Analysis Methods for
Solar Heating and Cooling Applications
Passive and Active Systems

SERI

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For information on the general operation of SERI, contact:

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Other publications in this series include:

Analysis Methods for Photovoltaic Applications, SERI/SP-35-230
Analysis Methods for Wind Energy Applications, SERI/SP-35-231

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SERI gratefully acknowledges the "Building Energy Analysis Computer Programs with Solar Heating and Cooling System Capabilities, Reference Manual," prepared by Arthur D. Little, Inc., Cambridge, Mass., for the Electric Power Research Institute (EPRI Project RP1269) and the "Survey of Currently Used Simulation Tools," prepared by Science Applications, Inc., McLean, Va., for the Department of Energy (Contract EM-78-04-4261). These documents were used extensively in preparing this brochure.

Analysis Methods for Solar Heating and Cooling Applications

Analysis methods for solar design allow the designer or researcher to investigate and, in many cases, predict the thermal performance of a particular building or system. These tools provide an alternative to constructing costly working models and often allow an extended forecast of system behavior under varying loads and inputs which may not be attainable through a physical representation.

This brochure, developed by the Systems Analysis, Market Development, and Data Base Systems branches, contains brief descriptions of analysis methods and design tools which are valuable in performing parametric studies of candidate designs. The methods included here range from simple rules-of-thumb aimed at builders and designers to the sophisticated simulation packages used by researchers. This brochure is aimed at providing information regarding common solar analysis methods and is not intended as a statement of advocacy for any of the methods described herein.

Output characteristics for these analysis methods range from graphical presentations useful for quick estimations by designers and architects to detailed hour-by-hour calculations. Various output formats may include heating and cooling loads, solar fractions, and economic considerations.

It must be emphasized that using a program without knowledge of the operation and underlying assumptions thereof can lead to erroneous results. A computer can analyze a user's input data only in the manner by which an author has programmed it. Thus, for these tools to function accurately, the user must carefully study the program user's guide or manual before performing the analysis.

SERI has begun to accumulate a comprehensive base of solar information and to be responsive to those who need it. More detailed information on these and other models and simulations can be obtained from SERI's Solar Models Data Base, which contains more than 200 models with solar applications ranging from predicting life-cycle costs to sizing solar collectors to measuring stress on ocean thermal platforms. The data base is accessible for online queries through the Solar Energy Information Data Bank, (303) 231-1960.

Detailed technical questions about the programs described in this document are best directed to the contacts listed with each entry. For information on applications or to report models or tools not included here, contact the Design Tool Manager, Market Development Branch. To submit descriptions of solar models or simulations for inclusion in the Solar Models Data Base, contact the Models Data Base Manager, Data Base Systems Branch.

Regional Solar Energy Centers are providing many services, particularly relating to the "ready now" solar technologies: passive solar heating and cooling, solar hot water, industrial process heat, small wind energy systems, and wood combustion. Centers and their service areas are:

Mid-American Solar Energy Complex
8140 26th Avenue, South
Bloomington, MN 55420

Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin

Northeast Solar Energy Center
70 Memorial Drive
Cambridge, MA 02142

Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont

Southern Solar Energy Center
61 Perimeter Park
Atlanta, GA 30341

Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, Puerto Rico, South Carolina, Tennessee, Texas, Virginia, West Virginia, Virgin Islands

Western Solar Utilization Network
921 S.W. Washington St.
Suite 160
Portland, OR 97205

Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming

The National Solar Heating and Cooling Information Center provides informative publications and specific answers to both technical and nontechnical questions regarding solar heating and cooling. Write the Center at P.O. Box 1607, Rockville, MD 20850; or call toll free: Telephone (800) 523-2929
From Pennsylvania (800) 462-4983
From Alaska, Hawaii (800) 523-4700

SHAC Manual Design Methods Summary

The following table describes solar heating and cooling manual design methods. This table does not give all of the design methods applicable to SHAC analysis, but it does contain the most currently used and best known methods. These methods do not require access to a computer although some (e.g., F-CHART) have been implemented on computers. They vary in degree of sophistication from the simple, almost rule-of-thumb type to methods requiring programmable calculators. Some of the latter type methods are available from the source indicated as prerecorded programs on magnetic cards.

Description	Author	Availability			Application				Col. Type		System Type		Tools Required				Basis of Method			Output		
		Cost ($)	Date	Reference/Source	Space Heat	Domestic Hot Water	Space Cooling	Economic Analysis	Liquid	Air	Active	Passive	Graphs/ Tables	4 Function Calculator	Scientific Calculator	Programmable Calculator	Detailed Simulation	F-Chart Correlation	Other Correlation	Solar Fraction	Optimum Area	Other
A Simplified Method for Calculating Solar Collector Array Size for Space Heating	J.D. Balcomb and J.C Hedstrom		1976	Sharing the Sun: Solar Technology in the Seventies. Vol. 4, American Section, International Solar Energy Society, 1976, pp. 281-284.	•	•			•	•	•		•	•					•		•	
Passive Solar Design Handbook	J.D. Balcomb and Bruce Anderson		Early 1980	Will be available from NTIS. 5285 Port Royal Road Springfield, VA 22161	•							•	•	•					•	•		
Optimal Sizing of Solar Collectors by the Method of Relative Areas	C.D. Barley and C.B. Winn		1978	Solar Energy, Vol. 21, No. 4, 1978, pp. 279-289.	•	•		•	•	•	•		•		•			•			•	
MESH	Dr. John Clark		1978	Dr. John Clark Central Solar Energy Research Corp. 1200 6th Street, Room 328 Detroit, MI 48226	•			•	•	•	•				•				•	•	•	
Predicting the Performance of Solar Energy Systems	U.S. Army Construction Engineering Research Lab		1977	Rept. No. AD-A035 608/9 ST (NTIS)	•	•	•	•	•	•	•		•	•					•	•	•	
Copper Brass Bronze Design Handbook—Solar Energy Systems	Copper Development Association	3	1978	Copper Development Association, Inc. 1011 High Ridge Road Stamford, CN 06905	•	•			•	•	•		•	•					•	•		
PEGFIX and PEGFLOAT	W. Glennie	75 both	1978	Princeton Energy Group 729 Alexander Road Princeton, NJ 08540	•							•				•	•					•
Solarcon Programs ST355 and ST365	R.W. Graeff	239 both 142 each 15 weather data	1977	Solarcon, inc. 607 Church Street Ann Arbor, MI 48104	•	•		•	•	•	•					•		•		•		
Solarcon Program ST33	R.W. Graeff	138	1979	Solarcon, Inc.	•							•				•	•			•		
Solar Heating Systems Design Manual	ITT Corporation Fluid Handling Division	2.50	1977	Bulletin TESE-576, Rev. 1 ITT Training & Education Dept. Fluid Handling Division Morton Grove, IL 60053	•	•			•	•	•		•	•			•			•		
A General Design Method for Closed-Loop Solar Energy Systems	S.A. Klein and W.A. Beckman		1977	Proceedings of the 1977 Annual Meeting, Vol. 1 American Section, International Solar Energy Society, 1977, pp. 8.1-8.5.			•		•		•		•		•			•		•		
Solar Heating Design by the F-Chart Method	S.A. Klein, W.A. Beckman, and J.A. Duffie	10	1977	John Wiley and Sons, New York, N.Y., 1977 (Publisher)	•	•		•	•	•	•		•	•				•		•		
A Design Procedure for Solar Heating Systems	S.A. Klein, W.A. Beckman, and J.A. Duffie		1976	Solar Energy, Vol. 18, No. 2, 1976, pp. 113-127.	•	•			•				•		•				•	•		
TEANET	J.T. Kohler and P.W. Sullivan	95	1978	Total Environmental Action, Inc. Church Hill Harrisville, NH 04350	•							•				•	•					•

