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THE ORKAND CORPORATION

SILVER SPRING, MARYLAND

SOLARSIM SPECIFICATIONS MANUAL

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MASTER

July 27, 1977

Prepared for:
Mr. Howard L. Walton
Technical Project Officer
Office of Energy Information & Analysis
Federal Energy Administration
Washington, D.C. 20461

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SOLARSIM SPECIFICATIONS MANUAL

July 27, 1977

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Prepared for:
Mr. Howard L. Walton
Technical Project Officer
Office of Energy Information and Analysis
Chief, Nuclear and New Technologies
Analysis Division
Federal Energy Administration
Washington, D.C. 20461

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TABLE OF CONTENTS

I.	GENERAL INFORMATION	I-1
	SUMMARY	I-1
	ENVIRONMENT	I-1
II	REQUIREMENTS	II-1
	DESCRIPTION	II-1
	FUNCTIONS	II-1
	PERFORMANCE	II-21
III.	OPERATING ENVIRONMENT	III-1
	EQUIPMENT	III-1
	SECURITY AND PRIVACY	III-1
IV.	DESIGN CHARACTERISTICS	IV-1
	OPERATIONS	IV-1
	SYSTEM/SUBSYSTEM LOGIC	IV-1
V.	PROGRAM SPECIFICATIONS	V-1
	PROGRAM REQUIREMENTS	V-1
	OPERATING ENVIRONMENT	V-1
	DESIGN CHARACTERISTICS	V-1

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LIST OF EXHIBITS

IV-1	Flowchart Showing the Inputs, Outputs, Data Files, and Data Flows of the SOLARSIM Solar Energy Model	IV-2
IV-2	Summary Matrix of SOLARSIM Model Components	IV-3
IV-3	Table of the User Specified Input Parameters to SOLARSIM	VI-5
V-1	File Description	V-4
V-2	Record Description	V-5
V-3	Record Description	V-6
V-4	Record Description	V-7
V-5	Record Description	V-8
V-6	Record Description	V-9
V-7	File Description	V-10
V-8	Record Description	V-11
V-9	File Description	V-12
V-10	National Simulation of Solar Energy Commercialization.	V-14

THE ORKAND CORPORATION

LIST OF EXHIBITS -- Cont.

V-11	National Simulation of Solar Energy Commercialization	V-15
V-12	National Simulation of Solar Energy Commercialization	V-16
V-13	SOLARSIM Main Program	V-17

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I. GENERAL INFORMATION

SUMMARY

SOLARSIM is a quantitative computer model which calculates, on a regional and national basis, domestic water and domestic space and water heating loads for single family detached dwellings. SOLARSIM is also capable of performing life-cycle cost analyses of solar space and water heating systems of various levels of intricacy. The main function of SOLARSIM, a solar energy financial incentive model for the applications of solar water heating and solar space and water heating, is to estimate the impacts of different economic and financial incentive scenarios designed to accelerate the market penetration of solar energy heating systems in the 48 contiguous states.

ENVIRONMENT

Project Sponsor

Federal Energy Administration
Office of Energy Information and
Analysis
Nuclear and New Technologies Analysis
Division

Developer

The Orkand Corporation
8630 Fenton Street, Suite 938
Silver Spring, Maryland 20910

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User

Nuclear and New Technologies Analysis
Division

Computer Center

Optimum Systems, Inc. (OSI)
Rockville, Maryland

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II. REQUIREMENTS

DESCRIPTION

The SOLARSIM model is composed of three integral components:

- Input
- Computation
- Output

The model uses economic, thermal, housing stock and climatic data as input. Computations performed are a function of the thermal and economic analyses, penetrations, data aggregations and other computed statistics.

SOLARSIM outputs are displayed by region, solar application (water heating, and space and water heating) and year. Regional outputs are aggregated to national levels. Lastly, comparative tables are displayed, presenting regional and national statistics.

The SOLARSIM model is comprised of a main program, eight subroutines, three functions and four data blocks. The following paragraphs present a description of each of these SOLARSIM program components.

FUNCTIONS

MAIN Program

The SOLARSIM main program is the hub of the various SOLARSIM program components. The main program controls the logic to process the subroutines, functions and data blocks. The main

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program also controls the solar simulation from year to year and region to region, and generates the SOLARSIM output report. The main program can best be described by its three main components:

- Input
- Computation
- Output

The following paragraphs provide a description fo the SOLARSIM main program components.

Input. All SOLARSIM thermal data is loaded into the model via arrays. That is, the FEA regions and latitudes, their heating degree-days, ambient temperatures and solar radiation are all read into the program and stored into arrays.

The housing stocks are read and stored for the 14 year simulation period. At the beginning of processing, all arrays are initialized to zero. Many arrays are necessary for model processing in order to keep track of regional and national statistics.

All of the SOLARSIM inputs are initialized to either user specified or default values as appropriate. Several SOLARSIM parameters are stored since they are changed over time or by FEA region during processing. They are:

- XLIST (30) - Annual Rise in Fuel Price
- XLIST (9) - Effective Building UA
- XLIST (19) - Collector Cost
- XLIST (21) - Down Payment
- XLIST (22) - Annual Interest Rate
- XLIST (23) - Term of Mortgage

Computation. The algorithm involved in the computation portion of the MAIN program of the SOLARSIM model is as follows:

- Input all data and intialize all variables.
- Start with year 1977 and loop to year 1990.

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- Start with Region 1 and loop to Region 10.
- Define characteristics of NEW space and water, OLD space and water and NOL (New-Old) space and water houses.
- Compute penetrations and other statistics.
- Define characteristics of NEW water only, OLD water only and NOL water only houses.
- Compute penetrations and other statistics.
- Continue over all 10 regions and 14 years.

Specifically, the model starts in 1977 with characteristics for Region 1, NEW space and water heated houses. The CALC subroutine of FCHART is called. CALC calls ECON, another subroutine, which computes "Years to Payback." Returned from the call are the following statistics:

- Total Yearly Load
- Total Collector Area
- Percent Solar
- "Years to Payback"

Years to payback is entered into the function XPENT which returns a % market penetration. This penetration is multiplied by the number of NEW space and water units in Region 1. The same procedure is used for OLD and NOL houses and for water heated only houses.

Once the two applications and three types of houses are processed through the model, specific statistics are accumulated, and the number of Retrofit Units is determined. Total collector areas and loads by application are also determined. Updates to the housing stocks are made accordingly (i.e., once a unit puts up a solar system, it can not put it up again). After this data is collected, the simulation proceeds with Region 2 for 1977. This procedure iterates through Region 10.

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At this point in time, the year is incremented, the price of fuel escalated, and the collector cost is modified by a learning function. The characteristics for Region 1, 1978 houses are processed and this procedure continues for the 14 years of the simulation period.

All computations and accumulations in the model are straightforward except for the updating of housing stocks. For each year, region, application and type of house, a housing stock number exists. This number must be decremented each time one of its members installs a solar system.

If an OLD space and water unit installs a solar system, all future OLD space and water only units are decremented. If a NOL or NEW space and water unit installs a solar system, all future NOL space and water and water only units are decremented.

If an OLD water unit installs a solar system, all future OLD water units are decremented and all future OLD space and water units are also decremented by the proportion of OLD space and water units to OLD water only units. If a NOL or NEW water unit installs a solar system, all future NOL water units are decremented and all future NOL space and water units are decremented by the proportion of NEW and NOL space and water units to NEW and NOL water only units.

Output. The Solar Simulation Model prints 24 pages of output. Specifically, the output is broken down into documentation, output matrices and comparative tables. The first page provides a brief description of the model and method of analysis. Then for each region, there is a two page output. The first page contains the output matrices for space and water heating and for water heating only applications. The second page contains the output matrix for the region totals, the summary statistics, and brief definitions of the output.

After the regional output (20 pages), two pages for the national simulation are printed following the same format procedure used by each region. Finally, the last page contains comparative tables of the various regional and national values.

The following paragraphs describe the elements of the output matrix, the summary statistics and the comparative tables.

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Output Matrix and Definitions - Each output matrix by region is identical in format but different in content. Each matrix displays values by year for each year from 1977 to 1990, and a 14 year total.

