic water heating combined with space heating and cooling, all calculations are done on an annual basis. That is, the solar radiation and the building thermal requirements are computed using yearly values for these parameters. For space heating only systems, the universal curve for heating must be applied on a monthly basis, and monthly energies summed for a yearly total. A number of detailed example problems illustrating the use of the universal curves are given in CERL Technical Report E-139.

The algorithms SOLFEAS uses to compute the thermal performance of the four solar system types are based on this universal curve approach. For service water heating, space heating only, and combined space-service water heating/space cooling systems, the curves described by the constants listed in

Table 1

Universal Curve Constants by System Type

Application	a	b
Domestic Water Heating	.78	.93
Space Heating Only	.46	.92
Space-Domestic Water Heating/Space Cooling	.32	1.07

$$\eta = 1 - e^{-a(SLR)^b}$$

Table 1 apply directly, either on a monthly or annual basis, as appropriate. For the combined space-service water heating system, the universal curve for space heating is assumed valid, and the program performs monthly calculations.

To estimate the performance of the four solar system types, SOLFEAS uses the following procedure:

1. The program computes the solar insolation on a unit area of collector tilted at the angle appropriate for each of the four applications (Q_C). These computations are possible because SOLFEAS contains long-term monthly averages of solar radiation for 248 National Weather Service sites.[7] The program user accesses this information by specifying the SOLMET site number corresponding to the building's location; appropriate values for the site number have been established for all U.S. Army installations and major activities.

2. Next, the program computes monthly or yearly values of the facility thermal energy requirement in the form of hot water (Q_L). Here, the user must enter monthly values of the facility's service water, space heating, and space cooling loads. For service water and space heating, these loads are equivalent to the energy output of on-site boilers. For absorption chilling, SOLFEAS converts user-input monthly chilled water demands to hot water requirements by dividing them by the assumed chiller coefficient of performance (COP), taken to be .65.

3. Once Q_C and Q_L have been determined, SOLFEAS computes, for each of the four solar system types, the collector area required to produce solar contributions (η); these range from 10 percent to 90 percent of the total specified load and are given in 10 percent increments. This computation involves a straightforward calculation, using the constants a and b from Table 1, given that the parameters Q_L, Q_C, A_C, and η are related by Eqs 1 and 2 for each type of solar system. The results of these computations are output for the user's inspection.

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[7] C. Knapp, T. Stoffel, and S. Whitaker, Insolation Data Manual, SERI/SP-755-789 (Solar Energy Research Institute, 1980).

Estimate of Fossil Fuel Savings

One of the primary reasons for considering the use of solar energy systems in military facilities is to reduce consumption of fossil fuels. SOLFEAS allows the specification of five conventional energy sources as backup for each of the four solar applications treated: electricity, natural gas, distillates, residuals, and coal. However, before the magnitude of the fuel savings can be estimated, each fuel's conversion efficiency for meeting the facility thermal loads must be determined. Table 2 summarizes the efficiencies assumed by the program for each of the five fuels in producing service water heating, space heating, and space cooling.

For example, consider a situation where electricity is used to supplement a solar cooling system. The value that appears under the category "Space Cooling" by "Electricity" reflects the fact that the seasonal COP of the chiller has been taken to be 3. For the relatively straightforward case of a domestic hot water system with a fuel oil boiler for auxiliary, the combustion efficiency of .75 implies that for every Btu of energy needed for hot water, 1/.75 Btus of oil must be purchased. Table 3 gives the assumed energy content of each fuel in Btus.

In all cases, the conversion efficiency for coal has been assigned a lower value than either oil or natural gas. This is because it is assumed that coal would most likely be used in a central plant. In this case, line losses from the point of production to the building boundary would have a measurable impact on overall conversion efficiency for this fuel relative to the others.

Table 2

Assumed Conversion Efficiency by Fuel Type

Fuel	Domestic Water Heating	Space Heating	Space Cooling
Electricity	1.00	1.00	3.00
Natural Gas	0.75	0.75	0.50*
Distillate	0.75	0.75	0.50*
Residual	0.75	0.75	0.50*
Coal	0.50	0.50	0.33**

* Includes a combustion efficiency of 0.75 and an absorption chiller COP of 0.65.

** Includes a combustion/distribution efficiency of 0.50 and an absorption chiller COP of 0.65.

Table 3

Assumed Heat Content by Fuel Type

Fuel	Heat Content
Electricity	3,412 Btu/kWh
Natural Gas	1,016 Btu/cu ft
Distillate	138,690 Btu/gal
Residual	149,690 Btu/gal
Coal	22,500 MBtu/ton

3 ECONOMIC EVALUATION

The cost-effectiveness of an active solar thermal energy system is a complicated function of a number of factors. These include the on-site availability of solar energy, the facility thermal energy demands, the solar system installed cost, the current price and projected escalation rate of the auxiliary fuel, the discount rate, the system M&R costs, the investment credit, and the assumed system final salvage value. Of these, the first two essentially determine the thermal performance of the solar system being considered; their treatment within SOLFEAS was discussed in Chapter 2. This chapter describes the treatment of the remaining factors.

As stated in ETL 1110-3-332, the economic ranking of alternate energy systems is to be based solely on total LCC. SOLFEAS computes the LCC for each candidate collector area and outputs this parameter for user inspection. For completeness, the program also computes and outputs the system savings-to-investment ratio (SIR) and discounted payback period as well.

These three indicators of economic feasibility are to be computed in accordance with criteria developed by the Department of Energy (DOE) in response to specific statutory requirements.[8] SOLFEAS has been developed to perform the solar economic studies as prescribed by this body of guidance.

For a given period of study life, all recurring costs are escalated at the prescribed rate, and then discounted to present values as determined by the given discount rate. Using calculated present values, the solar system LCC and SIR may be expressed as follows:

$$LCC = (C_2 - C_3) - (C_1 - C_4) \qquad \text{[Eq 3]}$$

$$SIR = (C_2 - C_3)/(C_1 - C_4) \qquad \text{[Eq 4]}$$

where

C_1 = the construction cost of the installed solar energy system.

C_2 = the life-cycle fuel cost savings resulting from the solar energy system.

C_3 = the life-cycle solar system maintenance and repair costs.

C_4 = final solar system salvage value.

It should be noted that when the LCC = 0, the SIR = 1.

The discounted payback period is defined as the period of time in years for which the LCC savings for the investment equals zero.

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[8] Code of Federal Regulations, Title 10, Part 436, Subpart A (10 CFR 436A), updated periodically.

Solar System Installed Cost

SOLFEAS uses the following procedure to estimate the installed solar system costs:

1. The components shown in Figure 1 were sized relative to the system collector area in accordance with published "rules of thumb."[8]

2. The relationship between the size of each component and its cost was established by an analysis of data taken from a recognized cost-estimating guide.[9]

3. This information was combined to yield the installed cost for each of the four system types for any collector area.

Table 4 lists the assumptions used to relate system collector area to component capacity. Analysis of the literature from a number of collector manufacturers indicated that a value of about 20 sq ft (1.8 m^2) was reasonable for the basic collector area increment. The volume of fluid contained within one such collector was found to be about .3 gal (1.13 L).

Table 4

Solar System Component Size and Line Length as a Function of System Collector Area Component Sizing

Parameter	Value
Unit collector area	20 sq ft
Collector volume	.3 gal/collector
Fluid flow rate	.5 gpm/collector
Collector array piping	20 ft/200 sq ft-collector
Storage tank volume	2 gal/sq ft-collector
Antifreeze/water mixture	50/50
Absorption chiller capacity	.0068 ton/sq ft-collector

System Piping

Line Length (ft)	Collector Area (sq ft)
100	0 to 800
200	800 to 5000
300	> 5000

[9] W. A. Beckman, S. A. Klein, and J. A. Duffie, Solar Heating Design by the F-Chart Method (Wiley-Interscience, 1977).
[10] Building Construction Cost Data (Robert Snow Means Co., Inc., 1981).

The assumed collector loop flow rate (.5 gpm [3.2 x 10^{-5} m^3/sec]/collector) had to be known to size the system heat exchanger and the collector and storage pumps. This sizing was done in accordance with standard plumbing practice, with the additional assumption that the flow rates in the collector and the storage loops are equal. The flow rate information was also used to size the system piping; larger collector array areas resulted in pipes with larger diameters to accommodate the required flow. Once pipe sizes were established as a function of the collector area, the system volume was determined. This permitted estimation of the appropriate capacity for a system expansion tank, and of the quantity of antifreeze required for freeze protection.

The allowance for system piping was as shown in Table 4, with additional piping in the amount 20 ft/200 sq ft (6 m/18 m^2) of collector allowed to account for the array plumbing. The storage tank volume was generated directly for each system size by including a factor of 2 gal (7.6 L) of storage per square foot of collector area.

For solar air conditioning, the appropriate factor for the absorption chiller's capacity was determined as follows: under sunny summer conditions, with an assumed radiation intensity of 250 Btu/sq ft-hr (787.5 W/m^2) a collector efficiency of 50 percent was considered reasonable. This implied a power input to the absorber's generator of 125 Btu/sq ft-hr (393.75 W/m^2). Multiplying by the chiller COP (.65) and converting to tons of cooling output yielded the chiller capacity of .0068 tons/sq ft (257 W/m^2) (Table 4).

Once the relationship between the solar system component size and collector area had been established, component costs were estimated, using the Means Building Construction Cost Data. This guide tabulates material and labor costs for a variety of items at a reference location; it also provides city multipliers to correct these figures for differing economic conditions at other sites. The procedure followed in SOLFEAS is identical for all components. A curve in the form

$$C = K_1 + K_2 A \qquad \text{[Eq 5]}$$

was developed for each system, where C is the total system cost, K_1 and K_2 are constants from curve fits to the data, and A is the solar system collector area.

Tables 5 through 8 summarize the results for the four solar system types. For each system, the materials and labor costs consist of two terms. The first, given by the constant K_1, is a fixed cost incurred independent of the solar system's size. In this nomenclature K_1 is given by the sum of all the component fixed costs for materials ($K_{1,m}$) and labor ($K_{1,\ell}$). The coefficient K_2 describes the dependence of the system cost on the collector area, where K_2 is the sum of all component costs per sq ft of collector area for materials ($K_{2,m}$) and labor ($K_{2,\ell}$). For the solar collectors and system controls, the Means Guide provides a range of prices rather than a single value. For these components, the lowest value has been assumed for the solar service water heating system, an intermediate value for the space heating only and combined space-service water heating systems, and the highest price for the combined space-service water heating/space cooling system.

Table 5

Component Costs Vs. Collector Area
Service Water Heating System

COST (C)
$C = K_1 + K_2A$

COMPONENT	Material		Labor	
	$K_{1,m}$ (\$)	$K_{2,m}$ (\$/sq ft)	$K_{1,l}$ (\$)	$K_{2,l}$ (\$/sq ft)
Collector panels and supports	0.0	21.00	0.0	7.00
Heat exchanger	257	0.85	10	0.052
Storage tank	121	0.97	5	0.21
Insulation (tank)	19	0.067	32	0.11
Expansion tank	-19	0.091	300	0.00
Pump (collector loop)	116	0.047	12	0.0047
Pump (storage loop)	116	0.047	12	0.0047
System piping (insulated)	1.4	1.06	355	1.09
Antifreeze (50%)	0.0	0.091	0.0	0.00
Controls and sensors	60	0.00	0.0	0.00
Valves	115	0.00	37.0	0.00
TOTAL	786	24.22	763	8.47

Table 6

Component Costs Vs. Collector Area
Space Heating Only System

COST (C)
$C = K_1 + K_2A$

COMPONENT	Material		Labor	
	$K_{1,m}$ (\$)	$K_{2,m}$ (\$/sq ft)	$K_{1,l}$ (\$)	$K_{2,l}$ (\$/sq ft)
Collector panels and supports	0.0	28.00	0.0	7.00
Heat exchanger	257	0.85	10	0.052
Storage tank	121	0.97	5	0.21
Insulation (tank)	19	0.067	32	0.11
Expansion tank	-19	0.091	300	0.00
Pump (collector loop)	116	0.047	12	0.0047
Pump (storage loop)	116	0.047	12	0.0047
System piping (insulated)	1.4	1.06	355	1.09
Antifreeze (50%)	0.0	0.091	0.0	0.00
Controls and sensors	155	0.00	0.0	0.00
Valves	115	0.00	37.0	0.00
TOTAL	881	31.22	[illegible]	8.47

Table 7

Component Costs Vs. Collector Area
Combined Space-Service Heating System

COMPONENT	COST (C) $C = K_1 + K_2A$ Material		Labor	
	$K_{1,m}$ ($)	$K_{2,m}$ ($/sq ft)	$K_{1,l}$ ($)	$K_{2,l}$ ($/sq ft)
Collector panels and supports	0.0	28.00	0.0	7.00
Heat exchanger	257	0.85	10	0.052
Storage tank	121	0.97	5	0.21
Insulation (tank)	19	0.067	32	0.11
Expansion tank	-19	0.091	300	0.00
Pump (collector loop)	116	0.047	12	0.0047
Pump (storage loop)	116	0.047	12	0.0047
System piping (insulated)	1.4	1.06	355	1.09
Antifreeze (50%)	0.0	0.091	0.0	0.00
Controls and sensors	185	0.00	0.0	0.00
Valves	170	0.00	53	0.00
TOTAL	966	31.22	779	8.47

Table 8

Component Costs Vs. Collector Area
Combined Space-Service Heating/Space Cooling System

COMPONENT	COST (C) $C = K_1 + K_2A$ Material		Labor	
	$K_{1,m}$ ($)	$K_{2,m}$ ($/sq ft)	$K_{1,l}$ ($)	$K_{2,l}$ ($/sq ft)
Collector panels and supports	0.0	34.00	0.0	7.00
Heat exchanger	257	0.85	10	0.052
Storage tank	121	0.97	5	0.21
Insulation (tank)	19	0.067	32	0.11
Expansion tank	-19	0.091	300	0.00
Pump (collector loop)	116	0.047	12	0.0047
Pump (storage loop)	116	0.047	12	0.0047
Pump (chiller loop)	116	0.047	12	0.0047
Pump (tower-chiller loop)	99	0.06	10	0.006
System piping (insulated)	1.4	1.06	355	1.09
Cooling tower	525	0.43	2[illegible]8	0.19
Absorption chiller	7751	1.06	2312	0.32
Tower-chiller piping (insulated)	849	1.17	1768	0.72
Antifreeze (50%)	0.0	0.091	0.0	0.00
Controls and sensors	250	0.00	0.0	0.00
Valves	230	0.00	74.0	0.00
TOTAL	10431	39.99	5200	9.71

By adopting this approach, the cost-estimating procedures have been simplified to such an extent that the SOLFEAS user need not input any system cost data. The total price for the four system types (summarized in Table 9 with a 25 percent overhead and profit included) is part of the program's input data. For example, consider a solar service water heating system with a collector area of 400 sq ft (36 m^2). Taking values of K_1 (= $K_{1,M} + K_{1,L}$) and K_2 (= $K_{2,M} + K_{2,L}$) from the table, the total installed system price ($18,285) which would be used for the economic evaluation of this case by the program, results from the sum of the fixed costs ($983 and $954), added to the product of the collector area (400 sq ft [36 m^2]) times the sum of the varying costs ($30.28 and $10.59).