The GFL Method for Sizing Solar Energy Space and Water Heating Systems	G.F. Lameiro and P. Bendt		1978	Rept. No. SERI-30 Solar Energy Research Institute 1617 Cole Boulevard Golden, CO 80401	•				•	•	•		•		•			•		•		
A Design Handbook for Direct Heat Transfer Passive Solar Systems	R.M. Lebens	10	1978	Northeast Solar Energy Association P.O. Box 541, 22 High Street Brattleboro, VT 05301	•			•				•	•			•	•			•		
A Rational Procedure for Predicting the Long-Term Average Performance of Flat-Plate Solar Energy Collectors	B.Y.H. Liu and R.C Jordan		1963	Solar Energy, Vol. 7, No. 2, 1963, pp. 53-70.	•	•			•	•	•		•		•		•			•		
Pacific Regional Solar Heating Handbook	Los Alamos Scientific Lab		1976	Rept. No. TID-27630 (NTIS)	•	•			•	•	•		•		•				•	•		
Prediction of the Monthly and Annual Performance of Solar Heating Systems	P.J. Lunde		1977	Solar Energy, Vol. 20, No. 3, 1977, pp. 283-287.	•	•			•		•		•	•					•	•		
SCOTCH Program	R. McClintock	195 Thermal alone, 175; econ. anal. alone, 75	1977	SCOTCH Programs P.O. Box 430734 Miami, FL 33143	•	•		•	•	•	•					•		•		•	•	
Solar Heating of Buildings and Domestic Hot Water	Naval Facilities Engineering Com. E.J. Beck, Jr. and R.L. Field		1976	Rept. No. AD-A021 862/8ST (NTIS)	•	•		•	•	•	•		•		•			•		•	•	
PCTS	J. Schoenfelder	F-Chart Therm. 35; F-Chart Econ. 35	1978	Central States Research Corp. P.O. Box 2623 Iowa City, IA 52240	•	•		•	•	•	•					•		•		•	•	
Domestic Hot Water Manual Using Sunearth Solar Collector Systems	Sunearth Corp.	3	1976	Sunearth Solar Products Corp. Technical Services R.D. 1 P.O. Box 337 Green Lane, PA 18054		•			•		•		•					•		•		
An Averaging Technique for Predicting the Performance of a Solar Energy Collector System	G.H. Stickford		1976	Sharing the Sun, Vol. 4, 1976, pp. 295-315.	•	•			•	•	•	•	•		•		•			•		
Calculation of Long-Term Solar Collector Heating System Performance	S.R Swanson and R.F. Boem		1977	Solar Energy, Vol. 19, No. 2, 1977, pp. 129-138.	•				•	•	•		•		•			•		•		
Minimum Cost Sizing of Solar Heating Systems	J.C. Ward		1976	Sharing the Sun, Vol. 4, 1976, pp. 336-348.	•			•	•	•			•		•			•		•	•	
Designing and Building a Solar House; Your Place in the Sun	D. Watson	9	1977	Garden Way Publishing Charlotte, VT 05445	•	•		•	•	•	•		•	•			•			•		
SEEC I — Heat Load, Monthly Solar Fraction, Economics	C.B. Winn	125	1976	Solar Environmental Engineering Co., Inc. 2524 East Vine Drive Fort Collins, CO 80522	•	•		•	•	•	•					•		•		•		
SEEC II — Collector Optimization, Annual Solar Fraction, Economics	C.B. Winn, D. Barley, G. Johnson, J. Leflar	95	1978	Solar Environmental Engineering Co., Inc.	•	•	•	•	•	•	•					•		•			•	
SEEC III — SEEC II Plus Insulation Optimization	C.B. Winn, D. Barley, G. Johnson, J. Leflar	125	1978	Solar Environmental Engineering Co. Inc.	•	•		•	•	•	•					•		•			•	
SEEC VI — Passive Solar Heating	C.B. Winn, D. Barley, G. Johnson, J. Leflar	125	1978	Solar Environmental Engineering Co., Inc.	•			•				•				•			•	•		
Sunshine Power Programs for Modeling Solar Energy Components and Systems	G. Shramek	30-60	1977	Sunshine Power Co. 1018 Lancer Drive San Jose, CA 95129	•	•		•	•	•	•	•				•	•	•	•	•		•
Mazria Design Patterns (Rule-of-Thumb) in The Passive Solar Energy Book	Edward Mazria	11	1979	Rodale Press, Emmaus, PA 18049	•				•	•		•	•				•			•	•	•

SHAC Computer Methods Summary

The following summary table and text describe the most frequently used and currently available solar analysis computer methods. The information was obtained largely from a program author survey conducted by Arthur D. Little, Inc. for the Electric Power Research Institute and primarily reflects the opinions of each program author.