The Percent Retrofit and other outputs are printed in each matrix and are defined as follows:

- Percent Retrofit is defined as the number of old units that installed a solar system during the year divided by the total number of solar units that installed a solar system during the year.
- Number of Solar Units is the number of NEW, OLD and NOL houses that installed a solar system during the year for a specific application.
- Total Available Units is the total number of houses that exist in the year, including solar units for a specific application.
- Total Collector Area is the number of square feet of solar collectors installed during the year for a specific application.
- Total Yearly Load is the number of BTU's that were used during the year by all units for a specific application.
- Yearly Discounted Fuel Saved is the dollar amount of fuel saved by solar units during the year. This is computed by the current price of fuel/MBTU times the number of MBTU's saved. This value is discounted to the present value.
- Yearly BTU's saved is the total number of BTU's saved by all solar units during the year for a specific application.

Note that in defining space and water heating and water heating only, the definitions are clear and straightforward for these applications, but in defining Region or Nation

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totals some specific accounting must be done. The population of houses is assumed to be electric water heated dwellings only. Electric space and water houses are assumed to be a subset of this population.

For Region or Nation total matrices, Percent Retrofit is equal to the total number of solar units that are OLD divided by the total number of units. Total Number of Units is equal to the total number of water heating only units. All other values in the Region or Nation total matrices are sums of the space and water and water heating only matrices. Note that in all output matrices, the total line is not always a straight sum. For example, the Total Cumulative Solar Units is the value for 1990 of cumulative solar units. Percent Retrofit must be recomputed for the total line by preceeding definition.

Summary Statistics. Summary statistics are printed for each region and nation. These statistics include the average space and water load for 1977 and 1990. This particular statistic shows that houses will be better insulated by the year 1990.

The average collector area for solar space and water heating and water heating only systems is also displayed, as is the average number of BTU's saved by both applications, space and water heating and water heating only. Percent penetration for the two applications, separate and combined, is printed for the years 1980, 1985, 1990 and for 1977 thru 1990.

Comparative Tables. The last page of output contains comparative tables which are a collection of the regional and national summary statistics. Printed by region and nation are:

- The average load for 1977 and 1990
- Collector area for solar space and water heating and water heating only
- MBTU's saved by the two applications.

Also printed by region and by nation are the market penetrations for the two applications, separate and combined, for the years 1980, 1985 and 1977 to 1990.

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CALC

The SOLARSIM thermal analysis is generated by the CALC subroutine of the SOLARSIM model. The CALC subroutine performs all of the calculations involved in the thermal analysis. The following calculations encompass the thermal analysis:

- Percent solar
- Incident solar
- Space heating load
- Domestic water load
- Degree-days
- Ambient temperature

All of the above calculations are computed by month and year. CALC utilizes certain parameters in order to facilitate the thermal analysis. These parameters and a brief description of them follows:

- XLIST - An array which contains user supplied values that become system parameters
- XLOAD - Contains user supplied (optional) monthly load factors
- RHO - Contains ground reflectance values
- IU - The unit, in either English or Metric specifications.

The CALC subroutine has the capability to optimize the collector area such that the present worth of a solar energy system is minimized. Also, if the optimized collector area is determined to be less than 40 ft.² for solar water heating and less than 150 ft.² for solar space and water heating, then the collector areas are specified to be 40 ft.² for water and 150 ft.² for space and water heating systems.

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Percent Solar.

Percent Solar equals $F(J)$

Where $J = 1, 2, \dots, 12$ for 12 months

and F_{YR} for yearly percent solar

Preliminary values must be computed before percent solar can be calculated.

First, $F1(J) = 1.029y - .065x - .245y^2 + .0018x^2 + .0215y^3$
for a water system,

and $F1(J) = 1.040y - .065x - .159y^2 + .00187x^2 - .0095y^3$
for an air system,

where $X = XDA * \text{Area of Collector}$

and $Y = YDA * \text{Area of Collector}$

and $XDA = \frac{XLIST(3) * (T_{REF} - TAMB) * 24 * \# \text{ days in } J^{th} \text{ month}}{TOTLM}$

and $YDA = XLIST(4) * S * TARAT;$

where T_{REF} is the reference temperature (100°C or 212°F)

and $TAMB$ is the ambient temperature for month J .

$TOTLM$ is the total monthly load which is the sum of the monthly domestic water load and the monthly domestic space heating load.

$XLIST(3)$ is $FRPRIME\text{-}TAU\text{-}ALPHA$ PRODUCT

and $XLIST(4)$ is $FRPRIME\text{-}UL$ PRODUCT, both of which are user supplied parameters.

S is incident solar which will be defined later.

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TARAT is the ratio of the average transmittance-absorptance product to that at normal incidence.

$$\text{Second, } F1 = 1.029y - .067x - .245y^2 + .0018x^2 + .0251y^3$$

where x and y are defined as before.

$$\text{Finally } F(J) = [F1 * DWLM(J) + F1(J) * SHLM(J)] / TOTLM(J)$$

where DWLM is the monthly domestic water load

and SHLM is the monthly space heating load.

Both DWLM and SHLM will be defined later. The yearly percent solar is FYR, defined as:

$$FYR = QUJR / TOTLYR$$

$$\text{where } QUJR = \sum_{j=1}^{12} F(J) * TOTLM(J)$$

FYR is a measure in percent of the total yearly load that can be accounted for by solar.

Incident Solar. The CALC subroutine also determines the value of Incident Solar.

Incident Solar equals S(J) for the 12 months

and equals SOLYR for yearly total.

The incident solar for the Jth month is

$$S(J) = H(J) * DD CONV * RBAR (Z)$$

where H(J) = monthly long-term average radiation incident on a horizontal surface

and DD CONV = 1 or 9/5 (a conversion factor between Celcius and Fahrenheit).

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RBAR is a function which calculates the ratio of daily extraterrestrial radiation incident on a tilted surface to that of a horizontal surface. Some of the input values to RBAR are latitude, collector slope, azimuth angle, H(J), RHO(J), and the number of transparent covers.

$$\text{SOLYR} = \sum_{j=1}^12 \text{S}(J) \text{ is the total yearly incident solar.}$$

Space Heating Load. Also determined by the CALC subroutine is the space heating load which is SHLM for each month and SHLYR for the year.

$$\text{SHLM}(J) = \text{XLOAD}(J) * \# \text{ days in month } J + \text{XLIST}(9) * \text{DD}(J) - \text{XLIST}(10) * \# \text{ days in month } J$$

where XLOAD(J) is the user supplied monthly load factors

and XLIST(9) is Effective Building UA,
DD(J) is degree days for month J

and XLIST(10) is constant daily building heat generation. Note that either XLOAD(J) = 0 or XLIST(9) = 0.

The yearly space heating load equals:

$$\text{SHLYR} = \sum_{j=1}^12 \text{SHLM}(J)$$

Similarly the domestic water load is calculated as SWLM for each month and DWLYR for yearly total.

$$\text{DWLM}(J) = \# \text{ days in month } j * \text{XLIST}(11) * \text{Cp} * (\text{XLIST}(12) - \text{XLIST}(13))$$

where XLIST(11) is hot water usage,

XLIST(12) is water set temperature

and XLIST(13) is water main temperature.

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Stated in another way, the monthly domestic water load equals the number of days in the month multiplied by the amount of water used multiplied by the number of BTU's necessary to raise the temperature of water 1° multiplied by the number of degrees that the temperature of water must be raised.

The yearly domestic water load equals:

$$DWLYR = \sum_{j=1}^{12} DWLM(J)$$

Degree-Days. The SOLARSIM thermal analysis also determines degree-days and ambient temperature. Monthly long-term degree-days and ambient temperature are a function of the information contained in the data blocks, DDATA and TADATA. The yearly long-term average degree-day is calculated as follows:

$$DWLYR = \sum_{j=1}^{12} DD(J)$$

ECON

the SOLARSIM economic analysis is generated by the ECON subroutine of the solar incentive model. This routine performs the life-cost analysis of the thermal system. The ECON subroutine calculates the present worth of yearly total costs for solar and conventional systems. Also, the statistic "Years to Payback" is computed. Financial incentives are incorporated into the calculation of Years to Payback.