The city cost multipliers for materials and labor have also been entered into SOLFEAS for each of the 248 weather locations. The user automatically has access to this information simply by specifying the appropriate site numbers for the solar system under design. The program uses these site-specific city multipliers to compute the installed system cost at each location.

Fuel Costs and Escalation Rates

The present cost and projected escalation rate for the fuel used by the conventional equipment which supplements the solar energy system significantly affects the solar system payback. Table 10 summarizes the SOLFEAS default fuel costs and escalation rates for the 10 DOE regions designated by state in Table 11. These figures, taken from 10 CFR 436A Industrial Tables, are for electricity, distillates, residuals, natural gas, and coal as shown. The energy costs for each region are given in dollars per million Btus; escalation rates are projected from mid-1981 through 1996 and beyond in 5-year increments.

Table 9

Summary of Solar System Costs
(Including Overhead and Profit)

	COST (C) $C = K_1 + K_2A$			
	Material		Labor	
COMPONENT	$K_{1,M}$ ($)	$K_{2,M}$ ($/sq ft)	$K_{1,L}$ ($)	$K_{2,L}$ ($/sq ft)
Domestic water heating	983	30.28	954	10.59
Space heating only	1101	39.03	954	10.59
Combined space-water heating	1208	39.03	974	10.59
Space-water heating/space cooling	13,039	49.99	6,500	12.14

Table 10

DOE Industrial Energy Prices and Escalation Rates

Current and Projected Energy Prices (in Mid-1981 Dollars)

DOE Region	Fuel Type	Mid-1981 Base Year (Dollars/10^6 Btu)	Projected Energy Price Escalation Rates (Percentage Change Compounded Annually) Mid-1981-mid-1985	Mid-1985-mid-1990	Mid-1990-mid-1995-and beyond
1	Electricity	20.47	5.27	-1.94	-4.07
	Distillate	9.11	2.51	2.69	6.39
	Residual	6.34	8.99	2.64	5.86
	Natural Gas	4.22	8.84	1.38	2.65
	Steam Coal	1.95	13.93	-2.78	.66
2	Electricity	16.76	5.29	-2.42	-.18
	Distillate	9.18	2.53	2.65	6.37
	Residual	6.47	9.01	2.59	5.69
	Natural Gas	4.02	8.87	1.52	2.69
	Steam Coal	1.63	13.92	1.93	.78
3	Electricity	12.22	5.28	.88	.18
	Distillate	9.37	2.51	2.62	6.27
	Residual	6.59	9.01	2.52	5.61
	Natural Gas	3.52	8.91	3.18	3.04
	Steam Coal	1.38	13.94	2.36	.90
4	Electricity	10.57	5.28	1.85	.81
	Distillate	9.37	2.51	2.62	6.32
	Residual	6.29	8.98	2.66	6.29
	Natural Gas	2.96	8.88	4.38	4.03
	Steam Coal	2.00	13.82	2.96	.06
5	Electricity	11.50	5.30	1.32	-.53
	Distillate	8.95	2.50	2.76	6.53
	Residual	6.29	9.02	2.71	-7.36
	Natural Gas	3.53	8.90	1.91	3.29
	Steam Coal	1.44	13.88	2.00	.18
6	Electricity	15.30	5.27	.28	.61
	Distillate	9.09	2.54	2.71	6.46
	Residual	6.32	9.00	2.58	6.85
	Natural Gas	3.39	8.86	.00	2.85
	Steam Coal	2.00	13.93	1.45	1.48
7	Electricity	19.41	5.28	-1.98	1.48
	Distillate	8.88	2.52	2.78	6.58
	Residual	6.32	9.03	2.70	-7.19
	Natural Gas	3.04	8.86	3.21	3.15
	Steam Coal	1.23	13.79	2.01	.73
8	Electricity	11.21	5.29	-5.89	-5.12
	Distillate	8.99	2.51	2.68	6.59
	Residual	6.15	9.00	2.70	6.56
	Natural Gas	3.33	8.86	.05	1.92
	Steam Coal	.97	13.87	.00	.58
9	Electricity	16.11	5.29	-.53	-.91
	Distillate	8.65	2.52	2.84	6.65
	Residual	6.03	9.00	2.80	6.53
	Natural Gas	4.25	8.87	-.77	.98
	Steam Coal	2.10	13.92	1.32	.00
10	Electricity	3.62	5.29	7.03	-2.29
	Distillate	8.65	2.52	2.84	6.65
	Residual	5.99	8.99	2.82	6.56
	Natural Gas	5.69	8.88	-4.64	-.65
	Steam Coal	1.36	13.76	7.52	1.15

Table 11

DOE Fuel Regions

Region	States
1	Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island
2	New York, New Jersey
3	Pennsylvania, Maryland, West Virginia, Virginia, District of Columbia, Delaware
4	Kentucky, Tennessee, North Carolina, South Carolina, Mississippi, Alabama, Georgia, Florida
5	Minnesota, Wisconsin, Michigan, Illinois, Indiana, Ohio
6	Texas, New Mexico, Oklahoma, Arkansas, Louisiana
7	Kansas, Missouri, Iowa, Nebraska
8	Montana, North Dakota, South Dakota, Wyoming, Utah, Colorado
9	California, Nevada, Arizona, Hawaii
10	Washington, Oregon, Idaho, Alaska

SOLFEAS treats the impact of these published fuel costs and escalation rates on the system payback as prescribed in 10 CFR 436A. After computing the quantity of auxiliary energy required for each collector area and system type (described in Chapter 2), the program calculates the supplemental energy cost for every case in constant dollars, using the escalation rates given. This calculation involves multiplying the first-year auxiliary energy cost by a series of factors which contain terms of the form $(1 + e)^n$, where e is the prescribed escalation rate and n is the year number within the interval under study. These terms are summed for all years of the study life. Because DOE is constantly updating these figures, SOLFEAS allows the user to modify any or all values as required.

Discount Rate

In any life-cycle economic analysis, the value of all future savings and expenditures must be expressed in terms of today's dollars. For a solar energy system, the initial capital cost of the solar equipment is offset by future savings of conventional fuel. The technique for calculating the present value of these future fuel savings involves the discount rate. This calculation requires multiplying the first-year auxiliary energy cost by a series of factors containing terms of the form $1/(1+d)^n$, where d is the discount rate, and n is the year number being considered. As with the fuel escalation factors, SOLFEAS sums these terms for the entire study life. In accordance with 10 CFR 436A, the real annual discount rate has been set at 7 percent; however, the program allows this figure to be reassigned to conform to future modifications of the existing legislation.

System Maintenance Repair Costs

The impact of solar system M R costs on the system economic feasibility is reflected in the term "C_3" of Eqs 3 and 4. In determining the magnitude of this term, SOLFEAS computes a first-year M R cost which is based on the first cost of the installed solar system. M&R costs for future years are discounted back to present dollars, and summed for the study life. A more complete description of the actual values used by the program for system maintenance and repair is given in Chapter 4.

Investment Credit and Salvage Value

The existence of a 10 percent investment credit for solar energy systems (per 10 CFR 436A) means that only 90 percent of the estimated system installed cost be used for the solar economic study. SOLFEAS takes this credit into account in performing the required economic analysis.

The solar system final salvage value enters the calculating of the system net LCC and SIR through the term labeled C_4 in Eqs 3 and 4. The magnitude of the salvage value is assigned by the user, and appears as a one-time credit taken by the program at the end of the study period. In calculating the system LCC and SIR, any future salvage value is expressed in terms of constant dollars.

Sensitivity Studies

Several sensitivity studies were performed to obtain a perspective of the relative impact of the various thermal and economic factors on the system economic payback. Table 12 gives the results of these studies. A "baseline" system was defined and the SIR for each collector area tabulated for each solar system type. These runs were then redone with the values of the solar insolation, building thermal loads, fuel cost, fuel escalation rate, and discount rate increased, one at a time, by 33 percent. In each case, the resulting SIRs were compared to the baseline values and the percentage change in optimal SIR was computed for each. For example, a 33 percent increase in the discount rate for a domestic water heating system led to a 12.1 percent decrease in the corresponding SIR. Table 12 shows that, according to SOLFEAS, solar system cost-effectiveness depends strongly on the solar insolation, fuel cost, fuel escalation rate, and the discount rate, but much less on the magnitude of the building thermal loads. This result is significant; it implies that SOLFEAS can be used to estimate the feasibility of a prospective solar energy system even if the building loads data are approximate. This would occur in most situations, since more exact loads information is not normally available in the early stages of the building design process.

Table 12

Dependence of SIR on System Thermal and Economic Factors

System Type	Solar Insolation	Load	Fuel Cost	Fuel Escalation Rate	Discount Rate
	% Change in Optimal System SIR with a 33% Increase in:				
1. Domestic Hot Water	+19.4	+1.8	+33.4	+16.1	-12.1
2. Solar Heating	+26.5	0.0	+33.3	+16.1	-12.0
3. Domestic Hot Water and Solar Heating	+24.3	+0.73	+33.3	+16.1	-12.1
4. Domestic Hot Water, Solar Heating, and Solar Cooling	+27.6	+0.27	+33.2	+16.1	-12.2

4 RUNNING THE PROGRAM

Program Overview

SOLFEAS is accessible to any Corps FOA or A/E office having an account with the Boeing Computer Service (BCS). Since Boeing presently has a Corps-wide computer services contract, accounts can be arranged for new users.

All SOLFEAS output is directed over the telephone to the local list device. Therefore, each user must have a printing terminal with modem. Any 80- or 132-column printer with keyboard is acceptable.

Figure 2 provides an overview of the program operation. The user must access the computer and complete the routine login procedure. This is done by dialing the local BCS telephone number and supplying his/her account number and password. The program is retrieved by typing only two commands as shown; the user is prompted for all subsequent input.

At this point the user has two options: (1) attach the default data set provided with the program, or (2) load data which he/she has saved from a previous run. First-time users should select the former, simply by typing a "Y".

Once the program has been retrieved and the data loaded, the designer has the option of listing the data, modifying it, or running the program. As shown in Figure 2, these options are invoked by typing one of four single-letter commands. The "L" command causes all the current program input data to be listed at this terminal. The "P" and "G" are partial and global change commmands which are provided so that any or all data may be modified to describe the facility under consideration. At the very least, the designer must use these commands to input monthly values for the facility's service water, space heating, and space cooling loads and to provide project descriptive data. (This information must be obtained before running SOLFEAS and entered for each facility on a case-by-case basis.) In most cases, the appropriate SOLMET station number must also be input to the program as well. The program is run by means of the "R" command.

Once run, SOLFEAS produces three pages of output. The first page summarizes the data entered for that particular analysis. The second page presents the results of the system thermal analysis for the four system types. The third page provides the economic analysis results. Based on these outputs, the user can determine the feasibility of the prospective solar energy system.

When the analysis is complete, the designer has the option of saving the input data file from that specific site for future use. This is done by specifying a filename for the saved data. If many solar designs are likely to be performed at the same installation, the user can employ this option to customize a data file for subsequent runs at that site.

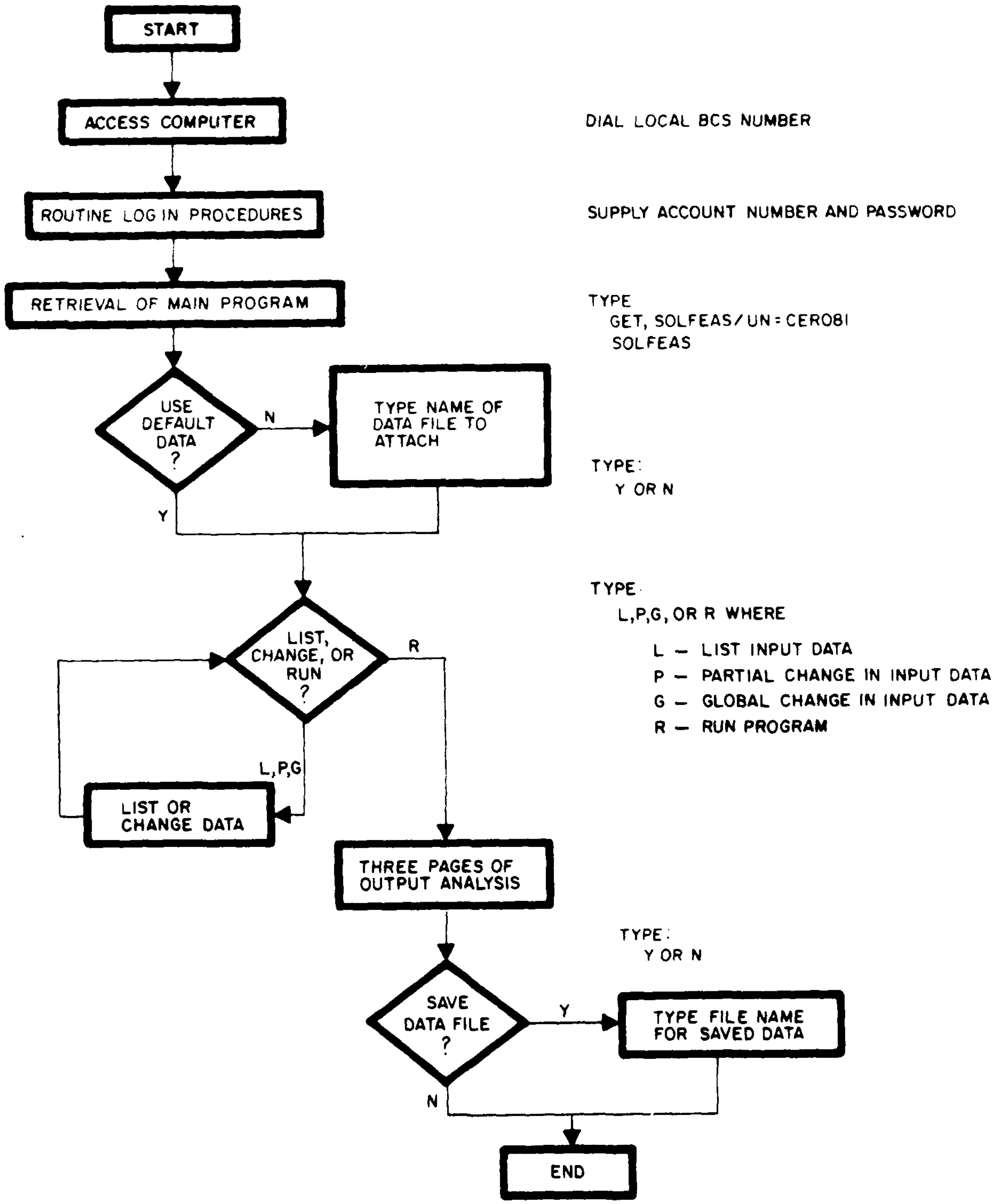

Figure 2. An overview of the SOLFEAS operation.