Most summary table categories are self-explanatory; however, the intended user category needs emphasis. Programs suitable for use by builders were limited to the interactive type program that interrogates the user by a question and answer methodology. Architects/engineers use mainly design-oriented computer programs and generally restrict their analysis to standard input/output options of the program. The research engineer generally has hands-on access to the program and is very familiar with both the operation and assumptions of the program and the details of the system being analyzed.

Program Name	Latest Version	Availability				Application							Intended Users			Computation Interval		Computer Versions Available	Economic Analysis	Sponsor
		Purchase ($)	Time Share	Special Arrangements	Comments	User Manual	Service Hot Water	Space Heating	Space Cooling	Process Heat	Active System	Passive System	Research Engineers	Architect/Engineers	Builders	Hour	Month			
ACCESS*	1978	10,000		●	No cost to EEI members	●	●	●	●	●	●		●	●		●		IBM	●	Edison Electric Institute (EEI)
BLAST*	1978	300	●		Training available	●	●	●	●		●		●	●		●		CDC	●	USAF, USA, GSA
DEROB	1979	Nom.				●		●	●			●	●	●		●		CDC		NSF, ERDA, DOE
DOE-2*	1979	400	●			●	●	●	●		●	●	●	●		●		CDC	●	LASL, DOE
EMPSS	1978	500		●	Consulting with ADL	●	●	●	●		●		●	●		●		IBM	●	EPRI
F-CHART	1978	100	●		Training available	●	●	●			●			●	●		●	CDC, IBM UNIVAC	●	DOE
FREHEAT	1979	150			Limited documentation			●				●	●			●		CDC	●	DOE
HISPER	1978	Avail. on request			Limited documentation		●	●	●		●		●			●		UNIVAC		NASA, MSFC
HUD-RSVP/2	1979	175	●		Based on F-CHART	●	●	●			●	△		●	●		●	CDC UNIVAC	●	HUD
SHASP	1978	Avail. on request				●	●	●	●		●		●			●		UNIVAC	●	DOE
SIMSHAC	1973	300					●	●			●		●			●		CDC	●	NSF
SOLAR-5	1979		●					●	●			●		●	●	●	●	CDC		UCLA, DOE
SOLCOST	1979	300	●			●	●	●			●			●	●		●	CDC, IBM UNIVAC	●	DOE
SOLOPT	1978	20				●	●	●			●		●				●	AMDAHL	●	Texas A&M Univ.
SOLTES	1979				Available Argonne Fall 1979	●				●	●		●			●		CDC		Sandia
SUNCAT	1979	Nom.			Limited documentation	●		●				●	●	●		●		Data General Eclipse	●	NCAT
SUNSYM®	1979		●	●		●	●	●	●		●			●		●		IBM	●	Sunworks Comp. Systems
SYRSOL	1978	Nom.			Avail. but not actively marketed		●	●	●			●	●	●	●	●		IBM	●	ERDA, NSF, DOE
TRACE SOLAR*	1979		●	●		●	●	●	●	●	●		●	●		●	●	IBM	●	The Trane Co.
TRNSYS	1979	200	●		Training required	●	●	●	●		●	△	●			●		CDC, IBM UNIVAC		DOE
TWO ZONE	1977			●		●		●	●			●	●			●		CDC	●	LBL
UWENSOL	1978	200				●		●				●	●			●		CDC		State of Wash.
WATSUN II	1978	200				●	●	●			●		●			●		IBM	●	Nat'l Research Center of Can.

*Programs are primarily developed for large-scale, multi-zone applications

△ Being added

ACCESS

The ACCESS (Alternate Choice Comparison for Energy System Selection) program was designed to provide economic comparisons among the different energy systems which may be used in buildings. ACCESS was developed in 1972 by Seelye, Stevenson, Value, and Knetch consulting engineers under funding by the Edison Electric Institute; the current Version 6 was released in 1978. Its primary purpose is to enable decisions on energy sources rather than to design an HVAC system. The program series consists of the energy analysis program and an independent short financial analysis program. The energy analysis program can analyze up to six separate mechanical/electrical systems including consideration of various lighting schemes, terminal systems, and primary systems in a single computer run. Onsite systems are simulated on a modular basis to facilitate specifications of various combinations of HVAC terminals and primary systems including cogeneration systems. Building loads may be input on an hourly basis, or total building design loads may be input for summer and winter design conditions and steady state hourly loads, then scaled based on the hourly weather conditions. The model simulates active liquid and air type solar heating and cooling systems with stationary as well as tracking collectors. Input consists of building construction data, occupancy schedules, base energy load profiles, heating and cooling load data, description of terminal systems, hourly meteorological data, and selection of the type of output. Output consists of monthly energy usage and demand levels for each input specified meter in the building, with the option of sample calculations for selected days, hours, and zones.

Reference

Douglas, Edwin and George Reeves, "ACCESS: Alternate Choice Comparison for Energy Systems Selection," ASHRAE Journal, November 1971, pp. 41-43.

Contact

Edison Electric Institute
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1140 Connecticut Ave.
Washington, DC 20036
(202) 862-3846

BLAST

The BLAST (Building Loads Analysis and System Thermodynamics) program, developed by the U.S. Army Construction Engineering Research Laboratory (CERL) with joint sponsorship by the U.S. Air Force and the U.S. Army, was released for public use in 1978. The program was written to permit analysis and design of energy conservation in new and existing buildings including application of liquid type active solar energy and total energy systems. Many of the methods used are based on ASHRAE and NBSLD algorithms; however, new algorithms have been included relating to building shading, cooling coil modeling, and room heat balances. The program employs its own English-like input language and can perform two types of analyses: (1) Hourly energy analysis in which actual hourly weather data are used to calculate hourly heating and cooling loads for each zone of the building. Output from the hourly energy analysis is used as input to the system simulation subprogram. (2) Design day analysis in which user-supplied input weather data are used to calculate hourly heating and cooling loads for each zone of the building for the specified design days. Life-cycle costs are computed for each central plant option selected on the basis of user-supplied or default capital costs, maintenance costs, operating costs, and utility rate schedules. Output data provide monthly and daily loads and energy consumption with separate meters for different end uses. Both average and peak day load and energy profiles may be output.

References

"The Building Loads Analysis and System Thermodynamics (BLAST) Program, Vol. I, User's Manual," AD-A048 982/3ST, 1977.