The following computations are also computed within the economic analysis of SOLARSIM. These computations are:

- Yearly mortgage payment
- Yearly interest paid
- Income tax saved
- Auxilliary fuel expense
- Miscellaneous expenses
- Yearly total solar costs
- Yearly total non-solar costs
- Initial cost of the solar system.

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In each case values are computed for several areas until the optimized area is determined. The optimized area is the area of the collector such that the present worth of yearly total costs with a solar system is minimum.

Present Worth. The following is the economic theory for the present worth analysis:

- Yearly cost with solar equals:

Mortgage payment + backup system fuel cost +
miscellaneous cost + property tax increase -
"solar" income tax credit

- Yearly cost without solar equals:

Conventional system fuel cost - "non-solar" income
tax credit

where for a non-income producing building:

- "Solar" income tax credit equals:

Tax rate * (interest paid + property tax paid)

- "Non-solar" income tax credit equals: Zero

and for commercial buildings:

- "Solar" income tax credit equals:

Tax rate * (interest paid + property tax paid +
miscellaneous expense + backup system fuel cost +
depreciation)

- "Non-solar" income tax credit equals:

Tax rate * (conventional system fuel costs).

Present worth for yearly total costs with a solar system equals:

$$\text{Downpayment} + \sum_{I=1}^{\text{Length of Analysis}} \frac{(\text{yearly cost with solar})}{(1 + \text{discount rate})^I}$$

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and, present worth for yearly total costs without solar equals:

$$\sum_{I=1}^{\text{Length of analysis}} (\text{yearly cost without solar}) / (1 + \text{Discount rate})^I$$

The equations and algorithms which comprise the life cost analysis are now described.

Parameters Passed to ECON from CALC. The following parameters are passed from the CALC subroutine to the ECON subroutine:

IOPMUM = $\begin{cases} 0 & \text{- not optimized} \\ 1 & \text{- optimized} \end{cases}$

XLIST = user supplied parameters

ORGINV = original investment = Area + cost/ft² of collector + fixed cost

TOTLYR = total yearly load for space and water heating

FYR = fraction of total heating load due to solar

PWSOL = present worth of yearly total costs with solar

PWCON = present worth of yearly total costs without solar

IERR = error code

IU = units

STAT = "Years to Payback"

INCEN = type of Financial Incentive

ITIME = Years of simulation (1 to 14)

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ECON Computed Values. The following values are computed by the ECON subroutine:

LENGTH = period of economic analysis = XLIST(18)

AINTRT = annual interest rate = XLIST(22)/100

N = term of mortgage = XLIST(23)

DISCRT = annual discount rate = XLIST(24)/100

DOWNPT = downpayment = ORGINV * XLIST(21)/100

ICOMR = XLIST(34) = $\begin{cases} 1 & \text{- if income producing building} \\ 2 & \text{- if residence} \end{cases}$

EFFTXR = effective federal income tax rate = XLIST(32)/100

PRPTXR = property tax rate = XLIST(33)/100

XMISCI = miscellaneous expenses of system in first year x = XLIST(25)

GINFLA = Annual increase in miscellaneous expenses x = XLIST(26)/100

CFINIT = Initial cost of auxilliary fuel = XLIST(27)

IOPTCF = XLIST(28) = $\begin{cases} 1 & \text{- linear rise in Conventional Fuel cost} \\ 2 & \text{- yearly rise} \\ 3 & \text{- sequence} \end{cases}$

SLOPE = XLIST(29) if IOPTCF = 1

FINFLA = XLIST(30)/100 = rate of Cf rise if IOPTCF = 2

IOPTDP = XLIST(35) = $\begin{cases} 1 & \text{- straight line depreciation} \\ 2 & \text{- decreasing balance} \\ 3 & \text{- sum of years digits} \\ 4 & \text{- none} \end{cases}$

POFSL = XLIST(36)/100 = % of straight line depreciation if IOPTDP = 1

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LIFE = XLIST(37) = useful life

SALVAL = XLIST(38) = salvage value

IOTYPE = XLIST(31) = $\begin{cases} 1 & \text{- printout by year} \\ 2 & \text{- cumulative} \end{cases}$

Yearly Cost of Auxilliary Fuel Computation. The computations of the yearly cost of auxilliary fuel are as follows:

If IOPTCF = 1 (linear rise)

$\Rightarrow CF(I) = CFINIT + SLOPE * (I-1); I = 2, 3, \dots, \text{length}$

If IOPTCF = 2 (yearly rise)

$\Rightarrow CF(I) = CFINIT * (1 + FINFLA)^{I-1};$
 $I = 2, 3, \dots, \text{length}$

If IOPTCF = 3 (sequence)

$\Rightarrow CF(I) = SEQ(I) \forall I$

Yearly Depreciation. The following are computations of yearly depreciation:

If ICOMR = 1 (income producing building)

then

If IOPTDP = 1 (straight line depreciation)

$\Rightarrow DEPYR(I) = (ORGINV - SALVAL) / LIFE$

for all $I=1, \dots, \min(LIFE, LENGTH)$

If IOPTDP = 2 (decreasing balance)

$$\Rightarrow DEPYR(I) = \frac{ORGINV_I - POFSL}{LIFE}$$

for all $I \in ORGINV \geq SALVAL$ and $I \leq LIFE$

and $ORGINV_I = ORGINV_{I-1} * (1 - POFSL / LIFE) \forall I \geq LIFE$

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If IOPTDP = 3 (sum of years digits)

$$\Rightarrow \text{DEPYR}(I) = \frac{(\text{LIFE} - I + 1)}{(\text{LIFE} * \text{LIFE} + \text{LIFE})/2} * (\text{ORGINV} - \text{SALVAL}) \quad \forall I \leq \text{LIFE}$$

If IOPTDP = 4 (none)

$$\Rightarrow \text{DEPYR}(I) = 0; \forall I$$

If ICOMR = 2 (residence building)

$$\text{then } \text{DEPYR}(I) = 0; \forall I.$$

Yearly Mortgage Payment. The following presents the computation of the yearly mortgage payment:

$$\text{FACTOR} = (1 + \text{AINTRT})^N; N = \text{term of mortgage}$$

$$\text{PAYMT} = (\text{ORGINV} - \text{DOWNPT}) * \text{AINTRT} * \frac{\text{FACTOR}}{(\text{FACTOR} - 1)}$$

Note that $\frac{\text{AINTRT} * \text{FACTOR}}{(\text{FACTOR} - 1)}$ is the capital recovery factor

$$\text{APAYMT}(I) = \begin{cases} \text{PAYMT} & \text{for } I \leq N \\ 0 & \text{for } I > N \end{cases}$$

or

$\text{APAYMT}(I)$ = annual mortgage payment.

Other Present Worth Computations. The following computations are necessary to compute present worth,

where $I = 1$ through length:

$$\text{PRINC}_1 = \text{initial principle} = \text{ORGINV} - \text{DOWNPT}$$

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$$\text{PRINC}_{I+1} = \begin{cases} \text{PRINC} - \text{APAYMT}(I) - \text{XINTPD}(I); & 1 < I \leq N \\ 0; & I > N \end{cases}$$

$$\text{XINTPD}(I) = \text{interest paid} = \begin{cases} \text{PRINC} * \text{AINTRT} & \text{if } \text{XINTPD} < \text{APAYMT} \\ \text{APAYMT} & \text{if } \text{XINTPD} > \text{APAYMT} \end{cases}$$

$$\text{TAXLOS}(I) = \text{property tax increase} = \text{PRPTXR} * \text{ORGINV}$$

$$\text{XMISC}(I) = \text{miscellaneous yearly costs} = \text{XMISC1} * (1 + \text{GINFLA})^{I-1}$$

$$\text{FRACSL} = \text{fraction of total heating load due to solar} = \text{FYR}$$

$$\text{FUELCT} = \text{backup system fuel costs}$$

or

$$\text{FUELCT} = (1 - \text{FRACSL}) * \text{TOTAL} * \text{CF}(I)$$

If ICOMR = 1 (income producing building) then

$$\text{CONCST}(I) + \text{yearly conventional system cost} = \text{TOTLYR} * \text{CF}(I) * (1 - \text{EFFTXR})$$

$$\begin{aligned} \text{and TAXSAV}(I) &= \text{"solar" income tax credit for commercial} \\ &\quad \text{building} = \text{EFFTXR} * (\text{FUELCT} + \text{SMISC}(I) + \\ &\quad \text{XINTPD}(I) + \text{DEPYR}(I) + \text{TAXLOS}(I)) \end{aligned}$$