Program Limitations

As developed, SOLFEAS applies to any type of solar system for which solar radiation data is available. Selections of solar radiation data for each Army installation or nearby city have been assigned and are available. However, two points must be emphasized. First, the program should be run as part of the concept design at a stage when final thermal loads data are not available. Because the system SIR does not depend strongly on the absolute magnitude of the building thermal loads, this preliminary information is entirely adequate for solar system feasibility studies. Second, the algorithms for computing the system thermal performance and installed costs are approximate only. When the solar system appears to be marginally cost-effective, a more detailed study is recommended.

Input Data Description

Figure 3 summarizes the input data required to run SOLFEAS. This figure has been printed in the same format the user would obtain by issuing an "L" command after SOLFEAS signs on. Each block of data has been grouped into one of 18 arrays, with the array number for each appearing on the right-hand side of the table. Each array consists of elements which are numbered from left to right or from top to bottom. For example, the system "DESIGNER" in this nomenclature would be designated by ARRAY 1 ("PROJECT DESCRIPTION"), ELEMENT 6. While the quantities given in Figure 3 are default values, any entry can be modified to allow the designer to describe his/her solar system to the program. Following is a more detailed description of the array data.

ARRAY 1

The seven elements of this array are "PROJECT TITLE," "PROJECT YEAR," "PROJECT NUMBER," "LOCATION," "CAT CODE," "DESIGNER," and "DATE." This descriptive information identifies the project when the program generates its output. Because of limitations in FORTRAN, each field for these descriptors must be limited to no more than 20 alphanumeric characters (including spaces).

ARRAY 2

This array contains four elements. The first -- "SOLMET #" -- refers to the SOLMET station number which identifies the site where the solar feasibility study will be performed. Weather and economic data for all major CONUS Army installations and activities have been built into the program. The user may access this information simply by specifying the appropriate site number for the installation being considered. Assignments of the approved SOLMET site for every Army installation have been made (see Appendix A). For cases in which a building will be constructed at a location which is not associated with an Army installation (e.g., an Armed Forces Reserve Center), the station number for the closest SOLMET site must be determined and input to the program. A complete list of SOLMET stations contained within SOLFEAS (taken from the SERI Insolation Data Manual) is provided in Appendix B.

The second element of this array describes the latitude of the SOLMET station corresponding to the specified number.

ARRAY NUMBER

*****PROJECT DESCRIPTION*****

PROJECT TITLE:	ADMINISTRATION BLDG	
PROJECT YEAR:	FY 84	
PROJECT NUMBER:	PN 123	
LOCATION:	FORT HOOD, TEXAS	
CAT CODE:	610-50	
DESIGNER:	JOHN DOE	1
DATE:	JANUARY 1982	

*****INPUT DATA*****

SOLMET #	LATITUDE (DEG)	STUDY LIFE (YRS)	DISCOUNT RATE (%)	ARRAY NUMBER
13959.	31.62	25.0	7.00	2

NOTE: SOLMET STATION # 13959. IS WACO, TX

*****FUEL COSTS*****

ELECT ($/MBTU)	N GAS ($/MBTU)	DIST ($/MBTU)	RES ($/MBTU)	COAL ($/MBTU)	ARRAY NUMBER
15.30	3.39	9.09	6.32	2.00	3

HORIZONTAL PLANE SOLAR INSOLATION (KBTU/SQFT-DAY) AND LOADS (MBTU)

JAN	FEB	MAR	APR	MAY	JUN	JUL
.83	1.10	1.43	1.61	1.77	2.11	2.13
11.56	10.44	11.56	11.19	11.56	11.19	11.56
119.24	86.86	63.81	16.76	0.00	0.00	0.00
0.00	0.00	10.20	38.37	96.33	191.02	250.61

AUG	SEP	OCT	NOV	DEC	ANN	TYPE ENTRY	ARRAY NUMBER
1.96	1.60	1.30	.96	.80	1.47	INSOLATION	4
11.56	11.19	11.56	11.19	11.56	136.10	SRVC WATER	5
0.00	0.00	11.43	54.67	100.95	453.72	SP HEATING	6
251.84	155.51	57.55	4.49	0.00	1055.92	SP COOLING	7

*****TYPE OF CONVENTIONAL FUELS*****

BACKUP FUEL (1-ELECTRICITY, 2-N GAS, 3-DISTILLATE, 4-RES, 5-COAL)	SYSTEM TYPE	ARRAY NUMBER
		8
4.	SERVICE HOT WATER (SWH)	
4.	SPACE HEATING (SH)	
1.	SPACE COOLING (SC)	

*****SYSTEM COST FIGURES*****

MATERIAL FIXED (K$)	INCRM ($/SQFT)	CITY INDEX	***LABOR*** FIXED (K$)	INCRM ($/SQFT)	CITY INDEX	COST MULTP	INVEST CREDIT (%CON)	SALVAG VALUE (%CON)	SYSTEM TYPE	ARRAY NUMBER
.98	30.28	1.00	.95	10.59	.82	1.00	10.0	0.0	SWH	9
1.10	39.03	1.00	.95	10.59	.82	1.00	10.0	0.0	SH	10
1.21	39.03	1.00	.97	10.59	.82	1.00	10.0	0.0	SWH,SH	11
13.04	49.99	1.00	6.50	12.14	.82	1.00	10.0	0.0	SWH,SH,SC	12

*****SYSTEM MAINTENANCE AND REPAIR COSTS*****

SYSTEM COST(K$)	0-5	5-25	25-100	100-500	500-	ARRAY NUMBER
M&R COST(% CON)	5.0	3.0	2.0	1.5	1.0	13

*****FUEL ESCALATION RATES*****

RATE (%)	INTVL (YRS)	RATE (%)	INTVL (YRS)	RATE (%)	INTVL (YRS)	RATE (%)	INTVL (YRS)	RATE (%)	INTVL (YRS)	FUEL TYPE	ARRAY NUMBER
5.3	4.0	.3	5.0	.6	91.0	0.0	0.0	0.0	0.0	ELEC	14
8.9	4.0	0.0	5.0	2.9	91.0	0.0	0.0	0.0	0.0	N GAS	15
2.5	4.0	2.7	5.0	6.5	91.0	0.0	0.0	0.0	0.0	DISTL	16
9.0	4.0	2.7	5.0	6.4	91.0	0.0	0.0	0.0	0.0	RES	17
13.9	4.0	1.5	5.0	1.5	91.0	0.0	0.0	0.0	0.0	COAL	18

Figure 3. SOLFEAS input data.

The third element of ARRAY 2 is the project study life in years. Consistent with current guidance, the default value for this parameter is given by 25 years or the expected life of the facility, whichever is shorter.

The fourth element is the discount rate to be used for the system economic analysis. In accordance with 10 USC 2857, the value required for this factor at this time is 7 percent per year.

Finally, the note on the last line of ARRAY 2 displays the SOLMET station corresponding to the station number given by ELEMENT 1.

ARRAY 3

The third block of input parameters provides for specifying of the cost of fuels available at the study site. The program uses these costs to compute the energy costs both for a conventional HVAC system at the candidate building and for the costs of auxiliary energy for each prospective solar system. The titles "ELECT," "N GAS," "DIST," "RES," and "COAL" refer to the local prices of electricity, natural gas, distillate fuels, residual fuels, and coal, respectively. The default values shown in Figure 3 correspond to typical values for these parameters in $/MBtu (MBtu = 1,000,000 Btu) from 10 CFR 436A cost tabulations and may be modified if necessary to reflect the local market.

ARRAY 4

This block is used to specify average monthly values of daily insolation on a horizontal surface at the building's location. The units of this parameter are KBtu/sq ft-day (KBtu = 1000 Btu). As shown in Figure 3, these data are displayed in the two lines (JAN-JUL and AUG-DEC) of ARRAY 4 and are identified by the title "INSOLATION" in the last column of the second line.

ARRAYS 5-7

These arrays are reserved for a description of the building thermal energy demands. They include the monthly service hot water, space heating, and space cooling loads expressed in MBtus. SOLFEAS can be run as soon as this information is available. For domestic water and space heating, these loads are equivalent to the energy output of on-site boilers. For solar cooling applications, these loads must be in terms of monthly chilled water demands.

ARRAY 8

This block consists of three elements used to specify the type of fuel which supplements the solar system for service hot water, space heating, and space cooling, respectively. The numeral "1" denotes electricity, "2" natural gas, "3" distillate, "4" residual, and "5" coal. As shown in Figure 3, the solar system for this example incorporates residual fuel as auxiliary (i.e., for the conventional system) for service hot water and space heating and electricity for space cooling.

The specification of an auxiliary energy source for a prospective solar system is a straightforward process. Facilities on Army installations are normally heated by (1) on-site boilers fired by natural gas or fuel oil, or

(2) central plants, where gas, fuel oil, or coal may be burned. The solar system designer should specify the option that has been selected for the conventional (or solar backup) energy system in the facility being studied.

Electricity is the most common form of energy for cooling. However, for cases where coal is burned in a central plant to drive basewide absorption chillers, this fuel should be specified to the program.

ARRAYS 9-12

These arrays have been reserved to input the solar system's differential costs as opposed to those of a conventional system for the study facility. Construction costs are divided into two categories: one for materials (ELEMENTS 1 through 3) and one for labor (ELEMENTS 4 through 6), for the four solar system types listed under the column entitled "SYSTEM TYPE" in the right-hand margin of Figure 3. These costs include a fixed value which is incurred regardless of the solar system size and an incremental cost which scales with the system collector area. For example, Figure 3 shows that a solar service hot water system (SCHEME 1) is estimated to cost $1930 ($980 + $950) plus $40.87 ($30.28 + $10.59) for each square foot of collector.

These costs have been determined for each solar system type in 1981 dollars (FY82) from an analysis of data in the <u>Means Cost Estimating Guide</u>. <u>It is recommended that these values not be varied during any study</u>. SOLFEAS automatically modifies the total system costs somewhat for different locations by changing the values under the column labeled "CITY INDEX." City indices for most major metropolitan areas within the United States have been tabulated in the <u>Means Cost Estimating Guide</u> to reflect local cost variations for both labor and materials. In this example, the city indices for material and labor for Waco, TX, are 1.00 and 0.82, respectively.

ELEMENT 7 of ARRAYS 9 through 13 (labeled "COST MULTP") has been included to allow SOLFEAS to compute the solar system construction costs for runs performed in future years. The procedure for doing this is as follows: the latest version of AR 415-17 (or updates implemented by current Engineering Improvement Recommendation System [EIRS] Bulletins) should be consulted to determine values for the Tri-Service Military Construction Program (MCP) Index for all years since FY82, the base year for the solar system costs. If not available locally, this information may be obtained from HQUSACE DAEN-ECE-S. The cost multiplier input to SOLFEAS is given by the following value: the product of one plus the annual rate of increase of the MCP Index for the first year, and one plus the second year's annual increase, and so on. For example, SOLFEAS is to be run in FY84. Suppose it is determined from AR 415-17 that the MCP Index increased by 8 percent in FY82 and 9.2 percent in FY83. The appropriate value of the cost multiplier for the four solar system types in this case is computed to be 1.18 [=(1.08)(1.092)].

The next two elements of ARRAYS 9 through 12 are labeled "INVEST CREDIT" and "SALVAG VALUE," and correspond to the investment credit and the system salvage value, respectively. Both of these parameters are input as a percentage of the solar system construction cost. As required by existing regulation, a value of 10 percent has been assigned for the investment credit. The default solar system salvage value is zero.

ARRAY 13

The solar system M&R cost factors are specified by the five elements of ARRAY 13. The default factors, input as a percentage of the "SYSTEM COST" in the five ranges shown, conform to current guidance. SOLFEAS handles the computation of M&R costs as follows: for solar systems which cost from 0 to $5K, a first-year maintenance fee of 5 percent of the system cost is assessed. (Future M&R costs are discounted back to present dollars.) As the solar system cost increases, the first-year M&R cost is given by $250 (5 percent of $5K) plus 3 percent of the amount in excess of $5K but less than $25K. Similarly, there are breaks in the system cost at $100K and $500K. At these points, the contributions to the annual M&R costs become 2 percent, 1.5 percent, and 1 percent, respectively. While the breakpoints in solar system cost are fixed within the program, the user can modify the M&R percentage factors for each range if directed to do so by future guidance.

ARRAYS 14-18

Finally, SOLFEAS allows an input of fuel escalation rates for the five possible fuel types over five user-specified intervals of time (10 elements/array). For example, Figure 2 shows that for this study, residual fuel is assumed to escalate at a rate of 9.0 percent for the first 4 years of the system life, 2.7 percent for the next 5 years, and 6.4 percent for the next 91 years. While the program may be run with the default parameters, guidance for selecting new escalation rates will be issued as the need arises. The sum of the interval periods for each type of fuel should be greater than or equal to 100 years, so that the program can correctly compute the solar system discounted payback period. For SOLFEAS runs in future years, the escalation rates of all fuels must conform to the prevailing guidance contained in 10 CFR 436A.

Accessing the Program

To access SOLFEAS, personnel from the Corps of Engineers or from private A/E offices must follow the routine EKS1 login procedure. (Corps users who do not have BCS accounts should contact their local ADP coordinators so that an EKS1 account can be established.) Even though the program executes interactively, SOLFEAS can be executed only when operating in the BATCH mode (as indicated by the existence of the "C>" prompt issued by the mainframe once login is complete).

SOLFEAS can direct its output to any 80-column or 132-column printing terminal, at any baud rate supported by the user's modem and the local Boeing service. The most common baud rates are 300 and 1200.

The user employs the same procedure for all commands. Nothing is processed by the mainframe until an entire line has been typed and the "RETURN" key depressed. In the description which follows, this sequence will be abbreviated "E/R"; this means that the user should enter the data and then depress the "RETURN" key. Either upper- or lower-case letters are allowed.

Once the EKS1 login procedure has been completed, the prompt C> should appear at the user's terminal. To execute SOLFEAS, E/R

```
C> GET, SOLFEAS/UN=CER081
C> SOLFEAS
```

At this point, a sign-on message issued by the program should appear. SOLFEAS is now running.