"The Building Loads Analysis and System Thermodynamics (BLAST) Program, Vol. II, Reference Manual," AD-A048 734/8ST, 1977.

Contact

U.S. Army Construction Engineering Research Lab
Attn: Douglas C. Hittle
P.O. Box 4005
Champaign, IL 61820
(217) 352-6511

DEROB

The DEROB (Dynamic Energy Response Of Buildings) programs have been under development since 1972 at the University of Texas as a research and design tool relating to heat flow in complex structures. In its current release, 1979, it is capable of simulation of a variety of passive solar system designs. The series consists of three main programs: (1) development of building geometric factors relating to radiation interchanges, (2) development of material properties for elements of the structures, and (3) calculations of hourly loads and interior distributions. This routine also allows for the modeling of a multizone configuration. Interior heat flow takes place by air circulation, conduction through opaque walls, and direct radiation via transparent walls. Interior temperature control is by passive means only. Input data consist of building geometry data, thermophysical property data, use factors, and hourly SOLMET weather data. Output data for daily, monthly, and yearly load profiles are available.

Reference

Arumi, F. and D. Northrup, "A Field Validation of the Thermal Performance of a Passively Heated Building as Simulated by the DEROB System," Energy and Buildings, Vol. 2, No. 1, January 1979, p. 65.

Contact

University of Texas
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DOE-2 Solar Simulator

An active solar system simulator package, designed as a stand-alone program or as a module of the DOE-2 building energy analysis program, was developed at Los Alamos Scientific Laboratories with release in early 1979. A component base approach is used whereby the user defines which components are present and the manner in which they are connected. The component library contains liquid and air collector systems (stationary or tracking), multiple storage units, and an absorption chiller. Several preconnected liquid or air solar heating systems are also included in the program library. As a stand-alone program it is applicable to residential building analysis; commercial building systems can be evaluated when the program is used as part of DOE-2. Features of the input processor include free-formatting of input data, defaults, and scaling of certain input variables by other inputs. Hourly weather data are user supplied in DOE-2 weather format. Several insolation models are available for both measured and calculated radiation. Output options allow the user to select predefined reports or to define reports or plots according to special requirements.

References

Hunn, B.D., et al., "CAL/ERDA Program Manual," Lawrence Berkeley Lab ANG/ENG-77-04, October 1977.

Roschke, M.A., B.D. Hunn, and S.C. Diamond, "Component-Based Simulator for Solar Systems," LA-UR-78-1494, Proceedings of Systems Simulation and Economic Analysis for Solar Heating and Cooling Conference, San Diego, Calif., June 1978.

Contact

Los Alamos Scientific Laboratory
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Mail Stop 985
Los Alamos, NM 87545
(505) 667-3348

EMPSS

EMPSS (EPRI Methodology for Preferred Solar Systems) is a solar simulation program, developed by Arthur D. Little, Inc. in 1977 under funding by the Electric Power Research Institute, to provide a basis on which to select a residential heating and cooling system which minimizes total life-cycle costs associated with owning and operating the equipment and with supplying electrical energy to meet the building's energy requirements. The program is capable of simulating on an hourly basis conventional, active solar, load management, or combinations of these systems. Inputs to the model consist of a weather tape; parameters describing the thermal characteristics of the building and its occupants; data related to the utility's cost of electrical supply, rate schedules, and system-wide loads; operating characteristics of the HVAC system and its control logic; and economic indices such as equipment life, mortgage rates, inflation rates, etc. The program user is permitted latitude in describing the house and choosing the HVAC system. Building loads are based on finite difference coupling equations. Both the electrical energy use and energy costs are output in monthly and annual summaries. Energy use data for the peak residence day of the month and the utility's peak generation day of the month are also output. The output summaries give a description of the technical performance of the house and its HVAC system and break down the cost by the various utility cost components.

Reference

"EPRI Methodology for Preferred Solar Systems (EMPSS) Computer Program Documentation, User's Guide," Arthur D. Little, Inc., EPRI ER-771, May 1978.

Contacts

Arthur D. Little, Inc.
Attn: Dan Nathanson
20 Acorn Park
Cambridge, MA 02140
(617) 864-5770

EPRI
Attn: James W. Beck
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Palo Alto, CA 94304
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F-CHART

A computer tool for estimating the long-term thermal performance and life-cycle cost of active solar heating systems, F-CHART was developed at the University of Wisconsin Solar Energy Laboratory in 1976 under funding by the Department of Energy. Its most current version (3.0) was released in June 1978. The F-Chart method, which models residential liquid or air solar water heating or combined solar water and space heating systems (solar cooling or heat pump systems cannot be modeled), is based on correlations of detailed computer simulations (using the TRNSYS model) in the form of "f-charts" showing the fraction of the total monthly loads carried by solar energy as a function of two dimensionless parameters (the ratio of available solar energy to the load and the ratio of a reference collector heat loss to the load). Weather data for 266 cities are built into the program with the ability offered to the user to input additional weather data at time of use. The program is interactive and requires the following general input data: Collector design parameters, storage capacity, building UA and internal heat generation, domestic water temperature and use, and various economic parameters. A list of default values is provided. Output data describe the monthly thermal loads, weather parameters and solar fraction and annual cash flow, corresponding to the life-cycle cost. Calculations may be made for a specified collector area or for an economic optimum collector area determined by the program.

References

"F-CHART User's Manual, An Interactive Program for Designing Solar Heating Systems," EES Report 49-3, Solar Energy Laboratory, University of Wisconsin, June 1978.

Beckman, W.A., S.A. Klein, and J.A. Duffie, Solar Heating Design by the F-Chart Method, Wiley-Interscience, New York, 1977.

Contact

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FREHEAT

FREHEAT was developed at Colorado State University (CSU) under funding from the Department of Energy, with its original release in 1978 and its current release in 1979. The program is intended as a research tool for the design of a passive solar heating system at CSU. A one-room system may be modeled with a simple mass wall or with an isothermal mass wall. Heat capacity may be added to the room and floor, or to the floor only. Direct gain systems may also be simulated, with the addition of a mass floor (either single node or multi-node), or an interior mass wall. Inputs to the system include hourly weather data, type of system, and thermodynamic properties. The outputs provided by the program are hourly room temperature, node temperatures, solar fraction, energy incident on wall, energy stored in wall, auxiliary energy required, and standard deviations in temperature, both daily and for the study period.

