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EVALUATION PROCEDURE FOR BUILDING ENERGY PERFORMANCE PREDICTION TOOLS

AUGUST 1985

DESIGN TOOL EVALUATION REPORTS

Aco2-83CE30752

PREPARED FOR:

U.S. DEPARTMENT OF ENERGY
ASSISTANT SECRETARY, CONSERVATION & RENEWABLE ENERGY
OFFICE OF SOLAR HEAT TECHNOLOGIES

PREPARED BY:

BUILDING ENERGY DESIGN TOOL DEVELOPMENT COUNCIL

DISCLAIMER

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III. BEDTDC Member Organizations:

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NAHB Research Foundation
National Concrete Masonry Foundation
National Institute of Building Sciences
National Laboratories
National Solar Design Tool Developers Association
Passive Solar Industries Council
Solar Energy Industries Association

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Four Design Tool Evaluation Reports

The BEDTDC design tool evaluation was exercised on four design tools as part of the projects test and refinement program. The reports resulting for these evaluations are contained in this document.

DESIGN TOOL EVALUATION REPORT
SUMMARY FORM

■ **SUMMARY NUMBER:**

■ **CATEGORY:**

■ **DESIGN TOOL TITLE:** ASEAM

■ **CONTACT:** Michael Dick
202/543-7212
W.S. Fleming & Assoc.

■ **DEVELOPER:** W.S. Fleming & Assoc., Inc.
536 Seventh Street S.E.
Washington, D.C. 20003
202/543-7212

AVAILABLE THROUGH: Designers Software Exchange, Laboratory of Architecture and Planning, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139
(617) 253-1350 or NTIS (202) 487-4650

■ **FORMAT:**

- Manual ☐
- Calculator ☐
- Microcomputer ☒
- Mini/Mainframe ☐

■ **ABSTRACT:** The ASEAM program has been developed for the Building Systems Division of the U.S. Department of Energy (DOE) as a public domain energy analysis tool for commercial buildings. This microcomputer program is based upon simplified analysis methods using modified annual "bin temperature frequency data". The load calculation routines are based on a methodology documented by the ASHRAE Technical Committee on Energy Calculations (TC 4.7). The HVAC system and heating and cooling plant routines were developed by W.S. Fleming & Associates (WSFA).

ASEAM is an "interactive" computer program. Its algorithms include heating and cooling calculations, and HVAC system and plant calculation routines with options to size cooling equipment and air flows. The program is structured so that input and output files can be manipulated to perform comparison studies. In addition to load calculation and HVAC system energy consumption reports, annual estimates for seven (7) energy end use categories are reported:

- o Heating
- o Cooling
- o HVAC Pumps
- o HVAC Fans
- o Cooling Tower
- o Lighting
- o Equipment

■ **SYSTEM REQUIREMENTS:** (for computer based tools)

- Display: Monochrome
- Printer Required: Yes
- Disks Required: 1 or 2 drives
- Memory Size Required: 64K
- Other Hardware: None
- Operating System: PC-DOS 2.0
- Language: IBM-BASIC
- Other Software: None

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DESIGN TOOL EVALUATION REPORT
KEY CHARACTERISTICS LIST

■ Name of Design Tool: ASEAM (A Simplified Energy Analysis Method)

■ Design Tool Category: Numerically based annual energy performance tool

■ Primary Application of Tool:

- Building Design Phases ☒
  - — Programming ☐
  - — Schematic ☒
  - — Design Development ☒
  - — Construction Documents ☐
- Research ☐
- Education ☐

■ Applicable Building Type:

	HTG	CLG	DHW	LTG	Misc.	Other
• Single Family Residential	☐	☐	☐	☐	☐	☐
• Multi-Family Residential	☐	☐	☐	☐	☐	☐
• Small Commercial	☒	☒	☐	☒	☐	☒
• Large Commercial	☐	☐	☐	☐	☐	☐

■ Form of Tool Availability:

- Manual/Hand Method ☐
- Programmable Calculator ☐
- Microcomputer ☒
- Mini/Mainframe Computer ☐

■ Conventional HVAC Simulation Capabilities:

- Seasonal/Annual Efficiencies ☐
- Dynamic Equipment Simulation ☒
  (Specify major types: VAV, CV, Heat Pump, Fan Coil, Package Terminal A/C)

■ Alternate Energy Simulation Capabilities:

- Active Solar ☐
  - — Space Heating ☐
  - — DHW ☐
  - — Industrial Process Heat ☐
- Passive Solar ☐
  - — Space Heating ☐
  - — Space Cooling ☐
  - — DHW (thermosyphon) ☐
- Other (specify _____) ☐

■ List Price: $ 25 from Designers Software Exchange

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DESIGN TOOL EVALUATION REPORT
USER UTILITY — CHARACTERISTIC CHECKLIST

A. PRIMARY APPLICATION (Y / N)
- 1. Design Phases: ✓ / —
  - Programming: —
  - Schematic: ✓
  - Design Development: ✓
  - Construction Documents: —
  - Post Construction: —
- 2. Research: — / —
- 3. Education: — / —

B. BUILDING TYPE

	HTG	CLG	DHW	LTG	MISC	OTHER
1. Single Family Resid.	—	—	—	—	—	—
2. Multi-Family Resid.	—	—	—	—	—	—
3. Small Commercial	✓	✓	—	✓	—	—
4. Large Commercial	—	—	—	—	—	—

C. AVAILABILITY
- 1. Origin
  - Public Domain: ✓ — Private/Public: —
  - Private Domain: —
- 2. Format
  - Manual: — — Microcomputer: ✓
  - Programmable: — — Mini/Mainframe: —

D. COST OF USE
- 1. Basic Purchase Price $ 2500 + DISK
- 2. Documentation cost (if separate) $ ____
- 3. Weather data cost (if separate) $ 1200 AIR FORCE MANUAL 88-29
- 4. Hardware required IBM-PC & PRINTER
- 5. Software/operating system req. DOS 2.0
- 6. Evaluator Profile FIRST TIME USER

	<1 hr	<4 hr	<1 day	<1 wk	<1 mth
7. Install and Debug					
Initial Installation	✓	—	—	—	—
Debug	✓	—	—	—	—
8. Learning Costs					
Setup/Familiarization	—	✓	✓	—	—
Training	—	✓	—	—	—
Tool Proficiency	—	—	✓	✓	—
9. Operating Costs					
Data Prep for Input	—	—	✓	—	—
Data Input	✓	—	—	—	—

Run time 30 hrs./min.

- 10. Maintenance Costs
  - Day to Day (ser. bureau) $ 0 /mo.
  - Updates $ COST OF DISK
  - Disk Replacement $ ____
  - Other $ ____

E. USER INFORMATION (Y / N)
- 1. Documentation
  - a. Format:
    - 1) Individual Manuals: — / —
      - a) User: ✓
      - b) Technical: ✓ ALGORITHMS
      - c) Programming: ✓ SOURCE CODE
    - 2) Imbedded in Software: — / —
  - b. Available explanations:
    - 1) Input parameters: ✓
    - 2) Output format: ✓
    - 3) Method of calculation: ✓
    - 4) Sources of methods: ✓
    - 5) Computer operations: ✓
    - 6) Weather data: ✓
    - 7) Common operating errors: ✓
    - 8) Error messages: ✓
    - 9) Other (specify) ____
  - c. Available examples:
    - 1) Sample problems: ✓
    - 2) Input: ✓
    - 3) Output: ✓
    - 4) Other (specify) ____