If ICOMR = 2 (Residence building) then

$$\text{CONCST}(I) = \text{yearly conventional system cost} = \text{TOTLYR} * \text{CF}(I)$$

$$\begin{aligned} \text{and TAXSAV}(I) &= \text{"solar" income tax credit for residence} \\ &\quad \text{building} = \text{EFFTXR} * (\text{XINTPD}(I) + \text{TAXLOS}(I)) \end{aligned}$$

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SOLCST(I) = yearly solar system cost =

FUELCT + APAYMT(I) + XMISC(I) + TAXLOS(I) - TAXSAV(I)

SOLSAV(I) = savings of solar to non-solar = CONCST(I) - SOLCST(I)

Present Worth Calculation. The following presents the present worth calculation:

PWSOL = present worth of yearly total costs with solar =

DOWNPT + $\sum_{I=1}^{\text{length}} \text{SOLCST}(I)/(1 + \text{DISCRT})^I$

PWCON = present worth of yearly total costs without solar =

$\sum_{I=1}^{\text{length}} \text{CONCST}(I)/(1 + \text{DISCRT})^I$

Financial Incentive Calculation

The following presents the possible financial incentive scenarios incorporated into the SOLARSIM model:

- Base Case - No Tax Deduction
- First Incentive - $\begin{bmatrix} 40\% \text{ on first } \$1,000 \\ 25\% \text{ on next } \$6,400 \end{bmatrix}$ for 8 years
- Second Incentive - $\begin{bmatrix} 40\% \text{ on first } \$1,000 \\ 25\% \text{ on next } \$6,400 \end{bmatrix}$ for 3 years
 $\begin{bmatrix} 30\% \text{ on first } \$1,000 \\ 20\% \text{ on next } \$6,400 \end{bmatrix}$ for next 2 years
 $\begin{bmatrix} 25\% \text{ on first } \$1,000 \\ 15\% \text{ on next } \$6,400 \end{bmatrix}$ for next 3 years
- Third Incentive - 20% on first \$10,000 for 5 years

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The method used to incorporate the above tax deductions (financial incentives), is to deduct the incentive amount from the original investment.

The parameters INCEN and ITIME are used to modify the value of ORGINV (original investment).

YEARS TO PAYBACK Calculation

The statistic "Years to Payback" is computed by the following formula:

$$\text{PBTIME} = \frac{\text{ORGINV}}{\text{FRACSL} * \text{TOTLYR} * \text{CF}(1)}$$

or

Years to Payback is computed as the original investment divided by the (\$) amount of fuel saved during the first year. (This value is returned to the main program.)

Other SOLARSIM Subroutines

YESNO - The purpose of the YESNO subroutine is to accept user specified parameters for "YES-NO" questions. YESNO sets the IFLG flag to "1" for "yes" response and the IFLG flag to "0" for a "no" response.

READIN - The READIN subroutine performs the function of free-format card reading. That is, input values specified by the user are accepted regardless of where they might appear in an 80 character card image. This flexible routine foregoes the user from having to "key-in" input values into specific columns or specified fields. This subroutine reads the user supplied inputs and returns those values to the MAIN program.

CYREAD - This subroutine reads and enters into the processing program the city data and associated latitudes for the 10 FEA regions used by SOLARSIM.

SLREAD - This subroutine reads and enters into the processing program the monthly long-term average total solar radiation data for the 10 FEA regions used by SOLARSIM.

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DDREAD - The DDREAD subroutine reads and enters into the processing program the monthly long-term average degree days for each of the 10 FEA regions.

TAREAD - This subroutine reads and enters into the processing program the monthly long-term average ambient temperatures for the 10 FEA regions.

Other SOLARSIM Functions

XPENT - The purpose of this function is to calculate the market penetration for space and water and water only houses. The function uses two parameters:

STAT - "Years to Payback"

HFLG - $\begin{cases} 0 & \text{for space and water} \\ 1 & \text{for water only} \end{cases}$

RBAR - The purpose of this function is to calculate the ratio of daily extraterrestrial radiation incidence on a tilted surface to that of daily intraterrestrial radiation incidence on a horizontal surface.

SOLARSIM Data Blocks

CITYDATA - The CITYDATA data block contains the names of each of the 126 cities and 10 FEA regions used in SOLARSIM plus their associated latitudes.

SOLDATA - The SOLDATA data block contains, for each of the 126 cities and 10 FEA regions, monthly long-term average total solar radiation data.

DDDATA - Monthly long-term average degree-days for the 126 cities and 10 FEA regions is contained in the DDDATA data block.

TADATA - The TADATA data block contains the monthly long-term average ambient temperatures for the SOLARSIM 126 cities and 10 FEA regions.

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PERFORMANCE

Accuracy

During the development of the SOLARSIM model, certain assumptions were specified and included in the model. The purpose of this section is to present the model assumptions and data limitations so as to provide a clear scope of the conditions which model assumes.

The COLLECTOR COST variable includes as part of its total, a fixed installation charge. The cost of \$25/ft.² for installed collectors have been used and the fixed costs associated with collectors are equal to zero.

The same market penetration curve is used for both space and water heating and water heating only applications. Currently, there is no learning process associated in the manufacturing of solar collectors. That is, the LEARN parameters of the model is equal to 1 such that solar collectors costs are not assumed to decrease over time as they would under a true learning curve scenario.

Electric single family water heated houses and electric space heated houses were the only cases for which this model was developed. Electric space cooling was not an application simulated by SOLARSIM. Electric space heating was assumed to be a subset of the electric water heating population

In computing and projecting electric water heating housing stocks, the total housing stock is assumed to be equal to all electric heated houses plus one half of all oil heated houses.

Flexibility

The SOLARSIM model has been developed in a structured manner such that program changes and modifications can be accomplished with minimal effort. However, SOLARSIM is based upon the previously developed FCHART and is therefore constrained by the design and architecture of FCHART. Parameters have been

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specified as "user supplied parameters" so that changes to these values can be accomplished by the user without changing the model source code. Provisions for a learning curve function and dedicated penetration functions by solar application have been incorporated into the model.

Although SOLARSIM was designed to operate in a batch mode, it can easily be modified to operate in an interactive environment. Because the SOLARSIM source code is written in FORTRAN IV the model can be made compatible with other IBM 360/370 environments or other environments which support a FORTRAN IV Compiler.

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III. OPERATING ENVIRONMENT

EQUIPMENT

The SOLARSIM model is developed to be operational on FEA's IBM 370/168 hardware configuration computer system. The SOLARSIM model simulation needs approximately 3 minutes of CPU time to execute. The size of SOLARSIM interval storage requirements is approximately 220K. All associated SOLARSIM files (input, output and intermediate) reside on on-line disk space.

SECURITY AND PRIVACY

Overall security of the SOLARSIM solar energy model is consistent with that procedure identified in FEA's User's Guide to the OSI Service Facility. Only valid user's (those who possess a valid LOGON ID, Account, and Password) may execute the model. Otherwise, no other specific security requirements have been stipulated.

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IV. DESIGN CHARACTERISTICS

OPERATIONS

The SOLARSIM solar energy model has been designed to operate from a remote batch terminal which interfaces with FEA's IBM 370/168 computer system operated by Optimum Systems, Inc. in Rockville, Maryland. The model is executable via a batch processing mode and model outputs can be retrieved at the remote batch terminal, if desired. All related software and associated files reside on on-line disk direct access storage devices at Optimum Systems, Inc.