Contact

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(303) 491-6783

HISPER

HISPER (High Speed Performance) was developed by NASA's Marshall Space Flight Center under funding from DOE and became public in 1978. The program simulates the operation of an active solar heating and cooling system in response to loads which are based upon measured climatic data. Loads calculations are limited to single family or small commercial dwellings with attic and floor losses considered. The dwelling heat build-up from incident wall and roof radiation is accounted for in two ways: (1) the ASHRAE Sol-Air temperature method and (2) limiting ambient temperatures above or below which no heating and cooling are required (by assumptions relating to the thermostat deadband). Dwelling orientation is limited to north-south and east-west. Input data for the loads calculations are heat transfer loss coefficients for the building walls, ceiling, and roof; building internally generated heat; and infiltration rates. Domestic hot water loads are taken from an interval 24-hour use table totaling 60 gallons per day. A flat-plate collector is modeled using either liquid or air as the heat transfer medium. In the liquid, the storage tank is assumed non-stratified. In the air system, rock bed storage is modeled after the NTU model of Hughes, Klein, and Close with axial conduction added. The program is available but has limited documentation.

Reference

Gray, J.C., "Solar Heating and Cooling High Speed Performance Program-HISPER," NASA/TN-240-1661, July 1976.

Contact

National Aeronautics and Space Administration
Attn: Robert Elkin
George C. Marshall Space Flight Center
Huntsville, AL 35812
(205) 453-1757

RSVP/2

RSVP (Residential Solar Viability Program) is an interactive computer program developed in 1977 and updated in 1979 by Booz, Allen & Hamilton, Inc. under contract with the U.S. Department of Housing and Urban Development (HUD). The program combines a simplified solar system performance model, which is taken from the latest version of F-CHART, with a comprehensive economic analysis model for residential solar applications. System performance is calculated on a monthly average basis and includes flat-plate air and water systems for hot water and space heating. The data base contains weather data for 266 cities, including cooling degree days for use in estimating conventional air conditioning loads. Auxiliary systems modeled include electric furnace, electric baseboard, heat pump, and gas and oil furnaces. Outputs include thermal system performance, building loads, and a variety of economic reports. The conversational interface is designed for a variety of users by allowing access to the program inputs at various levels of detail and providing default values and data checks for most input variables. It contains features such as report selection and an iteration routine that facilitates sensitivity analysis. The economic routines include an income property analysis.

References

"HUD Residential Solar Economic Performance Model: User's Manual," U.S. Department of Commerce, PB-273-199, June 1977.

"HUD Residential Solar Economic Performance Model: Programmer's Manual," U.S. Department of Commerce, PB-273-200, June 1977.

Contact

RSVP
National Solar Heating and Cooling Information Center
P.O. Box 1607
Rockville, MD 20850
(202) 223-8105

SHASP

SHASP (Solar Heating and Air-Conditioning Simulation Programs) was developed within the Mechanical Engineering Department at the University of Maryland with funds provided by the Department of Energy. Originally released in 1977, SHASP consists of a set of eight programs designed to simulate the performance of solar heating, cooling, and hot water systems, subject to a variety of operational control strategies using real or stochastic weather data. Although the system configurations are built into the program, the performance characteristics of the components can be specified by the user via performance curves. Liquid, flat-plate and evacuated tube type collectors can be simulated as can solar cooling derived from an absorption machine or a Rankine cycle heat engine vapor compression system. Although the program has to date been primarily used by and for researchers, the user's manual and source code are available at no cost by contacting the authors.

Reference

"SHASP Solar Heating and A/C Simulation Program," Solar Energy Project Report, Department of Mechanical Engineering, University of Maryland, December 1978.

Contact

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SIMSHAC

SIMSHAC (Simulation Model for Solar Heated And Cooled Buildings) was developed and released in 1973 by Colorado State University under a National Science Foundation grant. The program was written primarily for control system studies associated with the development of the CSU-I solar demonstration house. The model contains a solar irradiation program, an implicit finite difference thermal analyzer program to calculate house heating loads, and a system simulation program based on the components (modular) approach. Inputs to the model include specification of the components that comprise the system and how they are connected, initial conditions, data relating to the building configuration, and weather data. Four different methods of modeling incident solar radiation are included in the program. Output data consist of daily, monthly, and annual building loads, energy usage, and energy costs based on energy and demand rate schedules.

Reference

Winn, C.B., G.R. Johnson, and T.E. Corder, "SIMSHAC — A Simulation Program for Solar Heating and Cooling of Buildings," Simulation, Vol. 23, No. 6, 1974.

Contact

Mechanical Engineering Department
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Colorado State University
Fort Collins, CO 80523
(303) 491-6783

SOLAR-5

SOLAR-5 is an interactive, computer-aided design tool intended for use at the very beginning of the design process when most of the decisions affecting the building's ultimate energy performance are made. Working at a graphic terminal, the architect can input a description of the building in about 10 minutes. The computer responds by plotting on the CRT a 3-dimensional picture of the building's heat gain or loss for each hour of each month of the year.

This "hour-month" surface resembles a topo map, showing the heating and cooling loads of the total building, or of any piece of the building's envelope, or of any internal loads. It takes less than a minute for the architect to make design revisions and see the results plotted.

Standard ASHRAE algorithms are used to compute hourly incident solar radiation, sol-air temperature, total equivalent temperature difference, heat loss, and heat gain. The Mackey and Wright algorithms account for the time lag and decrement factor of the building envelope. Hourly weather data are generated from NOAA monthly averages.

It must be emphasized that SOLAR-5 is an architectural design tool and not an HVAC simulation program. Its objective is to help architects evaluate different building envelope designs; therefore, it needs to provide detailed information about instantaneous heating and cooling loads, but only a general approximation of annual energy consumption.

Reference

Milne, M. and S. Yoshikawa, "SOLAR-5, An Interactive Computer-Aided Passive Solar Building Design System," Proceedings of the 3rd Annual Passive Solar Conference, AS/ISES, January 1979, San Jose, California.