SOLFEAS Commands

After the sequence described above is completed, the following text will be displayed immediately after the introductory message:

```
DO YOU WISH TO BEGIN WITH THE DATA SET PROVIDED WITH THE PROGRAM?
(YES/NO)
I>
```

At this point, the designer has two options. An E/R of "Y" causes a default data file to be loaded into the computer memory; for first-time users, this is the appropriate response. For those who have completed previous SOLFEAS runs, an E/R of "N" results in the prompt:

```
PLEASE ENTER THE DESIRED FILENAME
I>
```

Now the user must respond with the name of the file under which data from a previous run was catalogued. This feature allows the designer to attach data for a particular installation which was saved from a previous run of the program.

After the source of the input data is established, the following text will be printed at the terminal:

```
ENTER L, P, G, OR R FOR
  L - LIST INPUT DATA
  P - PARTIAL CHANGE IN INPUT DATA
  G - GLOBAL CHANGE IN INPUT DATA
  R - RUN (NO CHANGE IN INPUT DATA)
  I>
```

The user is now said to be in the "command mode." The next action the program takes is based on the next letter the designer types. The available commands are "L", "P", "G", and "R".

If an "L" is E/R, all the current program input data is listed for user inspection in the format shown in Figure 3. Prior to performing an "R" command, at least one "L" should be executed so that the input data may be verified as correct. After the listing is completed, the text

```
L, P, G, or R?
I>
```

is printed. The program uses this abbreviated version of the command prompt to solicit subsequent user input.

Any of the input data can be changed in two ways. The first way is using the "P" or partial command. In this mode, the user can change any specific element of any single array. For example, in Figure 3, suppose the user wants to modify the cost of electricity (ARRAY 3, ELEMENT 1). When a "P" is typed and the "RETURN" key is depressed, the program responds:

```
ARRAY NUMBER?
I>
```

The user must E/R "3". The program will then prompt:

```
ELEMENT NUMBER?
I>
```

The reply here is "1". At this time, the program will display:

```
OLD DATA = 15.30:  NEW DATA =
I>
```

The designer can now enter a new value corresponding to the price of electricity he/she wants to use for the system economic analysis. The program then returns to the command mode.

Generally, the "P" command is used to modify a single input data element. However, there is one exception to this rule. If the user changes the study site number (ARRAY 2, ELEMENT 1), many other elements will be modified automatically, particularly if the new site is in a different DOE zone. These include the site latitude (ARRAY 2, ELEMENT 2), all values of the site fuel costs (ARRAY 3), the solar radiation (ARRAY 4), the city cost indices (in ARRAYS 9 through 12), and the fuel escalation rates (ARRAYS 14 through 18). SOLFEAS contains the appropriate values for all these parameters within the program. The "P" command has been structured in this way so that the user does not have to enter all these data for each new site.

The global change command ("G") is similar to "P" except that the program prompts the user through every element of the specified array automatically. For example, if the user wants to enter new values for the building's monthly service hot water loads, a "G" would be typed, and ARRAY 5 specified as the one to be modified. SOLFEAS would then prompt the user for data for the 12 months of the design year.

Once the desired input data has been entered, the user may check the final data file by typing another "L". Note that the commands "L", "P", and "G" may be executed in any order.

When all the data entries have been edited and verified, the user can obtain the program outputs by E/R an "R". For each study, this will normally be the last command entered. When the output listings are complete, the program will inquire:

```
WANT ANOTHER RUN? Y (YES) OR N (NO)
I>
```

If the response is "Y", the program enters the command mode as before. If an "N" is E/R, the message

```
DO YOU WISH TO SAVE THE DATA SET?  (YES/NO)
I>
```

is issued so that the file can be used for subsequent runs. A "Y" response results in the prompt:

```
PLEASE ENTER THE NAME FOR SAVING
I>
```

Any valid filename (seven letters/characters or fewer) is allowed here. In future runs, this file may be attached when SOLFEAS signs on, as discussed on p 33.

5 SOLFEAS OUTPUTS

When an "R" from the program command mode is executed, three output pages of "SOLAR ENERGY LIFE CYCLE COST ANALYSIS" will be printed at the user's terminal. This section illustrates and explains the contents of each page.

Project Summary Data

The first page of output (Figure 4) summarizes the input data used to generate the solar system thermal and economic analysis. The format of this page is similar to the output of the "L" command except that the ARRAY numbers no longer appear in the right-hand margin. These entries are self-explanatory. However, the designer should verify the correctness of each value for every parameter. This is done by comparing the results displayed to the values output by SOLFEAS when an "L" was executed in the program command mode. This page forms part of the study documentation, which demonstrates that a solar feasibility study has been carried out for the building under consideration, as required.

Results of Solar System Thermal Analysis

The second page of output (Figure 5) contains an analysis of the solar system thermal performance. Here, the title, "RESULTS OF SOLAR SYSTEM THERMAL ANALYSIS" appears, followed by the project summary information. The first column, "SYSTEM OPTION," designates the system number for nine alternative collector areas for each of the four solar applications. The first number (1, 2, 3, or 4) preceding the hyphen identifies the system type; "1" refers to solar service water heating, "2" space heating only, "3" combined space-service water heating, and "4" combined space-domestic water heating/space cooling. The digit following the hyphen (1-9) allows the user to distinguish between systems. (There are nine different collector areas for each of the four applications.) These areas are computed by the program and correspond roughly to 10 percent increments in the system solar fraction. The selected areas for each system appear under the second column labeled "COLLECTOR AREA."

The next three columns, appearing under the title "BASE ENERGY CONSUMED," tabulate the type and amount of fuel required annually by a totally conventional HVAC system at the facility under study; the labels "SWH," "SH," and "SC" refer to service water heating, space heating, and space cooling loads, respectively. The entries appearing under the title "BASE ENERGY MINUS SOLAR CONTRIBUTION" reflect the amount of auxiliary energy the building will need annually in meeting the facility's thermal loads if a solar system of the specified area is installed. The units for the six columns are MBtu/year.

For cases in which electricity, natural gas, distillates, or residuals have been declared as a supplement to the solar system, these six columns tabulate building-boundary energy requirements. Where coal has been specified for backup energy, SOLFEAS computes and outputs the quantity of coal (in MBtu/year) which must be delivered to the central plant of the installation where the building will be located. Any solar energy produced by the various systems is assumed to be used in the following order: first for domestic

SOLAR ENERGY LIFE CYCLE COST ANALYSIS

**********PROJECT SUMMARY DATA**********

PROJECT TITLE:	ADMINISTRATION BLDG
PROJECT YEAR:	FY 84
PROJECT NUMBER:	PN 123
LOCATION:	FORT HOOD, TEXAS
CAT CODE:	610-50
DESIGNER:	JOHN DOE
DATE:	JANUARY 1982

STUDY LIFE (YRS)	DISCOUNT RATE (%)	SOLMET NUMBER	LATITUDE (DEG)	SOLMET SITE
25	7.0	13959.	31.62	WACO, TX

HORIZONTAL PLANE SOLAR INSOLATION (KBTU/SQFT-DAY) AND LOADS (MBTU)

JAN	FEB	MAR	APR	MAY	JUN	JUL
83	1.10	1.43	1.61	1.77	2.11	2.13
11.56	10.44	11.56	11.19	11.56	11.19	11.56
119.24	86.86	63.81	16.76	0.00	0.00	0.00
0.00	0.00	10.20	38.37	96.33	191.02	250.61

AUG	SEP	OCT	NOV	DEC	ANN	TYPE ENTRY
1.96	1.60	1.30	.96	.80	1.47	INSOLATION
11.56	11.19	11.56	11.19	11.56	136.10	SRVC WATER
0.00	0.00	11.43	54.67	100.95	453.72	SP HEATING
251.84	155.51	57.55	4.49	0.00	1055.92	SP COOLING

******FUEL FOR CONVENTIONAL SYSTEM******

SYSTEM TYPE	FUEL TYPE
SERVICE WATER HEATING (SWH)	RES
SPACE HEATING (SH)	RES
SPACE COOLING (SC)	ELECT

***************FUEL COST***************

ELECT ($/MBTU)	N GAS ($/MBTU)	DIST ($/MBTU)	RES ($/MBTU)	COAL ($/MBTU)
15.30	3.39	9.09	6.32	2.00

*******FUEL COST ESCALATION RATES*******

RATE (%)	INTVL (YRS)	RATE (%)	INTVL (YRS)	RATE (%)	INTVL (YRS)	RATE (%)	INTVL (YRS)	RATE (%)	INTVL (YRS)	FUEL TYPE
5.27	4	.28	5	.61	91	0.00	0	0.00	0	ELECT
8.86	4	0.00	5	2.85	91	0.00	0	0.00	0	N GAS
2.54	4	2.71	5	6.46	91	0.00	0	0.00	0	DIST
9.00	4	2.68	5	6.35	91	0.00	0	0.00	0	RES
13.93	4	1.45	5	1.48	91	0.00	0	0.00	0	COAL

**********SYSTEM COST FIGURES**********

MATERIAL			***LABOR***			COST	INVEST	SALVAG	SYSTEM
FIXED (K$)	INCRM ($/SQFT)	CITY INDEX	FIXED (K$)	INCRM ($/SQFT)	CITY INDEX	MULTP	CREDIT (%CON)	VALUE (%CON)	TYPE
.98	30.28	1.00	.95	10.59	.82	1.00	10.0	0.0	SWH
1.10	39.03	1.00	.95	10.59	.82	1.00	10.0	0.0	SH
1.21	39.03	1.00	.97	10.59	.82	1.00	10.0	0.0	SWH,SH
13.04	49.99	1.00	6.50	12.14	.82	1.00	10.0	0.0	SWH,SH,SC

SYSTEM MAINTENANCE AND REPAIR COSTS*

SYSTEM COST(K$)	0-5	5-25	25-100	100-500	500-
M&R COST(% CON)	5.0	3.0	2.0	1.5	1.0

Figure 4. Project summary data.

SOLAR ENERGY LIFE CYCLE COST ANALYSIS
*****RESULTS OF SOLAR SYSTEM THERMAL ANALYSIS*****

PROJECT TITLE: ADMINISTRATION BLDG
PROJECT YEAR: FY 84
PROJECT NUMBER: PN 123
LOCATION: FORT HOOD, TEXAS
CAT CODE: 610-50
DESIGNER: JOHN DOE
DATE: JANUARY 1982

SYSTEM OPTION	COLLECTOR AREA (SQFT)	BASE ENERGY CONSUMED (CONVENTIONAL SYSTEM) SWH RES (M/YR)	SH RES (M/YR)	SC ELECT (M/YR)	BASE ENERGY MINUS SOLAR CONTRIBUTION SWH RES (M/YR)	SH RES (M/YR)	SC ELECT (M/YR)	% SAVE BASE ENERGY (%)
1-1	40.0	181.5	0.0	0.0	155.9	0.0	0.0	14.1
1-2	80.0	181.5	0.0	0.0	135.9	0.0	0.0	25.1
1-3	120.0	181.5	0.0	0.0	119.1	0.0	0.0	34.4
1-4	150.0	181.5	0.0	0.0	104.7	0.0	0.0	42.3
1-5	220.0	181.5	0.0	0.0	86.6	0.0	0.0	52.3
1-6	280.0	181.5	0.0	0.0	71.9	0.0	0.0	60.4
1-7	380.0	181.5	0.0	0.0	53.0	0.0	0.0	70.8
1-8	520.0	181.5	0.0	0.0	35.0	0.0	0.0	80.7
1-9	750.0	181.5	0.0	0.0	17.4	0.0	0.0	90.4
2-1	300.0	0.0	605.0	0.0	0.0	543.7	0.0	10.1
2-2	700.0	0.0	605.0	0.0	0.0	483.9	0.0	20.0
2-3	1220.0	0.0	605.0	0.0	0.0	423.0	0.0	30.1
2-4	1880.0	0.0	605.0	0.0	0.0	362.0	0.0	40.2
2-5	2700.0	0.0	605.0	0.0	0.0	302.3	0.0	50.0
2-6	3780.0	0.0	605.0	0.0	0.0	241.8	0.0	60.0
2-7	5260.0	0.0	605.0	0.0	0.0	181.1	0.0	70.1
2-8	7460.0	0.0	605.0	0.0	0.0	120.7	0.0	80.0
2-9	11500.0	0.0	605.0	0.0	0.0	60.3	0.0	90.0
3-1	240.0	181.5	605.0	0.0	98.8	605.0	0.0	10.5
3-2	560.0	181.5	605.0	0.0	22.7	605.0	0.0	20.2
3-3	1020.0	181.5	605.0	0.0	0.0	547.7	0.0	30.4
3-4	1520.0	181.5	605.0	0.0	0.0	470.9	0.0	40.1
3-5	2440.0	181.5	605.0	0.0	0.0	392.8	0.0	50.1
3-6	3560.0	181.5	605.0	0.0	0.0	314.0	0.0	60.1
3-7	5120.0	181.5	605.0	0.0	0.0	235.4	0.0	70.1
3-8	7480.0	181.5	605.0	0.0	0.0	157.0	0.0	80.0
3-9	11840.0	181.5	605.0	0.0	0.0	78.5	0.0	90.0
4-1	1340.0	181.5	605.0	352.0	0.0	489.6	352.0	10.1
4-2	2700.0	181.5	605.0	352.0	0.0	193.4	352.0	20.1
4-3	4130.0	181.5	605.0	352.0	0.0	0.0	335.4	30.1
4-4	5840.0	181.5	605.0	352.0	0.0	0.0	287.5	40.1
4-5	7760.0	181.5	605.0	352.0	0.0	0.0	239.7	50.0
4-6	10080.0	181.5	605.0	352.0	0.0	0.0	191.6	60.1
4-7	13000.0	181.5	605.0	352.0	0.0	0.0	143.8	70.0
4-8	17040.0	181.5	605.0	352.0	0.0	0.0	95.9	80.0
4-9	23820.0	181.5	605.0	352.0	0.0	0.0	47.9	90.0

NOTE: SYSTEM OPTION (THE 1ST COLUMN) INCLUDES 1)SERVICE HOT WATER SYSTEM (1-1 THROUGH 1-9), 2)SPACE HEATING SYSTEM (2-1 THROUGH 2-9), 3)COMBINED SPACE HEATING AND SERVICE HOT WATER SYSTEM (3-1 THROUGH 3-9), AND 4)COMBINED SPACE HEATING/COOLING AND SERVICE HOT WATER SYSTEM (4-1 THROUGH 4-9).