SYSTEM/SUBSYSTEM LOGIC

Exhibit IV-1, on the following page, presents a flowchart showing the inputs, outputs, data files, and data flows of the SOLARSIM solar energy model. This flowchart depicts the major SOLARSIM routines and processes and how they are logically associated with the other major SOLARSIM routines and processes. Associated exhibits are provided to further explain the solar simulation model.

A Summary Matrix of SOLARSIM Model Components is provided in Exhibit IV-2. This matrix briefly describes the major SOLARSIM components as depicted in the SOLARSIM flowchart exhibit.

Exhibit VI-3 presents a table of the user specified input parameters to SOLARSIM. These parameters must be determined and specified by the user before exercising the model. If user parameters are not specified, the default values shown in Exhibit II-3 are used.

Exhibit IV-1

Flowchart Showing the Inputs, Outputs, Data Files, and Data Flows of the SOLARSIM Solar Energy Model

Exhibit IV-2

Summary Matrix of SOLARSIM Model Components

COMPONENTS	DESCRIPTION
1. MAIN Program	A central program thermal logic controller
2. Subroutines 2a. CALC 2b. ECON 2c. YESNO 2d. READIN 2e. CYREAD 2f. SLREAD 2g. DDREAD 2h. TAREAD	Performs thermal analysis Performs economic analysis Accepts user specified parameters Reads user supplied inputs and returns values to the MAIN program Reads city and latitude data for 126 cities and 10 regions Read monthly long-term average total solar radiation for 126 cities and 10 regions Reads monthly long-term average degree-days for 126 cities and 10 regions Reads monthly long-term average ambient temperatures for 126 cities and 10 regions

Exhibit IV-2 - (Cont.)

COMPONENTS	DESCRIPTION
<p>3. Functions</p> <p>3a. RBAR</p> <p>3b. TAUALF</p> <p>3c. XPENT</p>	<p>Calculates ratio of daily extraterrestrial radiation incidence of a tilted surface</p> <p>Calculates transmittance-absorptance product</p> <p>Calculates market penetration from Years to Payback</p>
<p>4. Data Blocks</p> <p>4a. CITYDATA</p> <p>4b. SOLDATA</p> <p>4c. DDATA</p> <p>4d. TADATA</p>	<p>Contains name and latitude of 126 cities and 10 regions</p> <p>Contains monthly long-term average solar radiation data for 126 cities and 10 regions</p> <p>Contains long-term average degree-days for 126 cities and 10 regions</p> <p>Contains monthly long-term average ambient temperatures for 126 cities and 10 regions</p>

Exhibit IV-3

Table of the User Specified Input Parameters to SOLARSIM

CODE	VARIABLE DESCRIPTION	VALUE	UNITS
1	AIR SYSTEM=1, LIQUID SYSTEM=2.....	2.00	
2	COLLECTOR AREA.....	538.20	FT ²
3	FRPRIME-TAU-ALPHA PRODUCT(NORMAL INCIDENCE)..	0.70	
4	FRPRIME-UL PRODUCT.....	0.83	BTU/H-F-F2
5	NUMBER OF TRANSPARENT COVERS.....	2.00	
6	COLLECTOR SLOPE INCREMENT.....	0.0	DEGREES
7	AZIMUTH ANGLE (E.G. SOUTH=0, WEST=90).....	0.0	DEGREES
8	STORAGE CAPACITY.....	15.00	BTU/F-FT2
9	EFFECTIVE BUILDING UA.....	526.60	BTU/HR-F
10	CONSTANT DAILY BLDG HEAT GENERATION.....	0.0	BTU/DAY
11	HOT WATER USAGE.....	79.20	GAL/DAY
12	WATER SET TEMPERATURE.....	140.00	F
13	WATER MAIN TEMPERATURE.....	51.80	F
14	CITY CALL NUMBER.....	62.00	
15	THERMAL PRINT OUT BY MONTH=1, BY YEAR=2.....	2.00	
16	ECONOMIC ANALYSIS? YES=1, NO=2.....	1.00	
17	USE OPTMZD. COLLECTOR AREA=1, SPECIFD. AREA=2.	2.00	
18	PERIOD OF THE ECONOMIC ANALYSIS.....	20.00	YEARS
19	COLLECTOR AREA DEPENDENT SYSTEM COSTS.....	10.00	\$/FT2 COLL
20	CONSTANT SOLAR COSTS.....	1000.00	\$
21	DOWN PAYMENT(% OF ORIGINAL INVESTMENT).....	0.0	%
22	ANNUAL INTEREST RATE ON MORTGAGE.....	8.00	%
23	TERM OF MORTGAGE.....	20.00	YEARS
24	ANNUAL NOMINAL(MARKET) DISCOUNT RATE.....	8.00	%
25	EXPENSES(INSUR., MAINT.) OF SYSTEM IN 1ST YEAR	0.0	\$
26	ANNUAL % INCREASE IN ABOVE EXPENSES.....	6.00	%
27	PRESENT COST OF AUXILIARY FUEL (CF).....	6.00	\$/MBTU
28	CF RISE' LINEAR=1, %/YR=2, SEQ. OF VALUES=3....	2.00	
29	IF 1, WHAT IS THE SLOPE OF CF INCREASE?.....	0.0	\$/MBTU-YR
30	IF 2, WHAT IS THE ANNUAL RATE OF CF RISE.....	10.00	%
31	ECONOMIC PRINT OUT BY YEAR=1, CUMULATIVE=2...	2.00	
32	EFFECTIVE FEDERAL-STATE INCOME TAX RATE.....	0.0	%
33	TRUE PROP. TAX RATE PER \$ OF ORIGINAL INVEST..	0.0	%
34	INCOME PRODUCING BUILDING? YES=1, NO=2.....	1.00	
35	DPRC.' STR.LN=1, DC.BAL.=2, SM-YR-DGT=3, NONE=4.	4.00	
36	IF 2, WHAT % OF STR.LN DPRC.RT.IS DESIRED?...	150.00	%
37	USEFUL LIFE FOR DEPREC. PURPOSES.....	20.00	YEARS
38	SALVAGE VALUE AT END OF DEPREC. PERIOD.....	0.0	\$

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V. PROGRAM SPECIFICATIONS

PROGRAM REQUIREMENTS

The main requirement of the SOLARSIM solar energy model is to estimate the impacts of different economic and financial incentive scenarios designed to accelerate the market penetration of solar energy heating systems. The quantitative model calculates, on a regional and national level, domestic water and domestic space and water heating loads for single family detached dwellings. Also included in the model are a thermal and economic analysis of solar energy systems as well as life-cycle cost analysis of solar energy heating systems to various levels of intricacy.

OPERATING ENVIRONMENT

The SOLARSIM model is operational on FEA's IBM 370/168 computer configuration operated by Optimum Systems, Inc. in Rockville, Maryland. Execution of the SOLARSIM model is performed via batch mode using remote batch terminals and SUPERWYLBUR, a software program which permits remote job entry.

DESIGN CHARACTERISTICS

Inputs

The SOLARSIM model has three input files. The file, INPUT.SIMUL contains the user supplied parameters specific to a computer run. The HOUSE.DATA file contains forecasted housing stocks and the FCHART2.DATA file contains all the thermal data for the 126 cities and 10 FEA regions for the simulation.

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INPUT.SIMUL is in free-form card format. The form of this data set is created by answering the following user questions:

1. You may use either Scientific or English units. Do you wish to use Scientific units?

Yes or No

2. Would you like a listing of locations for which calculations can be made?

Yes or No

3. You may model the space heating load using the degree-day concept or you may type in a space heating load for each month. Do you wish to use the degree-day concept?

Yes or No

If "No", answer questions 3a. and 3b.

3a. Type in 12 load values, January first

3b. Do you wish to have these values relisted?

Yes or No

4. You may either have the ground reflectance set to .2 for all months or you may type in a value for each month. Do you wish to have the ground reflectance set to .2 for all months?

Yes or No

If "No", answer questions 4a. and 4b.

4a. Type in 12 values of ground reflectance, January first.

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4b. Do you wish to have these values relisted?

Yes or No

5. Would you like the program to perform an Economic Analysis?

Yes or No

If "Yes", answer question 5a.