Contact

School of Architecture and Urban Planning
Attn: Murray Milne
University of California, Los Angeles
Los Angeles, CA 90024
(213) 825-7370

SOLCOST

SOLCOST calculates optimized components and compares life-cycle costs of a solar system versus a conventional HVAC system including tax incentive advantages. It was developed by Martin Marietta Aerospace Corp. in 1978 under contract to ERDA. The current (1979) version has a user-friendly interactive front end and is maintained by International Business Services, Inc. SOLMET weather data are used together with gross solar system performance characteristics (both from the program's data base) to calculate heating and cooling loads for the specific residence and then to choose an optimum collector area and storage volume. The optimum system is that with the lowest life-cycle cost (compared with a conventional system) as derived from the user's choice of financial indices and type of solar system. Space and domestic water heating systems with air or liquid collectors, pressure systems, and component sizing subroutines constitute the current capabilities of SOLCOST. The hot water systems may be single family or multifamily and commercial with or without a heat exchanger. For a typical analysis, SOLCOST calculates the portion of the load supplied by solar, the optimum collector size, and the payback period for the solar system investment compared to a conventional system. Sizing the collector is based on calculations for a single day in each of the 12 months of the year. Weather data consist of historical averages of maximum and minimum temperatures, degree days, and percentage of sunshine. Financial analysis incorporates the owner's tax structure and initial outlay for the solar system when computing a life-cycle cost based on constant fuel or electric (energy/demand) rates during each year with provision made for cost escalation over the equipment life.

Reference

"SOLCOST: Space Heating Handbook with Service Hot Water and Heat Loads Calculations," DOE/CS -0042/3, July 1978.

Contact

International Business Services, Inc.
1010 Vermont Ave., N.W.
Suite 1010
Washington, DC 20005
(202) 628-1470

SOLOPT

This program was developed at and sponsored by Texas A & M University. After its original release in 1978, a later version of SOLOPT appeared in the same year. Although the program is available to the public, its primary use is as a life-cycle cost optimization tool for Texas A & M students taking a solar systems design course. A variety of liquid circulant solar collectors with liquid storage medium may be simulated with this program. Flat-plate, evacuated tube, and focusing collector models are provided internally in the program. They may be of the stationary or hourly tracking type, and the user need only specify gross collector performance parameters in order to obtain annual performance predictions. Hourly calculations for the collector are performed over the entire year using weather data that need only be resolved on a monthly basis. No building heating or hot water loads are evaluated by the program and must be provided by the user as input data. Simulation of conventional HVAC systems as auxiliaries to the solar collector is limited to forced air furnaces, either gas, oil, or electric, and to an electric heat pump. Output from the program includes daily, monthly, and annual energy use provided by the solar system and by the HVAC auxiliaries. Life-cycle cost of the solar system is based upon uniform electric rates (energy only) and single metering for the residence.

Reference

Degelman, L., "User's Guide to SOLOPT, Mod 2: A Computer Program for Optimization of Flat-Plate Solar Collector Areas," Department of Agriculture, Texas A & M University, 1978.

Contact

Department of Agriculture
Attn: Larry O. Degelman
Texas A & M University
College Station, TX 77843
(713) 845-1015

SOLTES

The original release of SOLTES in 1978 signaled the debut of the first general purpose computer program for simulation of industrial process heat operations and thermal electric systems. It was developed by Sandia Laboratories under contract to DOE and is available to the public through Argonne National Laboratory. SOLTES is a model solar program based on the component method. Mathematical models of solar collectors, pumps, switches, extraction turbines, condensers, regenerative heaters, air conditioners, and other components currently exist. SOLTES also allows user-supplied routines. A preprocessor constructs a SOLTES program that uses only those routines in the system model. A load management capability allows SOLTES to stimulate total energy systems that simultaneously follow heat and power loads and demands. Cooling, heating, electrical, mechanical, thermal, and/or hot water loads may be read from a data file, combined by category, scaled and/or peak shaved and followed. Although building space conditioning loads are not currently calculated, SOLTES can read and follow cooling and/or heating loads that represent real data, typical data, or data generated by building space conditioning loads programs. Hourly weather data from TMY are used or the user can supply weather data with any time increment. The system performance and energy accounting parameters may be written to a file for access by user-supplied economic, rate, or auxiliary supply analysis programs.

Reference

Fewell, M.E. and N.R. Grandjean, "User's Manual for Computer Code SOLTES-1 (Simulation of Large Thermal Energy Systems)," SAND 78-1315 (Revised), May 1978.

Software Contact

Sandia Laboratories
Attn: Norman Grandjean
Division 423
Albuquerque, NM 87185
(505) 264-6296

Engineering Contact

Sandia Laboratories
Attn: Merton Fewell
Division 5512
Albuquerque, NM 87185
(505) 264-3041

SUNCAT

The SUNCAT program was developed by the National Center for Appropriate Technology (NCAT) to simulate the thermal performance of a passive solar structure. The program consists of two mainline programs which simulate the transmissivity and shading of a user-specified glazing system and the thermal performance of a user-specified passive solar structure. Input to the program consists of hourly radiation and temperature data files and a window and building description. The present version of the program allows for interactive creation of the window and building descriptions. The output of the program is a tabulation by zone and total building of the thermal characteristics of the passive system, including solar fraction and the useful heat delivered.

Contact

National Center for Appropriate Technology
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P.O. Box 3838
Butte, MT 59701
(406) 723-5475

SUNSYM®

The SUNSYM® program was developed privately by Sunworks Computer Services for primary use in designing solar collectors. Two versions of the program exist: SUNSYM1, based on the general theory of flat-plate collector performance, and SUNSYM2, based on the performance equation and incident angle modifier as determined by ASHRAE 93-77 testing. SUNSYM2 is particularly useful in making performance comparisons between collector manufacturers. SUNSYM1 is useful when it becomes necessary to vary a collector's design parameters. There is also a version of the program which determines the extent of shading for adjacent rows of collectors. In addition to these programs, Sunworks also has Sun Shadow which optimizes collector spacing with respect to a shadow length cast from a given collector row. This program assists designers in determining the collector placement on a roof with respect to spacing and collector tilt. Sunworks also has a return on investment program, ROI, which is modeled from the basic NBS solar economic analysis program. This program analyzes the return on investment potential for solar systems, taking into account fuel escalation, inflation, depreciation, tax incentives, solar fraction, and other pertinent data.