Figure 5. Solar system thermal analysis.

water heating, then for space heating, and finally for space cooling. The last column of Figure 5 ("% SAVE BASE ENERGY") contains entries which correspond to the percentage of the annual facility thermal load (expressed in terms of hot water requirements) provided by solar energy for each application and every collector area. The note at the bottom of the page defines the system options described previously.

For example, consider the results from Figure 5 for a combined service water-space heating/space cooling system. For the alternative labeled 4-2, the program output indicates that 2700 sq ft of collector would be needed at this site to meet 20.1 percent of the total building load. In this case, the solar system has met 100 percent of the annual energy requirements for service hot water; however, the building is still projected to need 193.4 MBtu of residual fuel for space heating and 352.0 MBtu of electricity for space cooling.

Results of Economic Evaluation

The final page of SOLFEAS output (Figure 6) summarizes the results of the solar system life-cycle economic analysis. The first column of the table, "SYSTEM OPTION," refers to those systems with the same nine collector areas assumed for the system thermal analysis. However, there is one difference between this and the previous table; four additional rows (1-0, 2-0, 3-0, and 4-0) are now included. The entries in these rows reflect the energy costs associated with a totally conventional HVAC (no solar) system in the building. The other rows (1-1 through 4-9) correspond to the same systems specified in Figure 5.

The column headed by "CONST COST" lists the cost differential between a totally conventional building and one containing a solar system of the specified collector area. The program has computed these installed system costs, in K$, based on the input information supplied. These entries correspond to the system base year first cost; they do not reflect the investment credit or the salvage value specified by the user.

In the three columns labeled "SWH ENERGY," "SH ENERGY," and "SC ENERGY," the system life-cycle energy costs, summed for the entire study period, are tabulated in K$ for service water heating, space heating, and space cooling, respectively. For alternatives 1-0, 2-0, 3-0, and 4-0, these costs would be incurred by a totally conventional system; for all the others, the energy costs are reduced as the system collector area increases. The total of these three columns is given under the heading "TOTAL ENERGY."

The solar system life-cycle M&R costs are tabulated for each system in the column entitled "M&R COST." These entries, computed from the user-specified M&R percentages, are expressed in present-value dollars. The solar system total life-cycle cost for the study period is given by the values which appear under the title "TOTAL COST" in Figure 6. In computing these numbers, SOLFEAS has taken into account the solar system construction cost, the investment credit, the system salvage value (computed in constant dollars), the life-cycle costs associated with the savings of fossil fuel, and the solar system life-cycle M&R costs.

SOLAR ENERGY LIFE CYCLE COST ANALYSIS
*****RESULTS OF ECONOMIC EVALUATION*****

PROJECT TITLE: ADMINISTRATION BLDG
PROJECT YEAR: FY 84
PROJECT NUMBER: PN 123
LOCATION: FORT HOOD, TEXAS
CAT CODE: 610-50
DESIGNER: JOHN DOE
DATE: JANUARY 1982

************* LIFE CYCLE COSTS *************
************** PERTAINING TO ***************

SYSTEM OPTION	CONST COST (K$)	SWH ENERGY (K$)	SH ENERGY (K$)	SC ENERGY (K$)	TOTAL ENERGY K($)	M&R COST (K$)	TOTAL COST (K$)	DSCD PBCK (YRS)	SVNG/ INVST RATIO	NET LCC SAVINGS (K$)
1-0	0.00	25.55	0.00	0.00	25.55	0.0	25.5	0.0	0.000	0.0
1-1	3.32	21.95	0.00	0.00	21.95	1.9	26.9	37.9	.555	-1.3
1-2	4.88	19.14	0.00	0.00	19.14	2.8	26.4	29.4	.813	-.8
1-3	6.43	16.77	0.00	0.00	16.77	3.4	26.0	26.6	.927	-.4
1-4	7.99	14.73	0.00	0.00	14.73	4.0	25.9	26.0	.953	-.3
1-5	10.33	12.19	0.00	0.00	12.19	4.8	26.3	26.8	.924	-.7
1-6	12.66	10.12	0.00	0.00	10.12	5.6	27.1	28.3	.863	-1.6
1-7	16.55	7.47	0.00	0.00	7.47	7.0	29.3	31.9	.747	-3.8
1-8	22.00	4.92	0.00	0.00	4.92	8.9	33.6	38.0	.594	-8.0
1-9	31.34	2.45	0.00	0.00	2.45	11.4	42.0	49.3	.415	-16.5
2-0	0.00	0.00	85.17	0.00	85.17	0.0	85.2	0.0	0.000	0.0
2-1	16.18	0.00	76.54	0.00	76.54	6.8	97.9	79.6	.124	-12.8
2-2	35.23	0.00	68.12	0.00	68.12	12.3	112.1	83.1	.150	-27.0
2-3	60.01	0.00	59.55	0.00	59.55	18.1	131.6	92.6	.140	-46.5
2-4	91.46	0.00	50.96	0.00	50.96	25.4	158.7	****	.107	-73.5
2-5	130.53	0.00	42.56	0.00	42.56	32.7	192.8	****	.084	-107.6
2-6	181.99	0.00	34.04	0.00	34.04	41.7	239.5	****	.057	-154.4
2-7	252.50	0.00	25.49	0.00	25.49	54.0	306.8	****	.025	-221.6
2-8	357.32	0.00	16.99	0.00	16.99	72.4	411.0	****	0.000	-325.8
2-9	549.81	0.00	8.50	0.00	8.50	103.1	606.4	****	0.000	-521.3
3-0	0.00	25.55	85.17	0.00	110.72	0.0	110.7	0.0	0.000	0.0
3-1	13.44	13.91	85.17	0.00	99.08	5.9	117.0	43.6	.477	-6.3
3-2	28.69	3.19	85.17	0.00	88.36	10.8	124.9	46.6	.449	-14.2
3-3	50.60	0.00	77.11	0.00	77.11	15.9	138.5	53.1	.389	-27.8
3-4	79.19	0.00	66.30	0.00	66.30	22.5	160.1	63.4	.307	-49.4
3-5	118.26	0.00	55.30	0.00	55.30	30.6	192.3	77.3	.233	-81.6
3-6	171.63	0.00	44.21	0.00	44.21	39.9	238.6	96.3	.172	-127.9
3-7	245.95	0.00	33.15	0.00	33.15	52.9	307.4	****	.111	-196.7
3-8	358.40	0.00	22.10	0.00	22.10	72.6	417.2	****	.050	-306.5
3-9	566.14	0.00	11.05	0.00	11.05	105.0	625.6	****	0.000	-514.9
4-0	0.00	25.55	85.17	77.53	188.24	0.0	188.2	0.0	0.000	0.0
4-1	98.56	0.00	68.93	77.53	146.46	27.0	262.2	90.2	.166	-74.0
4-2	179.96	0.00	27.22	77.53	104.75	41.4	308.1	75.4	.260	-119.8
4-3	268.55	0.00	0.00	73.88	73.88	56.8	372.4	84.2	.238	-184.2
4-4	367.91	0.00	0.00	63.34	63.34	74.2	468.7	****	.153	-280.4
4-5	482.84	0.00	0.00	52.80	52.80	94.3	581.7	****	.095	-393.4
4-6	621.71	0.00	0.00	42.20	42.20	111.5	713.2	****	.062	-525.0
4-7	796.49	0.00	0.00	31.67	31.67	131.9	880.4	****	.034	-692.1
4-8	1038.31	0.00	0.00	21.13	21.13	160.0	1115.6	****	.008	-927.4
4-9	1444.14	0.00	0.00	10.55	10.55	207.3	1517.6	****	0.000	-1329.4

NOTE: 1)SYSTEM OPTIONS 1-0, 2-0, 3-0, & 4-0 REPRESENT *CONVENTIONAL* SYSTEMS FOR APPLICATIONS AS DEFINED ON PREVIOUS PAGE.
2) **** INDICATES A DISCOUNTED PAYBACK IN EXCESS OF 100 YEARS.

Figure 6. Solar system economic evaluation.

SOLFEAS computes and displays three indicators of the solar energy system cost-effectiveness. The first of these, appearing under the column "DSCD PBCK," is the system discounted payback period. This is defined as the period of time (in years) for which the LCC savings for the investment equals zero. The asterisks appearing under this column in Figure 6 indicate a value for this parameter in excess of 100 years.

The second measure of solar feasibility is provided by the system SIR. This quantity is tabulated in the column labeled "SVNG/INVST RATIO" as shown in Figure 6. The SIR is a numerical ratio calculated with the numerator being the reduction in energy costs less the net of increased nonfuel maintenance and repair costs, and the denominator being the increase in investment cost, minus increased salvage values. A solar system is considered to be cost-effective only if its SIR exceeds one; the higher the ratio, the greater the dollar savings per dollar spent.

The final indication of the solar system economic feasibility is provided by the numbers listed in the column "NET LCC SAVINGS." This quantity represents the difference between the total life-cycle costs of the conventional and solar-assisted systems for the facility under design. In accordance with current guidance, an evaluation of the cost-effectiveness of the solar investment should be based solely on the total LCC savings which would be achieved by using the solar energy system. If the total LCC savings is determined to be positive, the solar investment is to be considered cost-effective and the solar energy system is to be incorporated into the design of the facility. If the total LCC savings is determined to be negative, the solar investment is to be considered not cost-effective, and use of the solar energy system is to be rejected.

Consider, as an example, the entries corresponding to system option 1-4 in Figure 6. According to the SOLFEAS economic analysis, this particular solar system for service water heating will cost $<u>7990</u> to install. The discounted payback period in this case is <u>26</u> years, and the SIR <u>0.953</u> is less than one. The total life-cycle cost of the facility (including solar) will be $<u>25,900</u>. The fact that this amount is $300 more than for the conventional system indicates that this solar application is <u>not</u> economically feasible. It should be noted that the net LCC savings computed from the entries in the system total cost column may not agree exactly with the output value of LCC. This slight discrepancy is due to the rounding, in FORTRAN, of the numbers involved.

<u>Costs To Run the Program</u>

The cost to the user for executing an interactive program on any nationwide computer service (such as the Boeing Computer Service) depends on several factors. These include the terminal connect time, the quantity of information transmitted, the amount of central processor time required, the number of disk accesses, and the existence of user discounts. Therefore, it is difficult to determine a single cost figure for running SOLFEAS. However, for a typical solar feasibility study, a Corps user would be billed $10 to $25 for computer charges. Even when allowing a reasonable amount of time for preparing input data, the total cost to the Army for using SOLFEAS in these studies would be considerably lower than that of current practice.

6 SAMPLE PROBLEM

In this chapter, a sample SOLFEAS session is given to illustrate how a typical user might interact with the program. For the purpose of this example, the default data file which corresponds to an FY84 administrative building at Fort Hood, TX, is modified to describe a Reserve Center for FY85 located in Albuquerque, NM. All user entries and computer responses have been reproduced exactly as they occurred during the run. The results of performing the 12 steps given below have been identified by step number on the pages which follow:

1. Complete the BCS login procedure, and retrieve SOLFEAS by typing "GET,SOLFEAS/UN=CER081" and then "SOLFEAS".

2. Specify that you wish to begin with the default data set provided with the program by typing a "y" in response to the prompt.

3. List the default data with the "l" command to establish which data must be changed.

4. Use the "g" command on ARRAY 1 to enter the new project description material.

5. Use the "p" command in ARRAY 2, ELEMENT 1, to specify the appropriate SOLMET site number for Albuquerque, NM. As shown in Appendix B, the number for this site is 23050.

6. Enter the appropriate values for the monthly building loads by executing a "g" command on ARRAYS 5 through 7.

7. Specify the fuel to be used by the facility conventional system with a "g" command on ARRAY 8. For the purpose of this example, natural gas is being considered for auxiliary service water and space heating, and electricity is used for backup space cooling.

8. Since this analysis is being performed on a building in FY83 for an FY85 MCA project, a solar system construction cost multiplier must be determined and entered into the program. The base year for the default system costs is the beginning of FY82. After consulting EIRS Bulletin 82-02, it is found that during FY82, the MCP index escalated by 9.2 percent. The appropriate cost multiplier for SOLFEAS (1.092) is then entered with the "p" command on ARRAYS 9 through 12, ELEMENT 7.

9. Verify the integrity of the new data set by listing it ("l" command) and inspecting the resulting printout.

10. Produce the program outputs with the "r" command.

11. Declare whether or not another run is desired, and if the data set is to be saved. In this example, the user has opted not to perform another run. The current values for all parameters, however, have been catalogued under the filename "albuq". The information in this file is available to him/her under this name for future runs at this site.

12. Logoff B.C.S. The "bye" accomplishes this.

Upon examining the final page of SOLFEAS output (labeled "RESULTS OF ECONOMIC ANALYSIS"), it is seen that none of the prospective solar systems exhibits a positive net life-cycle cost. Thus, a more detailed solar system design should not be considered for this facility. It is interesting to note that, of the four solar applications treated, the service water heating system is the most cost-effective.

```
welcome to the bcs network
your access port is cix 030
```

STEP 1

```
select desired service:  eksl

 82/10/08. 09.26.46.
EKS1 760E.N0501.64 C 82/09/26.DS-0 00.12.12. 82/10/06.
[redacted]
TERMINAL      265, TTY
RECOVER/USER ID: sohn

 ***  PLANNED CRAY CHANGES.                    SEE MSG,VSPADV.  ***

C>get,solfeas/un=cer081
C>solfeas


           ***********************************************************
           *                  SOLAR FEASIBILITY STUDY                *
           *             FOR U.S. ARMY CORPS OF ENGINEERS            *
           *                       DEVELOPED BY                      *
           * U.S. ARMY CONSTRUCTION ENGINEERING RESEARCH LABORATORY *
           *                           AND                           *
           *        THE U.S. ARMY ENGINEER DISTRICT, FORT WORTH      *
           ***********************************************************


 DO YOU WISH TO BEGIN WITH THE DATA SET PROVIDED WITH
 THE PROGRAM? (YES/NO)
I>y
```

STEP 2

```
ENTER L, P, G, OR R FOR
L - LIST INPUT DATA
P - PARTIAL CHANGE IN INPUT DATA
G - GLOBAL CHANGE IN INPUT DATA
R - RUN (NO CHANGE IN INPUT DATA)


L, P, G, OR R?
I>l
```

STEP 3

ARRAY NUMBER

*****PROJECT DESCRIPTION*****

PROJECT TITLE: ADMINISTRATION BLDG
PROJECT YEAR: FY 84
PROJECT NUMBER: PN 123
LOCATION: FORT HOOD, TEXAS
CAT CODE: 610-50
DESIGNER: JOHN DOE 1
DATE: JANUARY 1982