E. USER INFORMATION (CONT.) (Y / N)
- d. Document Indexing: ✓ / —
- 2. User Support
  - a. Direct User Support: — / —
    - 1) Available from:
      - a) Tool Developer: ✓
      - b) Vendor: —
      - c) Other (specify) ____
    - 2) Is a fee charged? — / —
    - 3) Method of Inquiry:
      - a) Toll-free number: —
      - b) Special format: —
    - 4) Is assistance available for ...
      - a) Document clarification: — / —
      - b) Startup Questions: ✓ / —
      - c) Technical Questions: ✓ / —
  - b. Updates: — / —
  - c. User Groups: — / —
  - d. Other (specify) ____
- 3. References
  - a. Source Code provided: ✓ / —
  - b. Technical sources identified: ✓ / —

F. INPUT/OUTPUT (Y / N)
- 1. Input
  - a. Basic Units of Measure: SI — English ✓ Either —
  - b. Manual Formats: Tabular ✓ Graphic —
  - c. Computer Formats:
    - 1) Interactive: ✓
    - 2) Batch with editor: —
    - 3) Batch without editor: —
    - 4) Interactive and batch: —
    - 5) Input storage and recall: ✓
    - 6) Input summary: ✓
  - d. Special Input Formats: — / —
  - e. Processors: Pre-processing — Post-processing ✓
  - f. Default Values: — / ✓
  - g. Diagnostic/Error Messages:
    - 1) Numeric error format: ✓
    - 2) Explicit error format: —
    - 3) Programming errors: —
    - 4) Data errors: ✓
    - 5) Help menu: —
- 2. Output
  - a. Unit Conversion Capability: — / ✓
  - b. Predetermined Reporting Formats: Numerical ✓ Graphical —
  - c. User Selected Formats: Numerical — Graphical — Both —
  - d. Diagnostic/Error Messages:
    - 1) Numeric error format: ✓
    - 2) Explicit error format: —
    - 3) Programming errors: —
    - 4) Data errors: —
    - 5) Help menu: —

G. STATUS OF COMPARATIVE TESTING (Y / N)
- 1. Whole building testing: ✓ / —
  - Tool to tool: ✓
  - Tool to real building: —
- 2. Tool component testing: — / —
  - Algorithms: —
  - Lab scale analysis: —
  - Monitored component: —
  - Performance data: —
- 3. Comments ____

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DESIGN TOOL EVALUATION REPORT
TECHNICAL CAPABILITY — CHARACTERISTIC CHECKLIST

	Y	N
A. HEAT TRANSFER		
1. Convection Heat Transfer	—	—
a. Intra-zonal	—	
b. Inter-zonal		
2. Conduction Heat Transfer	✓	—
a. Inter-zonal	—	
3. Radiation Heat Transfer	—	—
a. Internal Only	—	
b. Multiple Surfaces	—	
B. COMPUTATION BASIS AND CALCULATION METHOD	Y	N
1. Computation Basis:		
a. Predominantly First Principle	✓	
b. Predominantly Correlation	—	
c. Hybrid	—	
2. Calculation Method:		
a. Steady-State (UA) Method	✓	
b. Response Factor	—	
c. Finite Difference	—	
d. Frequency Domain	—	
e. R-C Network	—	
f. Transfer Function	—	
g. Other _____		
C. TIME STEPS	Y	N
1. 8,760 Sequential Hours	—	
2. Representative Time Periods	—	
3. Typical Time Periods:		
a. Degree/Day Temperature Bins	✓	
b. Variable Degree Hours/Days	—	
4. Hourly Weather — Representative Days	—	
D. BUILDING LOADS AND PROFILES	Y	N
1. Thermal Zoning	✓	
a. Single Zone Only	—	
b. Multiple Zones	✓	
2. External Load Factors	—	—
a. Infiltration Losses	—	
b. Radiant Heat Losses	—	
c. Envelope Heat Losses	✓	
d. Basement Heat Losses	—	
e. Slab/Slab Edge Heat Losses	—	
f. Attic/Plenum Losses	—	
g. Solar	✓	
h. Glazing	✓	
i. Weather Data	✓	
3. Internal Loads/Profiles	✓	—
a. Occupants	✓	
b. Lighting Loads	✓	
c. Process Heat Loads	—	
d. Ventilation	—	
e. Internal Load Profiles	✓	
f. System/Plant Profiles	—	
g. Comfort Models	—	
E. PASSIVE SOLAR SYSTEM SIMULATION	Y	N
1. Passive Heating	—	✓
a. Direct Gain	—	
b. Mass Wall	—	
c. Isolate Heat Gain	—	
2. Passive Cooling	—	✓
a. Natural Ventilation	—	
b. Evaporative Cooling	—	
c. Roof Ponds	—	
d. Earth Contact	—	
e. Atria	—	
f. Other _____		
3. Daylighting	—	✓
a. Daylighting Devices	—	
b. Artificial Light Controls	—	
4. Interaction With Conventional HVAC	—	✓
5. Comfort/Overheating Assessment	—	✓
6. Other _____		
F. HVAC SYSTEM SIMULATION	Y	N
1. Seasonal and/or Yearly Efficiencies	✓	—
2. Variable Efficiencies	—	✓