5a. Is this an income producing building?

Yes or No

6. Do you need instructions to change other parameters?

Yes or No

The user should answer these questions and enter them sequentially into the input data set. The user has the capability to change the values of certain parameters from the default values, if desired. The possible parameters and their default values are listed in Exhibit IV-3. The format to change a parameter value is:

- Code # NEW VALUE

where Code # is the parameter number and NEW VALUE is the value you want the parameter to contain. Inputs for each of the 10 FEA regions are specified, as is each region fuel price, etc. After each of the region specific data has been specified as input, a 'RUN' card should follow. At the end of the data set, a STOP card must be specified. Then, this data set should be saved in card format.

All three input files are described in Exhibits V-1 thru V-9.

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FILE DESCRIPTION

DRN: _____

System Name: SOLARSIMFile Name: Thermal DataDSName: CN6231.KW3.FCHART2.DATA VOL = SER = FEA 011Description: File contains the solar radiation data, degree days, ambient temperature, city name or FEA region and latitudes for all 126 cities and 10 regions.

Security: _____

DSORG: PS UNIT: 3350 Disk LABEL: -RECFM: FB LRECL: 80 BLKSIZE: 3120

Update Frequency: _____ Retention Period: _____

Sequence (Major Field to Minor Field):

<u>Field Name</u>	<u>Characters</u>	<u>Form</u>	<u>Location</u>
<u>XLIST-14</u>	<u>-</u>	<u>-</u>	

Program Usage:

<u>Program</u>	<u>I</u>	<u>O</u>	<u>S</u>	<u>Program</u>	<u>I</u>	<u>O</u>	<u>S</u>

Records:

<u>Record Name (Mnemonics)</u>	<u>Record Length</u>	<u>Approx. Volume</u>
<u>CITY-LATT</u>	<u>28</u>	<u>137 records</u>
<u>AMB-TEMP</u>	<u>72</u>	<u>137 records</u>
<u>DEGREE-DAYS</u>	<u>72</u>	<u>137 records</u>
<u>SOLAR-RAD</u>	<u>72</u>	<u>137 records</u>
<u>ID</u>	<u>6</u>	<u>4 records</u>

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Page 1 of 1

RECORD DESCRIPTION

DRN: _____

System Name: SOLARSIM

Record Name: CITY-LATT

Record Length: Fixed 80 Variable (Max.)

Description: Record contains city and FEA regions with latitude.

File(s) of Which Record is an Element:

<u>File Name</u>	<u>File Name</u>	<u>File Name</u>
Thermal Data		

Security: _____

Data Elements Included:

[illegible]

*Element or Group

THE ORKAND CORPORATIONPage 1 of 1**RECORD DESCRIPTION**

DRN: _____

System Name: SOLARSIMRecord Name: AMB-TEMPRecord Length: Fixed 80 Variable (Max.)Description: Record contains ambient temperature by month for 126 cities and
10 FEA regions.

File(s) of Which Record is an Element:

<u>File Name</u>	<u>File Name</u>	<u>File Name</u>
Thermal Data		

Security: _____

Data Elements Included:

<u>Data Name (Mnemonic)</u>	<u>Format (Picture)</u>	<u>Position From</u>	<u>To</u>	<u>Field Form</u>	<u>Context E or G*</u>
Amb.-Temp. - Jan.	F6.0	1	6		
Amb.-Temp. - Feb.	F6.0	7	12		
Amb.-Temp. - Mar.	F6.0	13	18		
Amb.-Temp. - April	F6.0	19	24		
Amb.-Temp. - May	F6.0	25	30		
Amb.-Temp. - June	F6.0	31	36		
Amb.-Temp. - July	F6.0	37	42		
Amb.-Temp. - August	F6.0	43	48		
Amb.-Temp. - Sept.	F6.0	49	54		
Amb.-Temp. - Oct.	F6.0	55	60		
Amb.-Temp. - Nov.	F6.0	61	66		
Amb.-Temp. - Dec.	F6.0	67	72		

*Element or Group

THE ORKAND CORPORATIONPage 1 of 1**RECORD DESCRIPTION**

DRN: _____

System Name: SOLARSIMRecord Name: DEGREE-DAYSRecord Length: Fixed 80 Variable (Max.)Description: Record contains monthly heating degree-days for 126 cities and
10 FEA regions

File(s) of Which Record is an Element:

<u>File Name</u>	<u>File Name</u>	<u>File Name</u>
<u>Thermal Data</u>		

Security: _____

Data Elements Included:

<u>Data Name (Mnemonic)</u>	<u>Format (Picture)</u>	<u>Position From</u>	<u>To</u>	<u>Field Form</u>	<u>Context E or G*</u>
<u>Deg. Days - Jan.</u>	<u>F6.0</u>	<u>1</u>	<u>6</u>		
<u>Deg. Days - Feb.</u>	<u>F6.0</u>	<u>7</u>	<u>12</u>		
<u>Deg. Days - March</u>	<u>F6.0</u>	<u>13</u>	<u>18</u>		
<u>Deg. Days - April</u>	<u>F6.0</u>	<u>19</u>	<u>24</u>		
<u>Deg. Days - May</u>	<u>F6.0</u>	<u>25</u>	<u>30</u>		
<u>Deg. Days - June</u>	<u>F6.0</u>	<u>31</u>	<u>36</u>		
<u>Deg. Days - July</u>	<u>F6.0</u>	<u>37</u>	<u>42</u>		
<u>Deg. Days - August</u>	<u>F6.0</u>	<u>43</u>	<u>48</u>		
<u>Deg. Days - Sept.</u>	<u>F6.0</u>	<u>49</u>	<u>54</u>		
<u>Deg. Days - Oct.</u>	<u>F6.0</u>	<u>55</u>	<u>60</u>		
<u>Deg. Days - Nov.</u>	<u>F6.0</u>	<u>61</u>	<u>66</u>		
<u>Deg. Days - Dec.</u>	<u>F6.0</u>	<u>67</u>	<u>72</u>		

*Element or Group

THE ORKAND CORPORATIONPage 1 of 1**RECORD DESCRIPTION**

DRN: _____

System Name: SOLARSIMRecord Name: SOLAR-RADRecord Length: Fixed 80 Variable (Max.)Description: Record contains monthly solar radiation for 126 cities and
10 FEA regions

File(s) of Which Record is an Element:

<u>File Name</u>	<u>File Name</u>	<u>File Name</u>
Thermal Data		

Security: _____

Data Elements Included:

<u>Data Name (Mnemonic)</u>	<u>Format (Picture)</u>	<u>Position From</u>	<u>To</u>	<u>Field Form</u>	<u>Context E or G*</u>
Solar-Rad. - Jan.	F6.0	1	6		
Solar-Rad. - Feb.	F6.0	7	12		
Solar-Rad. - March	F6.0	13	18		
Solar-Rad. - April	F6.0	19	24		
Solar-Rad. - May	F6.0	25	30		
Solar-Rad. - June	F6.0	31	36		
Solar-Rad. - July	F6.0	37	42		
Solar-Rad. - August	F6.0	43	48		
Solar-Rad. - Sept.	F6.0	49	54		
Solar-Rad. - Oct.	F6.0	55	60		
Solar-Rad. - Nov.	F6.0	61	66		
Solar-Rad. - Dec.	F6.0	67	72		

*Element or Group

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Page 1 of 1

RECORD DESCRIPTION

DRN: _____

System Name: SOLARSIM

Record Name: _____ ID _____

Record Length: Fixed 80 Variable (Max.)

Description: Contains ID to # of cities and regions (i.e., 136)

File(s) of Which Record is an Element:

<u>File Name</u>	<u>File Name</u>	<u>File Name</u>
Thermal Data		

Security: _____

Data Elements Included:

[illegible]

*Element or Group

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FILE DESCRIPTION

DRN: _____

System Name: SOLARSIMFile Name: Housing DataDSName: CN6231.KW3.HOUSE.DATA VOL = SER = FEA011Description: File contains forecasted housing stocks for 1977-1990 for electrically heated spece and water and water only houses by FEA region.