Contact
Sunworks
Division of Sun Solector Corp.
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Somerville, NJ 08876
(201) 469-0399

SYRSOL

The SYRSOL (Syracuse University Solar Building Energy Analysis) program for simulating the hourly thermal performance of a multizone building with a solar assisted series of commercially available water-to-air heat pumps in a closed loop was developed at Syracuse University in 1976 under funding by ERDA and NSF. The solar system consists of commercially available flat-plate collectors, a water storage tank, and a cooling tower integrated in a fixed manner with the heat pump system. Building thermal loads include heat transmission through walls based on the Sol-Air method, ventilation, and internal heat inputs from lighting and building occupants, with flexible hourly building use schedules permitted. Sensible heat recovery from ventilation air and heat pump domestic water heating may be simulated. Generalized weather functions are built into the program for 13 citiies, consisting of sinusoidal representations of daily dry bulb and wet bulb temperatures and monthly averaged "cloud cover modifiers" to estimate the incident solar flux. The output data provide daily, monthly, and annual building loads and energy uses by zone with energy costs by energy rates.

Reference
Ucar, M., et al., "Solar Building Energy Use Analysis," Proceedings, Section 6, Session D-4, American Section, ISES Conference, Winnipeg, 1977.

Contact
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Syracuse, NY 13210
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TRACE SOLAR

The first version of TRACE, (TRane Air Conditioning Economics Solar Program), developed by the Trane Company, was introduced in 1973 as an aid to architects and engineers in comparing life-cycle costs of various architectural, HVAC system, and equipment alternatives. The fourth version of the program, released in 1978, incorporates a solar capability which uses as a basis for solar collector evaluation the TRNSYS program. The program provides an interface to handle hourly system loads from the system simulation phase and passes those loads which cannot be handled by solar on any given hour back to the equipment simulation phase for processing by conventional HVAC equipment. Using the ASHRAE Handbook (1972) algorithms for calculating heat gains and losses by zone, the load phase calculates peak and hourly loads by zone. The system simulation phase translates the building heat gain and loss calculations into loads imposed upon the equipment, taking into account full and part load operation of the HVAC systems. The equipment loads are then converted to fuel and electrical usage rates in the equipment simulation phase where as many as four distinct alternatives may be considered simultaneously. The input for the program consists of a building description and operating schedules, design conditions for various thermal zones, equipment types, and various economic data. Solar weather data for a number of cities are included in the TRACE data base. The program output contains building system and equipment loads; peak loads by day, month, and hour; monthly fuel and electrical usage by component as well as demand requirements by component by month; peak hourly loads; and economic comparisons of the selected alternatives. TRACE SOLAR can accommodate a variety of energy/demand electric rates. Its solar capacity extends to 20 user-selected solar system configurations involving air or liquid stationary flat-plate collectors. The Trane Company will frequently modify TRACE at no cost to the user to incorporate special features of interest to a user.

Contact

The Trane Company
Attn: Neil R. Patterson
3600 Pammel Creek Road
LaCrosse, WI 54601
(608) 787-3228

TRNSYS

A program for simulating the dynamic thermal behavior of active solar heating and cooling systems. TRNSYS was developed at the University of Wisconsin Solar Energy Laboratory in in 1974 under funding from ERDA (DOE) and has been continually upgraded and maintained with its most current version (10.1) released in 1979. It is based on a modular approach whereby the user specifies which components comprise the system and the manner in which they are connected. TRNSYS is applicable to process heat and passive systems as well as to solar domestic water heating. The components models, which are formulated as separate ANSI standard FORTRAN subroutines, including collectors, controls, storage tanks, heat exchangers, furnaces, building loads, an integration procedure, etc., are linked by an executive routine. Several convenient "combined components" which model common subsystems are also included. The subroutine library allows simulation of both air and liquid type systems including stratified thermal storage units. The program also facilitates the introduction of additional user-supplied component subroutines. Inputs and outputs from the component subroutines correspond to inputs and outputs of the modeled hardware. Building heating and cooling loads may be calculated by the degree-day method, by using input response factors, or may be input from another model. Card image records of hourly weather data are required. Output data include heating and cooling loads, energy use by various system components, auxiliary energies, and overall system thermal energy balances for error checking. Plotting and histogram routines which use the line printer or terminal are included in the subroutine library.

References

"TRNSYS: A Transient Simulation Program — Report No. 38," Solar Energy Laboratory, University of Wisconsin, February 1978.

Klein, S.A., W.A. Beckman, and J.A. Duffie, "TRNSYS—A Transient Simulation Program," ASHRAE Transactions, Vol. 82, Part 1, 1976.

Contact

Solar Energy Laboratory
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Madison, WI 53706
(608) 263-1589

TWO-ZONE

Motivation for the development of this program in 1975 stemmed from a desire to analyze the collection efficiencies of windows in a residence. The program computes the hourly heating and cooling loads for the north and south zones ("two-zones") of a single-family dwelling and provides for thermal coupling between them through convective air exchange. Hourly weather data are used in the calculation in addition to various active controls such as thermostat setback, scheduled shade or curtain closings, and window opening for ventilation. In addition to these passive solar capabilities, the current program version (1977) provides for simulation of evaporative coolers and for some economic analysis. Program input consists of the hourly weather data, a description of the internal loads (appliances, occupants, etc.), schedules for active controls, and calculated transfer functions for the dynamic thermal response of the walls and roof. Output from the simulation includes monthly summaries of the total heating and cooling loads for the residence as well as a breakdown by contribution (windows, walls, infiltration, etc.). HVAC equipment simulation is limited to the evaporative cooler and a warm-air furnace with a fixed efficiency. No active solar systems are simulated by TWO-ZONE. Energy use by the auxiliary systems is reported in the output, and their life-cycle costs, based upon constant annual fuel or electric (energy/demand) rates, are included if desired.

Reference
A.G. Gadgil, G. Gibson, and A.H. Rosenfeld, "User's Manual," Lawrence Berkeley Laboratory, Report LBL-6840, March 1978.