	Y	N
F. HVAC SYSTEM SIMULATION (CONT.)		
3. Conventional HVAC System Types	✓	—
a. Direct-Fire Hot Air Furnace	✓	
b. Single Duct Systems	✓	
c. Dual Duct Systems	✓	
d. Multi-Zone Systems	✓	
e. Fan Coil	✓	
f. Induction Systems	—	
g. Unit Ventilator	—	
h. Unit Heater	—	
i. Heat Pumps	✓	
j. Unitary Clg. w/Separate Heating	✓	
k. Heat Recovery Systems	—	
l. Fans/Blower Control	—	
m. Fan/Motor Arrangements	—	
4. Conventional Plant Equipment	✓	—
a. Water Chillers	✓	
b. Absorption Chillers	✓	
c. Boilers	✓	
d. Thermal Storage	—	
e. Diesel Generator/Cogeneration	—	
f. Auxiliaries	—	
g. District Services	—	
h. Evaporative Coolers	—	
i. Other _____		
5. Control Systems/Operating Modes	✓	—
a. Thermostat Setpoints	✓	
b. Thermostat Schedule		
c. Thermostat Types	✓	
d. Controllers	—	
e. Other _____		
6. Domestic Hot Water Systems	—	✓
a. Solar Heated	—	
b. Conventional Heating	—	
c. DHW Variables	—	
7. Active Solar Space Conditioning	—	✓
a. Solar Collectors	—	
b. Thermal Storage System	—	
c. Heat Exchanger	—	
d. Solar Controller	—	
8. Equipment/Component Sizing	—	
9. Coupling of Load/System Plant	—	✓
10. Economic Calculations	—	✓
a. Type of Economic Analyses	—	
b. Economic Variables	—	
G. COMPUTATION OUTPUT REPORTS	Y	N
1. Peak Load Determinants:		
a. Building Components	✓	
b. Thermal Zones	✓	
c. HVAC Systems	—	
d. Plant		
e. Building	✓	
2. Time Variance of Load Determinants:		
a. Hour (or Less)	—	
b. Day	—	
c. Month		
d. Season	✓	
e. Year	—	
3. Temperatures:		
a. Air, Dry Bulb	—	
b. Air, Wet Bulb	—	
c. Surface	—	
d. Chilled Water	—	
e. Hot Water/Steam	—	
f. Domestic Hot Water	—	
g. Storage	—	
h. Other _____		
4. Site Energy Consumption:		
a. Time of Day Reports	—	
b. Monthly	—	
c. Seasonal		
d. Annual	✓	
5. System and Components	✓	—
6. Energy Systems	✓	—
7. Total Building	✓	—
a. Per Square Foot Basis	✓	
b. By Source and Site	✓	
c. By Energy End Uses	✓	
d. By Units of Consumption	✓	