Security: _____

DSORG: PS UNIT: 3350 Disk LABEL: -RECFM: FB LRECL: 80 BLKSIZE: 3120Update Frequency: - Retention Period: -

Sequence (Major Field to Minor Field):

<u>Field Name</u>	<u>Characters</u>	<u>Form</u>	<u>Location</u>
<u>REGION</u>	<u>2</u>	<u>I2</u>	
<u>YEAR</u>	<u>4</u>	<u>I4</u>	

Program Usage:

<u>Program</u>	<u>I</u>	<u>O</u>	<u>S</u>	<u>Program</u>	<u>I</u>	<u>O</u>	<u>S</u>

Records:

<u>Record Name (Mnemonics)</u>	<u>Record Length</u>	<u>Approx. Volume</u>
<u>HOUSE</u>	<u>80</u>	<u>140</u>

THE ORKAND CORPORATIONPage 1 of 1

RECORD DESCRIPTION

DRN: _____

System Name: SOLARSIMRecord Name: HOUSERecord Length: Fixed 80 Variable (Max.)Description: Record contains forecasted housing stocks

File(s) of Which Record is an Element:

<u>File Name</u>	<u>File Name</u>	<u>File Name</u>
<u>Housing Data</u>		

Security: _____

Data Elements Included:

<u>Data Name (Mnemonic)</u>	<u>Format (Picture)</u>	<u>Position From</u>	<u>To</u>	<u>Field Form</u>	<u>Context E or G*</u>
<u>YEAR</u>	<u>I4</u>	<u>1</u>	<u>4</u>		
<u>REGION</u>	<u>I2</u>	<u>6</u>	<u>7</u>		
<u>SPACE + WATER HOUSES - NEW</u>	<u>F9.3</u>	<u>10</u>	<u>18</u>		
<u>SPACE + WATER HOUSES - OLD</u>	<u>F9.3</u>	<u>21</u>	<u>29</u>		
<u>SPACE + WATER HOUSES - NOL</u>	<u>F9.3</u>	<u>32</u>	<u>40</u>		
<u>WATER ONLY HOUSES - NEW</u>	<u>F9.3</u>	<u>43</u>	<u>51</u>		
<u>WATER ONLY HOUSES - OLD</u>	<u>F9.3</u>	<u>54</u>	<u>62</u>		
<u>WATER ONLY HOUSES - NOL</u>	<u>F9.3</u>	<u>65</u>	<u>73</u>		

*Element or Group

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FILE DESCRIPTION

DRN: _____

System Name: SOLARSIMFile Name: INPUT DATADSName: CN6231.KW3.INPUT.SIMUL VOL = SER = FEA009Description: Contains input data and parameters for a given simulation
- Format is Free-Format Card Image -

Security: _____

DSORG: PS UNIT: 3350 Disk LABEL: -RECFM: FB LRECL: 80 BLKSIZE: 3120

Update Frequency: _____ Retention Period: _____

Sequence (Major Field to Minor Field):

<u>Field Name</u>	<u>Characters</u>	<u>Form</u>	<u>Location</u>
<u>NONE</u>			

Program Usage:

<u>Program</u>	<u>I</u>	<u>O</u>	<u>S</u>	<u>Program</u>	<u>I</u>	<u>O</u>	<u>S</u>

Records:

<u>Record Name (Mnemonics)</u>	<u>Record Length</u>	<u>Approx. Volume</u>
<u>See Documentation</u>		

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Outputs

Examples of SOLARSIM output reports are contained in Exhibits V-10, V-11 and V-12. Exhibit V-10 shows typical simulation results for a particular region (FEA regions 1-10). Exhibits V-11 shows results for the nation and Exhibit V-12 shows a summary of regional and national statistics.

Program Logic

Exhibit V-13 presents a process level flowchart of the SOLARSIM model. The flowchart is broken down into 3 basic parts:

- MAIN (including XPENT, YESNO, READIN, CYREAD, SLREAD, DDREAD, TAREAD)
- CALC (including TAUALF, RBAR)
- ECON

Exhibit V-10

DATE: 06/02/77

NATIONAL SIMULATION OF SOLAR ENERGY COMMERCIALIZATION
FEDERAL ENERGY ADMINISTRATION

PAGE: 2

S I N G L E F A M I L Y E L E C T R I C H O U S E S

BASE CASE - - NO FINANCIAL INCENTIVES

REGION: 1

S P A C E A N D W A T E R H E A T I N G

YEAR	PERCENT RETROFIT	CUM. SOLAR UNITS (X1000)	# SOLAR UNITS (X1000)	TOTAL AVAIL. UNITS (X1000)	CUM. COLL. AREA(FT2) (X10**6)	TOT. COLL. AREA(FT2) (X10**6)	TOT. YRLY LOAD(BTUS) (X10**12)	YRLY DISCNTD FUEL SVD(\$) (X10**6)	YRLY BTUS SAVED (X10**12)
1977	80.6	2.065	2.065	129.03	0.440	0.440	20.335	1.114	76.86
1978	84.1	4.905	2.840	146.23	1.074	0.634	22.805	2.548	186.39
1979	86.0	7.956	3.052	162.49	1.796	0.722	25.140	3.985	308.99
1980	85.6	11.262	3.305	181.39	2.671	0.876	27.865	5.513	453.05
1981	86.3	14.823	3.561	200.92	3.710	1.039	30.685	7.110	619.28
1982	86.9	18.629	3.806	221.17	4.928	1.217	33.613	8.760	808.66
1983	89.7	23.565	4.936	242.13	6.621	1.693	36.647	10.901	1066.66
1984	87.8	28.915	5.351	263.80	8.637	2.016	39.788	13.157	1364.48
1985	88.1	34.521	5.605	286.19	10.899	2.262	43.036	15.382	1690.85
1986	88.1	40.352	5.831	308.20	13.445	2.546	46.218	17.578	2048.02
1987	88.2	46.424	6.072	331.34	16.302	2.857	49.567	19.742	2437.95
1988	88.2	54.467	8.043	355.60	20.358	4.056	53.085	22.745	2977.06
1989	88.2	62.736	8.269	380.99	24.817	4.459	56.770	25.621	3554.37
1990	88.2	71.236	8.500	407.27	29.704	4.887	60.590	28.365	4170.87
TOTAL	87.5	71.236	71.236	407.27	29.704	29.704	546.145	182.522	21763.49

REGION: 1

D O M E S T I C W A T E R H E A T I N G

YEAR	PERCENT RETROFIT	CUM. SOLAR UNITS (X1000)	# SOLAR UNITS (X1000)	TOTAL AVAIL. UNITS (X1000)	CUM. COLL. AREA(FT2) (X10**6)	TOT. COLL. AREA(FT2) (X10**6)	TOT. YRLY LOAD(BTUS) (X10**12)	YRLY DISCNTD FUEL SVD(\$) (X10**6)	YRLY BTUS SAVED (X10**12)
1977	93.6	11.357	11.357	702.72	0.466	0.466	10.772	1.230	84.86
1978	95.2	25.164	13.807	706.63	1.031	0.565	10.832	2.567	187.73
1979	94.3	38.859	13.695	710.08	1.616	0.585	10.885	3.780	293.04
1980	93.6	52.397	13.537	718.30	2.239	0.623	11.011	4.900	402.69
1981	94.6	68.926	16.529	728.40	3.048	0.809	11.166	6.229	542.51
1982	92.9	85.505	16.579	740.45	3.909	0.861	11.351	7.457	688.36
1983	92.7	101.901	16.397	754.42	4.801	0.892	11.565	8.554	837.03
1984	94.0	122.364	20.463	770.28	5.978	1.177	11.808	9.925	1029.34
1985	92.3	142.875	20.511	788.01	7.215	1.236	12.080	11.168	1227.58
1986	92.0	162.944	20.068	800.29	8.471	1.258	12.268	12.241	1426.17
1987	93.2	187.166	24.222	814.92	10.048	1.577	12.492	13.534	1671.32
1988	91.6	211.108	23.942	831.82	11.687	1.639	12.751	14.673	1920.50
1989	89.2	234.875	23.767	850.91	13.371	1.685	13.044	15.661	2172.64
1990	91.2	262.375	27.500	871.81	15.386	2.015	13.364	16.795	2469.60
TOTAL	92.7	262.375	262.375	871.81	15.386	15.386	165.391	128.713	14953.37