Contact
University of California
Attn: Arthur H. Rosenfeld
Lawrence Berkeley Laboratory, Building 90
Berkeley, CA 94720
(415) 843-2740, X5711

UWENSOL

The State of Washington's plans for construction of a series of buildings prompted funding of a team of architects and engineers at the University of Washington (Seattle) to develop energy conservation guidelines for those buildings. These guidelines were embodied in a pair of computer programs released in 1978 which were designed to be used in tandem to minimize the lighting and comfort maintenance requirements of a multizone structure. Reductions in these requirements are achieved by changing the building's architecture and fenestration to achieve passive control and augmentation of the two functions. Changes are directed at reducing the heating and cooling loads which would need to be met by an HVAC system selected for the building. Architectural changes which reduce these loads are feasible so long as the lighting levels and thermal insulation values stipulated in building codes are met, and there is an acceptable thermal comfort level maintained under all weather conditions. The lighting program UWLIGHT first determines the lighting distribution in the building and the steady-state heat transmission coefficients of its envelope to ensure code compliance. UWENSOL then performs a dynamic hour-by-hour simulation of the building using a finite-difference approximation of the zonal interactions and calculates the transient heating and cooling load requirements for the HVAC system. Architectural changes are then made to reduce these loads, and the attractiveness of the modifications is later checked by evaluating a thermal comfort level for each zone. Electrical load profiles or fuel requirements for the comfort control system are not determined by this program, and no active solar system (collectors) can be simulated. Input requirements for the program emphasize the passive aspects of the structure since its principal concern is with the building's reaction to solar input. Hourly data for ambient temperature and humidity, direct and diffuse solar radiation, etc., must be supplied by the user. Program output includes daily heating and cooling loads for the various thermal zones as well as average and peak day hourly load profiles.

Reference
Emery, A.F., et al., "UWENSOL: A Computer Program for the Dynamic Simulation of the Thermal Response of Buildings with Emphasis on Human Comfort," University of Washington, 1978.

Contact
Department of Mechanical Engineering, FU-10
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University of Washington
Seattle, WA 98195
(206) 543-5338

WATSUN II

A second version of this program (WATSUN-II) was made available in 1978 following release of the original in 1977. Both were developed by the University of Waterloo (Ontario) under contract to the National Research Council of Canada as part of NRCC's continuing research in solar water heating and space heating. WATSUN is intended to simulate the operation of an active solar system and storage in response to specified weather conditions and the heating load profile of a residence. As such, the program does not have the capability to calculate the heating or hot water load for the structure, so these hourly load profiles must be supplied to the program as input data. WATSUN will then simulate the hourly performance of the solar collector and storage and the auxiliary (conventional) systems in meeting the designated load profiles under user-specified weather conditions. Either flat-plate or evacuated tube stationary collectors may be simulated with suitable choice of gross performance indices for either liquid or air circulants, or a detailed collector model may be specified where the standard performance indices are inadequate. The program will also handle a variety of storage systems including rock, liquid, phase change, stratified, etc. Auxiliary systems include an instantaneous-recovery water heater, electric or fossil-fueled furnaces, and an electric heat pump. Life-cycle costs of operation of the solar equipment may be calculated and are based upon a uniform electric rate (energy only).

Reference

Orgill, J.F. and K.G.T. Hollands, "A Solar Heating Simulation and Economic Evaluation Program: User's Manual," University of Waterloo, Canada, April 1976. (Available from U.S. DOE Technical Information Center, P.O. Box 62, Oak Ridge, TN 37830)

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HVAC Computer Programs Summary

The following table lists programs intended primarily for building heating and cooling load analysis. Some provide for solar analysis, but in such cases it is secondary to the conventional energy analysis. The programs have been generally developed and maintained by heating, ventilating, and air conditioning (HVAC) consulting engineers for their own analysis use; however, most are available through special arrangements with the contact.

Program Name	Sponsor	Author	Contact	Original Release	Current Version	Application				Availability		
						Building Load	HVAC System	Active Solar	Passive Solar	Source Cost ($)	Time Share	Special Arrangements
ECUBE III	American Gas Association (AGA)	Subcontractors	American Gas Association 1515 Wilson Blvd. Arlington, VA 22209 (203) 841-8400 David S. Wood		1979	•	•		•	No info	•	•
ENERGY 1	Gibson-Yackey-Trindade Assoc.	Robert Gibson	Gibson-Yackey-Trindade Associates 311 Fulton Ave. Sacramento, CA 95811 (916) 483-4369 Robert Gibson	1974	1974	•	•	•		Not avail.	N/A	•
EP	Energy Management Services (EMS)	EMS	Energy Management Services 0435 SW Iowa Portland, OR 97201 (503) 244-3613 Robert M. Helm	1976	1978	•	•	•	•	Not avail.	•	•
ESAS	Ross F. Meriwether & Associates, Inc.	Ross F. Meriwether	Ross F. Meriwether & Associates 1600 NE Loop 410 San Antonio, TX 78209 (512) 824-5302	1969	1978	•	•	•	•	Not avail.	N/A	•
ESP–1	Automatic Procedures for Engineering Consultants (APEC)	Stone and Webster	APEC, Inc. Executive Off. Grant-Doneau Tower Suite M-15 40th & Ludlow Streets Dayton, OH 45402 (513) 228-2602 Doris Wallace	1977	1978	•	•	•		6,000 no cost to APEC members	N/A	•
HACE	William Tao & Associates (WTA)	WTA/Computer Services, Inc.	WTA/Computer Services, Inc. 2357 59th Street St. Louis, MO 63110 (314) 644-1400 Richard Lampe	1970	1978	•	•	•	•	Not avail.	•	•
NECAP	NASA	NASA	NASA, Langley Research Center Mail Stop 453 Hampton, VA 23665 (804) 827-4641 Ron Jensen	1974	1975	•	•	•			N/A	N/A
SCOUT	Guard, Inc.	Guard, Inc.	Guard, Inc. 7440 N. Natchez Ave. Niles, IL 60648 (312) 647-9000 Robert Henninger	1976	1978	•	•		•	See contact	N/A	•
SEE	The Singer Co. (NSF Grant)	W.S. Fleming & Assoc., Inc., The Singer Co.	The Singer Co. Climate Control Division 62 Columbus St. Auburn, NY 13201 (315) 253-2771, X391 Philip Parkman	1975	1977	•	•	•	•	Not avail.	N/A	•
Westinghouse Programs	Westinghouse Electric Corp.	Westinghouse Electric Corp.	Westinghouse Electric Corp. Energy Systems Analysis 2040 Ardmore Blvd. Pittsburgh, PA 15221 (412) 256-3168	1964	1978	•	•	•	•	Not avail.	N/A	•

N/A = Not applicable

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