*****INPUT DATA*****

SOLMET #	LATITUDE (DEG)	STUDY LIFE (YRS)	DISCOUNT RATE (%)	ARRAY NUMBER
13959.	31.62	25.0	7.00	2

NOTE: SOLMET STATION # 13959. IS WACO, TX

*****FUEL COSTS*****

ELECT ($/MBTU)	N GAS ($/MBTU)	DIST ($/MBTU)	RES ($/MBTU)	COAL ($/MBTU)	ARRAY NUMBER
15.30	3.39	9.09	6.32	2.00	3

HORIZONTAL PLANE SOLAR INSOLATION (KBTU/SQFT-DAY) AND LOADS (MBTU)

JAN	FEB	MAR	APR	MAY	JUN	JUL
.83	1.10	1.43	1.61	1.77	2.11	2.13
11.56	10.44	11.56	11.19	11.56	11.19	11.56
119.24	86.86	63.81	16.76	0.00	0.00	0.00
0.00	0.00	10.20	38.37	96.33	191.02	250.61

AUG	SEP	OCT	NOV	DEC	ANN	TYPE ENTRY	ARRAY NUMBER
1.96	1.60	1.30	.96	.80	1.47	INSOLATION	4
11.56	11.19	11.56	11.19	11.56	136.10	SRVC WATER	5
0.00	0.00	11.43	54.67	100.95	453.72	SP HEATING	6
251.84	155.51	57.55	4.49	0.00	1055.92	SP COOLING	7

*****TYPE OF CONVENTIONAL FUELS*****

BACKUP FUEL SYSTEM TYPE
(1-ELECTRICITY, 2-N GAS, 3-DISTILLATE, 4-RES, 5-COAL) 8

BACKUP FUEL	SYSTEM TYPE
4.	SERVICE HOT WATER (SWH)
4.	SPACE HEATING (SH)
1.	SPACE COOLING (SC)

*****SYSTEM COST FIGURES*****

MATERIAL			***LABOR***								
FIXED (K$)	INCRM ($/SQFT)	CITY INDEX	FIXED (K$)	INCRM ($/SQFT)	CITY INDEX	COST MULTP	INVEST CREDIT (%CON)	SALVAG VALUE (%CON)	SYSTEM TYPE	ARRAY NUMBER
.98	30.28	1.00	.95	10.59	.82	1.00	10.0	0.0	SWH	9
1.10	39.03	1.00	.95	10.59	.82	1.00	10.0	0.0	SH	10
1.21	39.03	1.00	.97	10.59	.82	1.00	10.0	0.0	SWH,SH	11
13.04	49.99	1.00	6.50	12.14	.82	1.00	10.0	0.0	SWH,SH,SC	12

*****SYSTEM MAINTENANCE AND REPAIR COSTS*****

SYSTEM COST(K$)	0-5	5-25	25-100	100-500	500-	ARRAY NUMBER
[illegible] COST(% CON)	5.0	3.0	2.0	1.5	1.0	13

*****FUEL ESCALATION RATES*****

RATE (%)	INTVL (YRS)	RATE (%)	INTVL (YRS)	RATE (%)	INTVL (YRS)	RATE (%)	INTVL (YRS)	RATE (%)	INTVL (YRS)	FUEL TYPE	ARRAY NUMBER
5.3	4.0	.3	5.0	.6	91.0	0.0	0.0	0.0	0.0	ELEC	14
8.9	4.0	0.0	5.0	2.9	91.0	0.0	0.0	0.0	0.0	N GAS	15
2.5	4.0	2.7	5.0	6.5	91.0	0.0	0.0	0.0	0.0	DISTL	16
9.0	4.0	2.7	5.0	6.4	91.0	0.0	0.0	0.0	0.0	RES	17
13.9	4.0	1.5	5.0	1.5	91.0	0.0	0.0	0.0	0.0	COAL	18

```
L, P, G, OR R?                STEP 4
I>g
ARRAY NUMBER? EG. 6
I>1
PROJECT NAME? MAXIMUM 20 CHARACTERS
I>reserve center
PROJECT YEAR? MAXIMUM 20 CHARACTERS
I>fy 85
PROJECT NUMBER? MAXIMUM 20 CHARACTERS
I>pn 321
LOCATION? MAXIMUM 20 CHARACTERS
I>albuquerque, nm
COST CODE? MAXIMUM 20 CHARACTERS
I>137-40
DESIGNER? MAXIMUM 20 CHARACTERS
I>bill doe
DATE? MAXIMUM 20 CHARACTERS
I>january, 1983

L, P, G, OR R?                STEP 5
I>p


ARRAY NUMBER?
I>2
ELEMENT NUMBER: 1, 2, ...?
I>1
OLD DATA=  13959.00:  NEW DATA=?
I>23050

L, P, G, OR R?                STEP 6
I>g
ARRAY NUMBER? EG. 6
I>5


SV HOT WATER LOAD, MBTU(MONTH), MONTH=1,2,...12
ENTER 12 MONTHS DATA: Q1,Q2,......,Q12
I>45.22,40.29,43.9,45.25,43.96,42.67,42.67,43.96,43.93,46.48,42.73,45.15

L, P, G, OR R?
I>g
ARRAY NUMBER? EG. 6
I>6


SPACE HEATING LOAD, MBTU (MONTH), MONTH=1,2,...12
ENTER 12 MONTHS DATA: Q1,Q2,......,Q12
I>394.47,315.07,285.93,160.16,66.86,7.09,0.0
I>0.3,19.0,145.62,284.93,404.93

L, P, G, OR R?
I>g
ARRAY NUMBER? EG. 6
I>7
```

```
SPACE COOLING LOAD, MBTU (MONTH), MONTH=1,2,...12
ENTER 12 MONTHS DATA: Q1,Q2,.......,Q12
I>7.08,14.0,74.44,117.28,178.0,
I>229.16,233.3,232.93,182.52,148.72,57.62
I>0.2

L, P, G, OR R?                    STEP 7
I>g
ARRAY NUMBER? EG. 6
I>8


*TYPE OF FUEL*: ANSWER WITH 1,2,3,4, OR 5,
                FOR 1=ELECTRICITY, 2=N GAS, 3=DISTILLATE, 4=RES, 5=COAL
KINDS OF FUEL FOR DHW, HTG, CLG? EG. 2,2,1
I>2,2,1

L, P, G, OR R?                    STEP 8
I>p


ARRAY NUMBER?
I>9
ELEMENT NUMBER: 1, 2, ...?
I>7
OLD DATA=       1.00:   NEW DATA=?
I>1.092

L, P, G, OR R?
I>p


ARRAY NUMBER?
I>10
ELEMENT NUMBER: 1, 2, ...?
I>7
OLD DATA=       1.00:   NEW DATA=?
I>1.092

L, P, G, OR R?
I>p


ARRAY NUMBER?
I>11
ELEMENT NUMBER: 1, 2, ...?
I>7
OLD DATA=       1.00:   NEW DATA=?
I>1.092

L, P, G, OR R?
I>p


ARRAY NUMBER?
I>12
ELEMENT NUMBER: 1, 2, ...?
I>7
OLD DATA=       1.00:   NEW DATA=?
I>1.092

L, P, G, OR R?                    STEP 9
I>l
```

ARRAY NUMBER

*****PROJECT DESCRIPTION*****

PROJECT TITLE:	RESERVE CENTER	
PROJECT YEAR:	FY 85	
PROJECT NUMBER:	PN 321	
LOCATION:	ALBUQUERQUE, NM	
CAT CODE:	137-40	
DESIGNER:	BILL DOE	1
DATE:	JANUARY, 1983	

*****INPUT DATA*****

SOLMET #	LATITUDE (DEG)	STUDY LIFE (YRS)	DISCOUNT RATE (%)	
23050.	35.05	25.0	7.00	2

NOTE: SOLMET STATION # 23050. IS ALBEQUERQUE, NM

*****FUEL COSTS*****

ELECT ($/MBTU)	N GAS ($/MBTU)	DIST ($/MBTU)	RES ($/MBTU)	COAL ($/MBTU)	
15.30	3.39	9.09	6.32	2.00	3

HORIZONTAL PLANE SOLAR INSOLATION (KBTU/SQFT-DAY) AND LOADS (MBTU)

JAN	FEB	MAR	APR	MAY	JUN	JUL
1.02	1.34	1.77	2.23	2.54	2.68	2.49
45.22	40.29	43.90	45.25	43.96	42.67	42.67
394.47	315.07	285.93	160.16	66.86	7.09	0.00
7.08	14.00	74.44	117.28	178.00	229.16	233.30

AUG	SEP	OCT	NOV	DEC	ANN	TYPE ENTRY	
2.29	1.97	1.55	1.13	.93	1.83	INSOLATION	4
43.96	43.93	46.48	42.73	45.15	526.21	SRVC WATER	5
.30	19.00	145.62	284.93	404.93	2084.36	SP HEATING	6
232.93	182.52	148.72	57.62	.20	1475.25	SP COOLING	7

*****TYPE OF CONVENTIONAL FUELS*****

BACKUP FUEL	SYSTEM TYPE	
(1-ELECTRICITY, 2-N GAS, 3-DISTILLATE, 4-RES, 5-COAL)		8
2.	SERVICE HOT WATER (SWH)	
2.	SPACE HEATING (SH)	
1.	SPACE COOLING (SC)	

*****SYSTEM COST FIGURES*****

MATERIAL FIXED (K$)	INCRM ($/SQFT)	CITY INDEX	***LABOR*** FIXED (K$)	INCRM ($/SQFT)	CITY INDEX	COST MULTP	INVEST CREDIT (%CON)	SALVAG VALUE (%CON)	SYSTEM TYPE	
.98	30.28	1.00	.95	10.59	.87	1.09	10.0	0.0	SWH	9
1.10	39.03	1.00	.95	10.59	.87	1.09	10.0	0.0	SH	10
1.21	39.03	1.00	.97	10.59	.87	1.09	10.0	0.0	SWH,SH	11
13.04	49.99	1.00	6.50	12.14	.87	1.09	10.0	0.0	SWH,SH,SC	12

*****SYSTEM MAINTENANCE AND REPAIR COSTS*****

SYSTEM COST(K$)	0-5	5-25	25-100	100-500	500-	
M&R COST(% CON)	5.0	3.0	2.0	1.5	1.0	13

*****FUEL ESCALATION RATES*****

RATE (%)	INTVL (YRS)	RATE (%)	INTVL (YRS)	RATE (%)	INTVL (YRS)	RATE (%)	INTVL (YRS)	RATE (%)	INTVL (YRS)	FUEL TYPE	
5.3	4.0	.3	5.0	.6	91.0	0.0	0.0	0.0	0.0	ELEC	14
8.9	4.0	0.0	5.0	2.9	91.0	0.0	0.0	0.0	0.0	N GAS	15
2.5	4.0	2.7	5.0	6.5	91.0	0.0	0.0	0.0	0.0	DISTL	16
9.0	4.0	2.7	5.0	6.4	91.0	0.0	0.0	0.0	0.0	RES	17
13.9	4.0	1.5	5.0	1.5	91.0	0.0	0.0	0.0	0.0	COAL	18

L, P, G, OR R?
I>r

STEP 10

SOLAR ENERGY LIFE CYCLE COST ANALYSIS

**********PROJECT SUMMARY DATA**********

PROJECT TITLE:	RESERVE CENTER
PROJECT YEAR:	FY 85
PROJECT NUMBER:	PN 321
LOCATION:	ALBUQUERQUE, NM
CAT CODE:	137-40
DESIGNER:	BILL DOE
DATE:	JANUARY, 1983

STUDY LIFE (YRS)	DISCOUNT RATE (%)	SOLMET NUMBER	LATITUDE (DEG)	SOLMET SITE
25	7.0	23050.	35.05	ALBEQUERQUE, NM

HORIZONTAL PLANE SOLAR INSOLATION (KBTU/SQFT-DAY) AND LOADS (MBTU)

JAN	FEB	MAR	APR	MAY	JUN	JUL
1.02	1.34	1.77	2.23	2.54	2.68	2.49
45.22	40.29	43.90	45.25	43.96	42.67	42.67
394.47	315.07	285.93	160.16	66.86	7.09	0.00
7.08	14.00	74.44	117.28	178.00	229.16	233.30

AUG	SEP	OCT	NOV	DEC	ANN	TYPE ENTRY
2.29	1.97	1.55	1.13	.93	1.83	INSOLATION
43.96	43.93	46.48	42.73	45.15	526.21	SRVC WATER
.30	19.00	145.62	284.93	404.93	2084.36	SP HEATING
232.93	182.52	148.72	57.62	.20	1475.25	SP COOLING

******FUEL FOR CONVENTIONAL SYSTEM******

SYSTEM TYPE	FUEL TYPE
SERVICE WATER HEATING (SWH)	N GAS
SPACE HEATING (SH)	N GAS
SPACE COOLING (SC)	ELECT

***************FUEL COST***************

ELECT ($/MBTU)	N GAS ($/MBTU)	DIST ($/MBTU)	RES ($/MBTU)	COAL ($/MBTU)
15.30	3.39	9.09	6.32	2.00

*******FUEL COST ESCALATION RATES*******

RATE (%)	INTVL (YRS)	RATE (%)	INTVL (YRS)	RATE (%)	INTVL (YRS)	RATE (%)	INTVL (YRS)	RATE (%)	INTVL (YRS)	FUEL TYPE
5.27	4	.28	5	.61	91	0.00	0	0.00	0	ELECT
8.86	4	0.00	5	2.85	91	0.00	0	0.00	0	N GAS
2.54	4	2.71	5	6.46	91	0.00	0	0.00	0	DIST
9.00	4	2.68	5	6.35	91	0.00	0	0.00	0	RES
13.93	4	1.45	5	1.48	91	0.00	0	0.00	0	COAL

**********SYSTEM COST FIGURES**********

MATERIAL			***LABOR***			COST	INVEST	SALVAG	SYSTEM
FIXED (K$)	INCRM ($/SQFT)	CITY INDEX	FIXED (K$)	INCRM ($/SQFT)	CITY INDEX	MULTP	CREDIT (%CON)	VALUE (%CON)	TYPE
.98	30.28	1.00	.95	10.59	.87	1.09	10.0	0.0	SWH
1.10	39.03	1.00	.95	10.59	.87	1.09	10.0	0.0	SH
1.21	39.03	1.00	.97	10.59	.87	1.09	10.0	0.0	SWH,SH
13.04	49.99	1.00	6.50	12.14	.87	1.09	10.0	0.0	SWH,SH,SC

SYSTEM MAINTENANCE AND REPAIR COSTS*

SYSTEM COST(K$)	0-5	5-25	25-100	100-500	500-
M&R COST(% CON)	5.0	3.0	2.0	1.5	1.0

SOLAR ENERGY LIFE CYCLE COST ANALYSIS
*****RESULTS OF SOLAR SYSTEM THERMAL ANALYSIS*****

PROJECT TITLE: RESERVE CENTER
PROJECT YEAR: FY 85
PROJECT NUMBER: PN 321
LOCATION: ALBUQUERQUE, NM
CAT CODE: 137-40
DESIGNER: BILL DOE
DATE: JANUARY, 1983