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DESIGN TOOL EVALUATION REPORT
NARRATIVE REPORT

DESIGN TOOL TITLE: ASEAM

PURPOSE OF DESIGN TOOL: A SIMPLIFIED ENERGY-ANALYSIS METHOD (ASEAM) is a microcomputer program developed for the purpose of comparing results predicted by the "ASHRAE TC 4.7" procedure with those of the DOE-2.1A hourly simulation computer program. ASEAM can be used to examine the energy aspects of alternative building designs using "conventional" construction and mechanical systems. The program can also be used to evaluate the individual or combined effects of various energy efficient design strategies and is structured to accommodate the comparison of a "base case" to an alternative.

PART I - USER UTILITY CHARACTERISTICS

A. PRIMARY APPLICATION: ASEAM is most useful during the schematic and design development phases of the design process.

B. BUILDING TYPE: ASEAM can best accommodate small, commercial buildings. Up to ten zones can be modeled for a variety of common commercial HVAC configurations. The program focuses on internal loads and schedules while treating skin-related factors in a simple manner. Active or passive solar systems are not handled, although solar gains are modeled using ASHRAE algorithms.

C. TYPE OF AVAILABILITY: ASEAM is a public domain program for Apple II or IBM PC microcomputers. It is available for $25 from:

Designer's Software Exchange (617) 253-1305
or
NTIS (202) 487-4650

D. COST OF USE: The basic cost for ASEAM is $25 for the program disk and manual. Weather files must be input using "bin temperature frequency data" contained in the Engineering Weather Data manual developed by the Departments of Air Force, Army and Navy. It is available for $12 from the Government Printing Office (202/783-3238). Other input data necessary for ASEAM is found in ASHRAE Fundamentals, which is available for $40 from ASHRAE. Since ASEAM is a microcomputer program, computer operation costs are minimal. Learning and set up costs are also minimized due to the fact that the input sheets eliminate the need for the computer while setting up program inputs.

E. USER INFORMATION: Designer's Software Exchange provides a 50% reduced double sided reformatting of the NTIS ASEAM manual. This reformatted version is 108 pages long.

The manual begins with a general discussion of ASEAM's capabilities and use. Each segment of the program is then treated separately and in great detail. All input values are defined, and sample menus and input screens show the user what will be seen at the terminal. A lengthy section of the manual describes the variety of HVAC systems that ASEAM can model and gives diagrams for each. References to ASHRAE Fundamentals and the Engineering Weather Data Manual, both of which are required for input values, are accompanied by samples from each

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source and specific chapter numbers where appropriate. In addition to the source code (unfortunately still from the Apple version), a listing of program variables and simplified algorithms is provided. It should be noted that the algorithms listed are not necessarily identical to those used by the program. Finally, results of an ASEAM/DOE 2 comparison are provided.

Although there is no formal user support system for ASEAM, technical questions can be directed to Michael Dick with W.S. Fleming & Associates, Inc. [(202) 543-7212].

F. INPUT/OUTPUT DATA: ASEAM uses English input units in an interactive, menu-driven, tabular format. Input sheets are provided which, once completed, keep actual data input time to a minimum. Data can be input and stored for each program segment, printed out in summary form, and called up and run as desired. Systems runs, based on systems inputs and load calculations, are used to create the "Building Energy Performance Report", which summarizes building energy use. This feature, where loads files are combined with systems files, allows for HVAC or building parametrics to be run very easily and logically. Default values are not provided, although the program will size the HVAC system. Some error messages exist, but are not extensive. Bin temperature frequency data must be input by the user, but the format follows that of the weather manual. Values from ASHRAE Fundamentals table are necessary for some portions of the loads section. Discussion, references, and examples are thorough enough to assure that most users will not have trouble finding appropriate values.

Output data is tabular. Zone-specific and temperature bin-specific data are given for the loads calculations. System energy is reported for both occupied and unoccupied periods, as annual totals, and in kBtu/SF/yr.