V-14

Exhibit V-11

DATE: 06/02/77

NATIONAL SIMULATION OF SOLAR ENERGY COMMERCIALIZATION FEDERAL ENERGY ADMINISTRATION

PAGE: 23

SINGLE FAMILY ELECTRIC HOUSES

BASE CASE - - NO FINANCIAL INCENTIVES

N A T I O N A L S U M M A R Y									
YEAR	PERCENT RETROFIT	CUM. SOLAR UNITS (X1000)	# SOLAR UNITS (X1000)	TOTAL AVAIL. UNITS (X1000)	CUM. COLL. AREA(FT2) (X10**6)	TOT. COLL. AREA(FT2) (X10**6)	TOT. YRLY LOAD(BTUS) (X10**12)	YRLY DISCND FUEL SVD(\$) (X10**6)	YRLY BTUS SAVED (X10**12)
1977	89.0	191.239	191.239	9675.85	17.895	17.895	629.945	43.516	3844.92
1978	91.1	426.215	234.977	9911.84	39.587	21.692	671.085	91.551	8420.41
1979	91.8	684.422	258.207	10123.34	65.049	25.462	708.851	143.439	13674.43
1980	91.8	986.292	301.871	10412.73	96.069	31.020	753.976	200.803	19889.61
1981	91.7	1323.142	336.850	10676.79	132.316	36.247	798.093	262.565	26962.92
1982	91.8	1682.433	359.291	10969.00	173.540	41.223	844.484	325.580	34731.21
1983	91.9	2083.978	401.545	11288.24	221.714	48.174	893.080	392.855	43536.61
1984	91.2	2519.231	435.253	11633.48	279.076	57.362	943.819	465.781	53604.71
1985	91.3	2984.658	465.427	12003.73	342.528	63.451	996.640	538.132	64423.91
1986	90.5	3498.949	514.291	12351.54	416.490	73.962	1049.177	615.962	76615.12
1987	90.1	4054.133	555.183	12739.04	501.312	84.823	1105.373	697.212	90186.87
1988	89.8	4667.258	613.126	13165.09	601.397	100.085	1165.179	784.370	105641.94
1989	88.7	5294.141	626.884	13628.74	708.644	107.247	1228.555	867.783	121800.75
1990	88.0	5981.375	687.237	14122.91	830.982	122.339	1294.800	954.165	139719.94
TOTAL	90.4	5981.375	5981.367	14122.91	830.982	830.980	14740.434	6383.691	803052.75

AVE. S + W HEATING LOAD FOR 1977 IN MBTU/UNIT: 111.7
 AVE. S + W HEATING LOAD FOR 1990 IN MBTU/UNIT: 114.5
 AVERAGE MBTU SAVED/UNIT/YEAR FOR S + W HEATING: 51.6

AVE. COLLECTOR AREA/UNIT FOR S + W : 329.0 FT2
 AVE. COLLECTOR AREA/UNIT FOR WATER : 59.8 FT2
 AVE. MBTU SAVED/UNIT/YEAR FOR WATER : 11.6

PERCENT PENETRATION FOR SPACE AND WATER HEATING: 1.53
 PERCENT PENETRATION FOR WATER HEATING : 2.00
 PERCENT PENETRATION FOR S+W AND W HEATING : 2.90

	1980	1985	1990	1977-1990
PERCENT PENETRATION FOR SPACE AND WATER HEATING:	1.53	1.62	1.82	16.16
PERCENT PENETRATION FOR WATER HEATING :	2.00	2.76	3.46	29.91
PERCENT PENETRATION FOR S+W AND W HEATING :	2.90	3.88	4.87	42.35

DEFINITION OF OUTPUT:
 PERCENT RETROFIT IS THE NUMBER OF OLD UNITS THAT INSTALLED SOLAR DIVIDED BY THE TOTAL # OF SOLAR UNITS.
 NUMBER OF SOLAR UNITS IS THE NUMBER OF HOUSES(NEW OR RETROFIT) THAT INSTALLED SOLAR EQUIPMENT DURING THE YEAR.
 TOTAL AVAILAELE UNITS IS THE TOTAL NUMBER OF HOUSES THAT EXIST IN THE YEAR INCLUDING SOLAR UNITS.
 TOTAL COLLECTOR AREA IS THE TOTAL SQUARE FEET OF COLLECTORS THAT WERE INSTALLED DURING YEAR.
 TOTAL YEARLY LOAD IS THE NUMBER CF MBTU THAT WERE USED DURING THE YEAR BY ALL UNITS.
 YEARLY FUEL SAVED IS THE \$ AMOUNT OF FUEL SAVED BY SOLAR UNITS DURING THE YEAR COMPUTED BY THE CURRENT PRICE OF FUEL/MBTU TIMES # MBTU SAVED. THIS VALUE IS DISCOUNTED TO THE PRESENT VALUE.
 YEARLY MBTU SAVED IS THE TOTAL MBTU SAVED BY ALL SOLAR UNITS DURING THE YEAR

Exhibit V-12

DATE: 06/02/77

NATIONAL SIMULATION OF SOLAR ENERGY COMMERCIALIZATION FEDERAL ENERGY ADMINISTRATION

PAGE: 24

SINGLE FAMILY ELECTRIC HOUSES

BASE CASE - - NO FINANCIAL INCENTIVES

REGIONAL AND NATIONAL SUMMARY

REGION	AVERAGE LOAD(MBTU)		COLLECTOR AREA(FT ²)		MBTU SAVED	
	1977	1990	S+W	WATER	S+W	WATER
1	157.6	148.8	417.0	58.6	58.5	9.4
2	148.0	140.3	235.4	53.3	32.1	7.8
3	116.5	110.3	278.4	60.7	40.8	10.3
4	84.9	80.5	256.7	62.2	42.0	12.6
5	146.5	138.8	319.3	57.6	47.7	9.7
6	88.9	85.9	484.8	67.2	63.8	14.0
7	124.9	118.2	406.8	60.4	63.1	12.1
8	160.0	151.0	361.3	47.2	81.3	11.3
9	117.5	114.1	441.2	53.5	82.5	13.3
10	148.7	140.0	354.0	53.1	60.1	10.1
NATION	111.7	114.5	329.0	59.8	51.6	11.6

PERCENT MARKET PENETRATION

REGION	SPACE AND WATER				WATER ONLY				TOTAL			
	1980	1985	1990	77-90	1980	1985	1990	77-90	1980	1985	1990	77-90
1	1.82	1.96	2.09	17.49	1.88	2.60	3.15	30.10	2.34	3.31	4.13	38.27
2	1.84	2.01	2.20	16.93	1.90	2.08	2.78	22.32	2.75	3.24	4.21	33.38
3	1.49	1.62	1.70	15.47	1.87	2.07	3.25	25.04	2.62	3.10	4.50	36.46
4	1.49	1.59	2.00	16.50	1.51	2.58	4.14	28.96	2.59	3.87	5.92	43.57
5	1.52	1.70	1.85	13.65	1.52	2.11	2.94	20.10	2.28	3.26	4.39	30.83
6	1.43	1.31	1.50	19.19	2.95	5.30	5.10	62.17	3.95	6.25	6.23	76.56
7	1.49	1.61	2.07	15.35	1.90	2.65	4.26	30.67	2.59	3.68	5.81	42.18
8	1.83	1.93	2.10	19.30	1.86	2.51	3.06	23.10	3.28	4.15	4.94	40.38
9	2.10	1.84	1.04	27.93	4.08	5.03	3.01	66.80	5.53	6.30	3.74	86.49
10	0.50	1.12	1.35	8.77	0.52	1.14	2.12	10.99	0.91	2.12	3.38	19.17
NATION	1.53	1.62	1.82	16.16	2.00	2.76	3.46	29.91	2.90	3.88	4.87	42.35

SOLARSIM Main Program

Exhibit V-13 — Cont.

Exhibit V-13 — Cont.