SYSTEM OPTION	COLLECTOR AREA (SQFT)	BASE ENERGY CONSUMED (CONVENTIONAL SYSTEM) SWH N GAS (M/YR)	SH N GAS (M/YR)	SC ELECT (M/YR)	BASE ENERGY MINUS SOLAR CONTRIBUTION SWH N GAS (M/YR)	SH N GAS (M/YR)	SC ELECT (M/YR)	% SAVE BASE ENERGY (%)
1-1	100.0	701.6	0.0	0.0	617.6	0.0	0.0	12.0
1-2	200.0	701.6	0.0	0.0	550.3	0.0	0.0	21.6
1-3	320.0	701.6	0.0	0.0	481.7	0.0	0.0	31.3
1-4	460.0	701.6	0.0	0.0	414.2	0.0	0.0	41.0
1-5	620.0	701.6	0.0	0.0	349.9	0.0	0.0	50.1
1-6	840.0	701.6	0.0	0.0	278.9	0.0	0.0	60.3
1-7	1120.0	701.6	0.0	0.0	210.1	0.0	0.0	70.0
1-8	1540.0	701.6	0.0	0.0	138.7	0.0	0.0	80.2
1-9	2260.0	701.6	0.0	0.0	69.2	0.0	0.0	90.1
2-1	780.0	0.0	2779.1	0.0	0.0	2500.6	0.0	10.0
2-2	1880.0	0.0	2779.1	0.0	0.0	2221.5	0.0	20.1
2-3	3260.0	0.0	2779.1	0.0	0.0	1944.5	0.0	30.0
2-4	5000.0	0.0	2779.1	0.0	0.0	1665.4	0.0	40.1
2-5	7180.0	0.0	2779.1	0.0	0.0	1389.3	0.0	50.0
2-6	10040.0	0.0	2779.1	0.0	0.0	1111.4	0.0	60.0
2-7	13980.0	0.0	2779.1	0.0	0.0	832.7	0.0	70.0
2-8	19880.0	0.0	2779.1	0.0	0.0	555.1	0.0	80.0
2-9	30720.0	0.0	2779.1	0.0	0.0	277.9	0.0	90.0
3-1	760.0	701.6	2779.1	0.0	351.9	2779.1	0.0	10.0
3-2	1820.0	701.6	2779.1	0.0	.1	2779.1	0.0	20.2
3-3	3180.0	701.6	2779.1	0.0	0.0	2433.3	0.0	30.1
3-4	4940.0	701.6	2779.1	0.0	0.0	2087.4	0.0	40.0
3-5	7240.0	701.6	2779.1	0.0	0.0	1740.0	0.0	50.0
3-6	10300.0	701.6	2779.1	0.0	0.0	1392.0	0.0	60.0
3-7	14540.0	701.6	2779.1	0.0	0.0	1044.1	0.0	70.0
3-8	20960.0	701.6	2779.1	0.0	0.0	695.9	0.0	80.0
3-9	32840.0	701.6	2779.1	0.0	0.0	347.7	0.0	90.0
4-1	2300.0	701.6	2779.1	491.8	47.7	2779.1	491.8	10.1
4-2	4620.0	701.6	2779.1	491.8	0.0	2178.0	491.8	20.0
4-3	7160.0	701.6	2779.1	491.8	0.0	1527.2	491.8	30.0
4-4	10020.0	701.6	2779.1	491.8	0.0	875.4	491.8	40.0
4-5	13320.0	701.6	2779.1	491.8	0.0	225.7	491.8	50.0
4-6	17280.0	701.6	2779.1	491.8	0.0	0.0	422.9	60.0
4-7	22320.0	701.6	2779.1	491.8	0.0	0.0	316.9	70.0
4-8	29260.0	701.6	2779.1	491.8	0.0	0.0	211.4	80.0
4-9	40880.0	701.6	2779.1	491.8	0.0	0.0	105.7	90.0

NOTE: SYSTEM OPTION (THE 1ST COLUMN) INCLUDES 1)SERVICE HOT WATER SYSTEM (1-1 THROUGH 1-9), 2)SPACE HEATING SYSTEM (2-1 THROUGH 2-9), 3)COMBINED SPACE HEATING AND SERVICE HOT WATER SYSTEM (3-1 THROUGH 3-9), AND 4)COMBINED SPACE HEATING/COOLING AND SERVICE HOT WATER SYSTEM (4-1 THROUGH 4-9).

SOLAR ENERGY LIFE CYCLE COST ANALYSIS
*****RESULTS OF ECONOMIC EVALUATION*****

PROJECT TITLE: *RESERVE CENTER*
PROJECT YEAR: FY 85
PROJECT NUMBER: PN 321
LOCATION: ALBUQUERQUE, NM
CAT CODE: 137-40
DESIGNER: BILL DOE
DATE: JANUARY, 1983

************* LIFE CYCLE COSTS *************
************** PERTAINING TO ***************

SYSTEM OPTION	CONST COST (K$)	SWH ENERGY (K$)	SH ENERGY (K$)	SC ENERGY (K$)	TOTAL ENERGY K($)	M&R COST (K$)	TOTAL COST (K$)	DSCD PBCK (YRS)	SVNG/ INVST RATIO	NET LCC SAVINGS (K$)
1-0	0.00	41.50	0.00	0.00	41.50	0.0	41.5	0.0	0.000	0.0
1-1	6.29	36.53	0.00	0.00	36.53	3.4	45.6	****	.283	-4.1
1-2	10.61	32.55	0.00	0.00	32.55	4.9	47.0	****	.427	-5.5
1-3	15.79	28.49	0.00	0.00	28.49	6.7	49.4	****	.445	-7.9
1-4	21.82	24.50	0.00	0.00	24.50	8.8	52.9	****	.418	-11.4
1-5	28.73	20.70	0.00	0.00	20.70	10.8	57.3	****	.388	-15.8
1-6	38.22	16.50	0.00	0.00	16.50	13.0	63.9	****	.349	-22.4
1-7	50.30	12.43	0.00	0.00	12.43	15.8	73.5	****	.293	-32.0
1-8	68.41	8.20	0.00	0.00	8.20	20.0	89.8	****	.216	-48.3
1-9	99.47	4.09	0.00	0.00	4.09	27.3	120.9	****	.113	-79.4
2-0	0.00	0.00	164.38	0.00	164.38	0.0	164.4	0.0	0.000	0.0
2-1	43.21	0.00	147.90	0.00	147.90	14.1	200.9	****	.060	-36.6
2-2	101.17	0.00	131.39	0.00	131.39	27.6	250.0	****	.059	-85.7
2-3	173.89	0.00	115.01	0.00	115.01	40.3	311.8	****	.058	-147.4
2-4	265.58	0.00	98.50	0.00	98.50	56.3	393.9	****	.040	-229.5
2-5	380.45	0.00	82.17	0.00	82.17	76.4	501.0	****	.017	-336.6
2-6	531.15	0.00	65.74	0.00	65.74	100.9	644.7	****	0.000	-480.3
2-7	738.76	0.00	49.25	0.00	49.25	125.1	839.3	****	0.000	-674.9
2-8	1049.65	0.00	32.83	0.00	32.83	161.4	1138.9	****	0.000	-974.5
2-9	1620.85	0.00	16.44	0.00	16.44	227.9	1703.1	****	0.000	-1538.7
3-0	0.00	41.50	164.38	0.00	205.88	0.0	205.9	0.0	0.000	0.0
3-1	42.29	20.82	164.38	0.00	185.20	13.9	237.2	****	.177	-31.3
3-2	98.15	.01	164.38	0.00	164.39	27.0	279.7	****	.165	-73.8
3-3	169.81	0.00	143.93	0.00	143.93	39.6	336.3	****	.146	-130.5
3-4	262.55	0.00	123.46	0.00	123.46	55.8	415.6	****	.113	-209.7
3-5	383.74	0.00	102.92	0.00	102.92	77.0	525.3	****	.075	-319.4
3-6	544.99	0.00	82.33	0.00	82.33	102.5	675.4	****	.043	-469.5
3-7	768.41	0.00	61.76	0.00	61.76	128.6	881.9	****	.022	-676.0
3-8	1106.70	0.00	41.16	0.00	41.16	168.0	1205.2	****	0.000	-999.3
3-9	1732.69	0.00	20.57	0.00	20.57	241.0	1820.9	****	0.000	-1615.1
4-0	0.00	41.50	164.38	108.32	314.19	0.0	314.2	0.0	0.000	0.0
4-1	172.53	2.82	164.38	108.32	275.52	40.1	470.9	****	0.000	-156.7
4-2	325.97	0.00	128.82	108.32	237.14	66.9	597.4	****	.035	-283.2
4-3	493.95	0.00	90.33	108.32	198.65	96.3	739.5	****	.043	-425.3
4-4	683.10	0.00	51.77	108.32	160.09	118.6	893.5	****	.058	-579.3
4-5	901.35	0.00	13.35	108.32	121.67	144.1	1077.0	****	.060	-762.8
4-6	1163.25	0.00	0.00	93.15	93.15	174.6	1314.7	****	.044	-1000.5
4-7	1496.57	0.00	0.00	69.79	69.79	213.4	1630.2	****	.023	-1316.0
4-8	1955.56	0.00	0.00	46.55	46.55	266.9	2073.5	****	.000	-1759.3
4-9	2724.05	0.00	0.00	23.29	23.29	356.5	2831.4	****	0.000	-2517.2

NOTE: 1)SYSTEM OPTIONS 1-0, 2-0, 3-0, & 4-0 REPRESENT *CONVENTIONAL* SYSTEMS FOR APPLICATIONS AS DEFINED ON PREVIOUS PAGE.
2) **** INDICATES A DISCOUNTED PAYBACK IN EXCESS OF 100 YEARS.

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WANT ANOTHER RUN? Y(YES) OR N(NO).
I>n
 DO YOU WISH TO SAVE THE DATA SET? (YES/NO)
I>y
 PLEASE ENTER THE NAME FOR SAVING
I>albuq
C>bye
 JOB PROCESSING CCUS      76.372
BYE  82/10/08. 09.50.35.
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STEP 11

STEP 12

7 CONCLUSIONS

This report has described the development of SOLFEAS -- an interactive computer program for making an initial assessment of the economic feasibility of an active solar thermal energy system. The program has the following advantages:

1. It requires a minimum of user input.

2. It is inexpensive to run.

3. It is sufficiently accurate for the purpose of performing solar feasibility studies.

4. It can account for future variations in the critical factors impacting a solar system payback.

5. It is structured around approved methodologies for performing economic feasibility studies.

APPENDIX A: WEATHER STATIONS FOR SOLAR INCIDENCE DATA AT ARMY INSTALLATIONS

Army Installation	Weather Site	SOLMET Station Number
ALABAMA (AL)		
Anniston Army Depot, Anniston	Birmingham, AL	13876
Ballistic Missile Defense Advanced Technology Center, Huntsville	Chattanooga, TN	13882
Coosa River, Anniston	Birmingham, AL	13876
Fort McClellan, Anniston	Birmingham, AL	13876
Fort Rucker, Daleville	Tallahassee, FL	93805
Huntsville Division Office	Chattanooga, TN	13882
Mobile District Office	Mobile, AL	13844
Phosphate Development Works, Sheffield	Memphis, TN	13893
Redstone Arsenal, Huntsville	Chattanooga, TN	13882
ALASKA (AK)		
Bassett Army Hospital	Fairbanks, AK	26411
Fort Greely	Big Delta, AK	26415
Fort Richardson	Gulkana, AK	26425
Fort Wainwright	Fairbanks, AK	26411
ARIZONA (AZ)		
Fort Huachuca, Huachuca City	Tucson, AZ	23160
Navajo Depot Activity, Flagstaff	Winslow, AZ	23194
Yuma Proving Ground, Yuma	Yuma, AZ	23195
ARKANSAS (AR)		
Fort Chaffee	Fort Smith, AR	13964
Little Rock District Office	Little Rock, AR	13963
Pine Bluff Arsenal	Little Rock, AR	13963
CALIFORNIA (CA)		
Camp Parks, Pleasanton	Oakland, CA	23230
Camp Roberts	Santa Maria, CA	23273
Fort Baker, Sausalito	San Francisco, CA	23234
Fort Hunter Liggett, Jolon	Sunnyvale, CA	23244
Fort Irwin, Barstow	Daggett, CA	23161
Fort McArthur, Long Beach	Long Beach, CA	23129
Fort Ord, Seaside	Sunnyvale, CA	23244
Letterman Army Medical Center, S.F.	San Francisco, CA	23234
Los Angeles District Office	Los Angeles, CA	23174
Oakland Army Base	Oakland, CA	23230
Presidio of Monterey	Sunnyvale, CA	23244
Presidio of San Francisco	San Francisco, CA	23234

Army Installation	Weather Site	SOLMET Station Number
Riverbank Army Ammunition Plant	Fresno, CA	93193
Sacramento Army Depot	Sacramento, CA	23232
Sacramento District Office	Sacramento, CA	23232
San Francisco Division Office	San Francisco, CA	23234
Sharpe Army Depot	Oakland, CA	23230
Sierra Army Depot, Herlong	Reno, NV	23185
COLORADO (CO)		
Fitzsimmons Army Medical Center	Denver, CO	23062
Fort Carson	Colorado Springs, CO	93037
Pueblo Army Depot Activity	Pueblo, CO	93058
Rocky Mountain Arsenal	Denver, CO	23062
CONNECTICUT (CT)		
Stratford Army Engine Plant	Central Park, NY	94728
DISTRICT OF COLUMBIA		
Army Topographic Station	Washington, DC	93734
Fort Lesley J. McNair	Washington, DC	93734
Walter Reed Army Medical Center	Washington, DC	93734
GEORGIA (GA)		
Atlanta Division Office	Atlanta, GA	13874
Dwight D. Eisenhower Army Medical Center	Augusta, GA	3820
Fort Benning, Columbus	Macon, GA	3813
Fort Gillem, Forest Park	Atlanta, GA	13874
Fort Gordon	Augusta, GA	3820
Fort McPherson	Atlanta, GA	13874
Fort Stewart	Savannah, GA	3822
Hunter Army Airfield	Savannah, GA	3822
Savannah District Office	Savannah, GA	3822
HAWAII (HI)		
Pohakuloa Training Area	Hilo, HI	21504
Schofield Barracks	Honolulu, HI	22521
Tripler Army Medical Center	Honolulu, HI	22521
Wheeler Army Airfield	Honolulu, HI	22521
ILLINOIS (IL)		
DARCOM Ammunition Center	Moline, IL	14923
Fort Sheridan	Chicago, IL	14819
Joliet Army Ammunition Plant	Chicago, IL	14819
Rock Island Arsenal	Moline, IL	14923