G. STATUS OF COMPARATIVE TESTING: ASEAM was developed specifically for testing the ASHRAE TC 4.7 methodology against DOE-2.1a. The results of this thorough comparison, which investigates HVAC system changes, HVAC plant changes, HVAC system parametrics and envelope parametrics, is included in the ASEAM manual.

PART II - TECHNICAL CAPABILITIES

A. HEAT TRANSFER: ASEAM simulates conduction, heat transfer, and solar gains, using ASHRAE algorithms. Each zone is treated separately, and interior zone interfaces assumed to be adiabatic.

B. COMPUTATION BASIS AND CALCULATION METHOD: ASEAM is a computerization of ASHRAE's TC-4.7 methodology, and as such uses ASHRAE algorithms for loads related calculations. Systems related algorithms used by ASEAM were developed by W.S. Fleming & Associates, Inc.

C. TIME STEPS: ASEAM uses 5°F "bin temperature frequency data" as a basis for building load calculations. The bin method places each hour in a year into these temperature bins. Frequencies, or number of hourly occurrences per year, are input for each of three 8 hour periods in a 24 hour day.

Because ASEAM uses this Annual Total Frequency of Occurrence data, the number of occupied/unoccupied hours are input for the same 8 hour time blocks used for the

weather data. Each bin is then treated as occupied and/or unoccupied depending on the mix of hours for that time block.

D. BUILDING LOADS AND PROFILE: As previously mentioned, ASEAM can model up to ten zones for a single HVAC system, but does not simulate interaction between zones.

External load factors are calculated using ASHRAE algorithms for envelope heat loss and solar loads through glazing. Slab losses and infiltration are not included in the loads portion of ASEAM, two capabilities that would increase the tool's usefulness, especially for residential applications.

ASEAM accepts ASHRAE values for Cooling Load Temperature Difference Factor (CLTD), Solar Heat Gain Factor (SHGF), Color Correction Factor (CCF), and Shading Coefficient (SC). Temperature Cooling Load Factor (TCLF) is input as the sum of ASHRAE hourly Cooling Load Factors. These inputs require a bit of work by the user, but result in greater accuracy without increasing hardware requirements.

Internal loads are handled simply, but effectively. As previously mentioned, each of the three 8 hour time blocks can be divided into occupied and unoccupied periods, primarily for the application of setbacks and load diversity factors. These diversity factors can be applied to lighting, occupancy and equipment loads for occupied periods. Latent loads are modeled only as a function of occupancy. A single diversity factor is input for unoccupied periods, and applies to all three load components. Some work on the part of the user is required to estimate a general unoccupied diversity factor.

Ventilation is not handled in the loads section of ASEAM, but is included as "Percent Outdoor Air" under the systems section. The fact that changing this input produced only slight changes in system energy use may be a function of its not being handled as a loads component.

E. PASSIVE SOLAR SYSTEM SIMULATION: ASEAM does not handle solar systems of any kind.

F. HVAC SYSTEM SIMULATION: ASEAM offers a variety of options for HVAC systems. The following basic systems can be modeled:

1) Double duct or multi-zone
2) Terminal reheat
3) Variable air volume
4) Ceiling bypass VAV
5) Variable temperature single-zone
6) Fan coil, two or four pipe
7) Water/air heat pump
8) Package terminal air conditioner

These systems are diagrammed and described in the manual, with appropriate comments for the best use of program options and inputs.

Although ASEAM's ability to model many different HVAC systems is an asset, it can also present problems for users who are not knowledgeable in this area. Despite

the option of having the program size the HVAC system, the amount of information required, combined with a lack of default values or numerical background information, necessitates a fairly strong understanding of the intricacies of HVAC systems. HVAC input formats are based on the selected system types, but serious errors can be made in choosing heating or cooling plant types to match the HVAC system. The addition of default values would represent a large increase in program complexity, but would improve the usefulness of ASEAM considerably. At least, the addition of basic system rules of thumb to the manual would be helpful.