Army Installation	Weather Site	SOLMET Station Number
Savannah Army Depot Activity	Moline, IL	14923
St. Louis Area Support Center, Granite City	St. Louis, MO	13994
St. Louis Area Support Center, Illinois	St. Louis, MO	13994
INDIANA (IN)		
Crane Army Ammunition Activity	Indianapolis, IN	93819
Fort Benjamin Harrison	Indianapolis, IN	93819
Indiana Army Ammunition Plant, Charleston	Louisville, KY	93821
Jefferson Proving Ground, Madison	Cincinnati, OH	93814
IOWA (IA)		
Iowa Army Ammunition Plant, Middletown	Burlington, IA	14931
KANSAS (KS)		
Fort Leavenworth	Kansas City, MO	3947
Fort Riley	Topeka, KS	13996
Kansas Army Ammunition Plant, Parsons	Springfield, MO	13995
Kansas City District Office	Kansas City, MO	3947
KENTUCKY (KY)		
Blue Grass Depot Activity, Lexington	Lexington, KY	93820
Fort Campbell	Nashville, TN	13897
Fort Knox	Louisville, KY	93821
Lexington-Blue Grass Depot Activity	Lexington, KY	93820
LOUISIANA (LA)		
Fort Polk	Lake Charles, LA	3937
Gulf Outport, New Orleans	New Orleans, LA	12916
Louisiana Army Ammunition Plant, Shreveport	Shreveport, LA	13957
MARYLAND (MD)		
Aberdeen Proving Ground	Baltimore, MD	93721
Baltimore (North Atlantic) District Office	Baltimore, MD	93721
Electronics R&D Command	Washington, DC	93734

Army Installation	Weather Site	SOLMET Station Number
Fort Detrick, Frederick	Baltimore, MD	93721
Fort George G. Meade	Baltimore, MD	93721
Fort Ritchie	Baltimore, MD	93721
Harry Diamond Lab	Washington, DC	93734
MASSACHUSETTS (MA)		
Army Materials and Mechanics Research Center	Boston, MA	94701
Fort Devens	Boston, MA	94701
Natick Research and Development Center	Boston, MA	94701
MICHIGAN (MI)		
Detroit Arsenal, Warren	Detroit, MI	14822
Michigan Army Missile Plant, Warren	Detroit, MI	14822
TARCOM Support Activity, Selfridge	Detroit, MI	14822
MINNESOTA (MN)		
Twin Cities Army Ammunition Plant	Minneapolis, St. Paul, MN	14922
MISSISSIPPI (MS)		
Mississippi Army Ammunition Plant, Bay St. Louis	New Orleans, LA	12916
MISSOURI (MO)		
Fort Leonard Wood	Springfield, MO	13995
Gateway Army Ammunition, St. Louis	St. Louis, MO	13994
Lake City Army Ammunition Plant, Independence	Kansas City, MO	3947
St. Louis Army Ammunition Plant, St. Louis	St. Louis, MO	13994
NEBRASKA (NB)		
Omaha District Office	North Omaha, NB	94918
Omaha Division Office	North Omaha, NB	94918
NEVADA (NV)		
Hawthorne Army Ammunition Plant	Tonopah, NV	23153

Army Installation	Weather Site	SOLMET Station Number
NEW JERSEY (NJ)		
Allentown District Office	Allentown, PA	14737
Fort Dix	Lakehurst, NJ	14780
Fort Monmouth	Lakehurst, NJ	14780
Picatinny Arsenal, Dover	Newark, NJ	14734
NEW MEXICO (NM)		
Fort Wingate Depot Activity, Gallup	Zuni, NM	93044
White Sands Missile Range	Truth or Consequences, NM	93045
NEW YORK (NY)		
Fort Drum, Watertown	Massena, NY	94725
Fort Hamilton	Central Park, NYC	94728
Fort Wadsworth	Central Park, NYC	94728
New York Division Office	Central Park, NY	94728
Seneca Army Depot, Romerlus	Syracuse, NY	14771
US Military Academy, West Point	Central Park, NYC	94728
Watervliet Arsenal	Albany, NY	14735
NORTH CAROLINA (NC)		
Camp MacKall, Hoffman	Raleigh-Durham, NC	13722
Fort Bragg	Raleigh-Durham, NC	13722
Sunny Point Military Ocean Terminal, Southport	Cherry Point, NC	13754
Tarheel Army Missile Plant, Burlington	Greensboro, NC	13723
OHIO (OH)		
Defense Construction Supply Center, Columbus	Columbus, OH	14821
Ravenna Army Ammunition Plant	Akron-Canton, OH	14895
US Army Modification Center, Lima	Fort Wayne, IN	14827
OKLAHOMA (OK)		
Fort Sill	Oklahoma City, OK	13967
McAlester Army Ammunition Plant	Tulsa, OK	13968
OREGON (OR)		
Umatilla Depot Activity, Hermiston	Pendleton, OR	24155

Army Installation	Weather Site	SOLMET Station Number
PENNSYLVANIA (PA)		
Carlisle Barracks	Harrisburg, PA	14751
Catalog Data Activity	Harrisburg, PA	14751
Defense Personnel Support Center, Philadelphia	Philadelphia, PA	13739
Fort Indiantown Gap, Annville	Harrisburg, PA	14751
Frankford Arsenal, Philadelphia	Philadelphia, PA	13739
Hayes Army Ammunition Plant, Pittsburgh	Pittsburgh, PA	94823
Letterkenny Army Depot, Chambersburg	Harrisburg, PA	14751
New Cumberland Army Depot	Harrisburg, PA	14751
Oakdale Support Center	Pittsburgh, PA	94823
Scranton Army Ammunition Plant	Scranton, PA	14777
Tobyhanna Army Depot	Wilkes-Barre, PA	14777
SOUTH CAROLINA (SC)		
Fort Jackson	Columbia, SC	13883
South Atlantic Outport, North Charleston	Charleston, SC	13880
TENNESSEE (TN)		
Holston Army Ammunition Plant, Knoxville	Knoxville, TN	13891
Memphis Defense Depot	Memphis, TN	13893
Milan Army Ammunition Plant	Nashville, TN	13897
Volunteer Army Ammunition Plant, Chattanooga	Chattanooga, TN	13882
TEXAS (TX)		
Brooke Army Medical Center, Fort Sam Houston	San Antonio, TX	12921
Camp Bullis	San Antonio, TX	12921
Camp Stanely Storage Activity, San Antonio	San Antonio, TX	12921
Corpus Christi Army Depot	Corpus Christi, TX	12924
Dallas Division Office	Dallas, TX	13960
Fort Bliss	El Paso, TX	23044
Fort Hood	Waco, TX	13959
Fort Sam Houston	San Antonio, TX	12921
Fort Worth District Office	Fort Worth, TX	3927
Lone Star Army Ammunition Plant, Texarkana	Shreveport, LA	13957

Army Installation	Weather Site	SOLMET Station Number
Longhorn Army Ammunition Plant, Marshall	Shreveport, LA	13957
Red River Army Depot, Texarkana	Shreveport, LA	13957
Saginau Army Aircraft Plant	Fort Worth, TX	3927
William Beaumont Army Medical Center, El Paso	El Paso, TX	23044
UTAH (UT)		
Dugway Proving Ground	Salt Lake City, UT	24127
Fort Douglas	Salt Lake City, UT	24127
Ogden Defense Depot	Salt Lake City, UT	24127
Toole Army Depot	Salt Lake City, UT	24127
VIRGINIA (VA)		
Arlington Hall Station	Washington, DC	93734
Cameron Station	Washington, DC	93734
Defense General Supply Center, Richmond	Richmond, VA	13740
Fort A. P. Hill, Bowling Green	Richmond, VA	13740
Fort Belvoir	Washington, DC	93734
Fort Eustis	Norfolk, VA	13737
Fort Lee	Richmond, VA	13740
Fort Meyer	Washington, DC	93734
Fort Monroe	Norfolk, VA	13737
Fort Pickett, Blackstone	Richmond, VA	13740
Fort Story	Norfolk, VA	13737
Norfolk District Office	Norfolk, VA	13737
Radford Army Ammunition Plant	Roanoke, VA	13741
Vint Hill Farms Station, Warrenton	Washington, DC	93734
WASHINGTON (WA)		
Fort Lewis	Seattle-Tacoma, WA	24233
Madigan Army Medical Center, Tacoma	Seattle-Tacoma, WA	24233
Vancouver Barracks	Portland, OR	24229
Yakima Firing Center	Yakima, WA	24243
WISCONSIN (WI)		
Fort McCoy, Sparta	La Crosse, WI	14920

APPENDIX B: SUMMARY OF WEATHER SITES FOR THE UNITED STATES

State	City	SOLMET Station Number
ALABAMA		
	Birmingham	13876
	Mobile	13894
	Montgomery	13895
ALASKA		
	Adak	25704
	Annette	25308
	Barrow	27502
	Bethel	26615
	Bettles	26533
	Big Delta	26415
	Fairbanks	26411
	Gulkana	26425
	Homer	25507
	Juneau	25309
	King Salmon	25503
	Kodiak	25501
	Kotzebue	26616
	McGrath	26510
	Nome	26617
	Summit	26414
	Yakutat	25339
ARIZONA		
	Phoenix	23183
	Prescott	23184
	Tucson	23160
	Winslow	23194
	Yuma	23195
ARKANSAS		
	Fort Smith	13964
	Little Rock	13963
CALIFORNIA		
	Arcata	24283
	Bakersfield	23155
	China Lake	93104
	Daggett	23161
	El Toro	93101
	Fresno	93193
	Long Beach	23129
	Los Angeles	23174
	Mount Shasta	24215

State	City	SOLMET Station Number
	Needles	23179
	Oakland	23230
	Point Magu	93111
	Red Bluff	24216
	Sacramento	23232
	San Diego	23188
	San Francisco	23234
	Santa Maria	23273
	Sunnyvale	23244
COLORADO		
	Colorado Springs	93037
	Denver	23062
	Eagle	23063
	Grand Junction	23066
	Pueblo	93058
CONNECTICUT		
	Hartford	14740
CUBA		
	Guantanamo Bay	11706
DELAWARE		
	Wilmington	13781
DISTRICT OF COLUMBIA		
	Washington/Sterling	93734
FLORIDA		
	Apalachicola	12832
	Daytona Beach	12834
	Jacksonville	13889
	Miami	12839
	Orlando	12841
	Tallahassee	93805
	Tampa	12842
	West Palm Beach	12844
GEORGIA		
	Atlanta	13874
	Augusta	3820
	Macon	3813
	Savannah	3822

State	City	SOLMET Station Number
HAWAII		
	Barbers Point	22514
	Hilo	21504
	Honolulu	22521
	Lihue	22536
IDAHO		
	Boise	24131
	Lewiston	24149
	Pocatello	24156
ILLINOIS		
	Chicago	14819
	Moline	14923
	Springfield	93822
INDIANA		
	Evansville	93817
	Fort Wayne	14827
	Indianapolis	93819
	South Bend	14848
IOWA		
	Burlington	14931
	Des Moines	14933
	Mason City	14940
	Sioux City	14943
KANSAS		
	Dodge City	13985
	Goodland	23065
	Topeka	13996
	Wichita	3928
KENTUCKY		
	Lexington	93820
	Louisville	93821
LOUISIANA		
	Baton Rouge	13970
	Lake Charles	3937
	New Orleans	12916
	Shreveport	13957

State	City	SOLMET Station Number
MAINE		
	Bangor	14601
	Caribou	14607
	Portland	14764
MARYLAND		
	Baltimore	93721
	Patuxent River	13721
MASSACHUSETTS		
	Boston	94701
MICHIGAN		
	Alpena	94849
	Detroit	14822
	Flint	14826
	Grand Rapids	94860
	Houghton	14858
	Sault Ste. Marie	14847
	Traverse City	14850
MINNESOTA		
	Duluth	14913
	International Falls	14918
	Minneapolis/St. Paul	14922
	Rochester	14925
MISSISSIPPI		
	Jackson	3940
	Meridian	13865
MISSOURI		
	Columbia	3945
	Kansas City	13947
	Springfield	13995
	St. Louis	13994
MONTANA		
	Billings	24033
	Cut Bank	24137
	Dillon	24138
	Glasgow	94008
	Great Falls	24143
	Helena	24144
	Lewistown	24036
	Miles City	24037
	Missoula	24153

State	City	SOLMET Station Number
NEBRASKA		
	Grand Island	14935
	North Omaha	94918
	North Platte	24023
	Scottsbluff	24028
NEVADA		
	Elko	24121
	Ely	23154
	Las Vegas	23169
	Lovelock	24172
	Reno	23185
	Tonopah	23153
	Winnemucca	24128
	Yucca Flats	3133
NEW HAMPSHIRE		
	Concord	14745
NEW JERSEY		
	Lakehurst	14780
	Newark	14734
NEW MEXICO		
	Albuquerque	23050
	Clayton	23051
	Farmington	23090
	Rosewell	23043
	Truth or Consequences	93045
	Tucumcari	23048
	Zuni	93044
NEW YORK		
	Albany	14735
	Binghamton	4725
	Buffalo	14733
	Massena	94725
	New York City (Central Park)	94728
	New York City (Laguardia)	14732
	Rochester	14768
	Syracuse	14771

State	City	SOLMET Station Number
NORTH CAROLINA		
	Asheville	3812
	Cap Hatteras	93729
	Charlotte	13881
	Cherry Point	13754
	Greensboro	12723
	Raleigh/Durham	13722
NORTH DAKOTA		
	Bismarck	24011
	Fargo	14914
	Minot	24013
OHIO		
	Akron/Canton	14895
	Cincinnati (Covington, KY)	93814
	Cleveland	14820
	Columbus	14821
	Dayton	93815
	Toledo	94830
	Youngstown	14852
OKLAHOMA		
	Oklahoma City	13967
	Tulsa	13968
OREGON		
	Astoria	94224
	Burns	24134
	Medford	24225
	North Bend	24284
	Pendleton	24155
	Portland	24229
	Redmond	24230
	Salem	24232
PACIFIC ISLANDS		
	Koror Island	40309
	Kwajalein Island	40604
	Wake Island	41606

State	City	SOLMET Station Number
PENNSYLVANIA		
	Allentown	14737
	Erie	14860
	Harrisburg	14751
	Philadelphia	13739
	Pittsburgh	94823
	Wilkes-Barre/Scranton	14777
PUERTO RICO		
	San Juan	11641
RHODE ISLAND		
	Providence	14765
SOUTH CAROLINA		
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