G. COMPUTATION OUTPUT REPORT: The Building Energy Performance (BEP) Report is by far the most useful output generated by ASEAM. Annual energy use values are provided for cooling, heating, lighting, pumps and fans, as well as total building energy use per square foot. The building loads and systems reports both offer information that follows the operation of ASEAM, that is, temperature bin specific for any function involving outdoor air temperature. This, however, severely limits the usefulness of these reports.

The systems report, which breaks down use into auxiliary and primary heating and cooling, and supply and return fans, is primarily useful in that energy use is divided into occupied and unoccupied components. Bin-specific information also allows one to assess the impact of deadband settings on building energy use, and the degree to which these settings truncate potential energy use. Heating and cooling plant size is required during the output for the building systems energy report. Because of the time involved in the systems run and the fact that the heating plant size input is requested long after the cooling plant size is input, the user cannot leave the computer for the duration of the systems run. This is an inconvenience that could easily be corrected.

ASEAM's load calculation section could also use some refinement. Because of the bin-specific data that is generated for temperature related loads, the results are only of use in comparing loads between zones or between parametric runs. All loads are "diversified" over the occupied and unoccupied portions of the day to produce single hourly values for each load contributor in each building zone. Peak values for winter and summer total sensible loads are included, but cannot be used for determining total peak loads for buildings with more than one zone due to different times of occurrence. Also, because all values are hourly and zone-specific, it is impossible to calculate yearly load totals. Given the lack of usefulness of the loads section of ASEAM, combined with the amount of time it takes to run and simultaneously print out, an option that would let loads be calculated internally is needed.

Two cautions should be exercised when running ASEAM on multi-zone building configurations. The Building Energy Performance Report section is set up to take a number of system files for combination into a single report. These combinations were found to be numerically inaccurate when compared to reports run for each zone individually. In addition, if one intends to run a series of different building energy performance reports it is best to return to the main program menu between runs to prevent the compilation of separate runs.

H. BENCHMARK COMPARISON: The results of the Commercial Benchmark Comparison for ASEAM must be viewed cautiously. A variety of factors involving the interpretation of the input data and the accuracy of the Benchmark values limits the usefulness of the results. This situation is exacerbated by the fact that

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DESIGN TOOL EVALUATION REPORT
NARRATIVE REPORT

ASEAM's loads calculations do not yield values that fit the BDTC format, thereby preventing comparisons between whole building loads and systems values.

The two ASEAM system options used were Variable Air Volume and Variable Temperature Single Zone (constant volume). The following system parameters remained constant for all of the benchmark runs:

Minimum Supply Air Temperature	= 55°F
Outside Air	= 10%
System Supply Air	= 28,000 CFM
Preheat	= Yes
Heating Type	- Hot Water or Steam Boiler
Cooling Type	- Direct Expansion
Low Temperature Cool Start	= 75°F
High Temperature Heat Start	= 60°F

These systems and parameters were judged to be the closest to those described for the base case systems, or at least typical for the building being modeled. Heating and cooling capacities were input as given, but heating efficiency, cooling part load performance factors, and coil control ramps are not user inputs for ASEAM.

The load inputs closely followed those indicated for the Benchmark, with a few simplifications and assumptions. ASEAM uses a single diversity factor for lights, people, and equipment during unoccupied periods. This was estimated to be 10% to account for outdoor lights and reduced interior lights. Infiltration and slab losses are not handled by the loads section of ASEAM, and no attempt was made to compensate for the absence of their contribution to the building load.

Benchmark Variable One, which reduces exterior glazing to 20%, results in very little change in heating, cooling, or fan energy use from the VAV base case. Despite the fact that loads values could not be adapted to the BDTC format, zone-specific solar gain and transmission loss information did indicate that loads were being influenced to a reasonable degree.

For the Constant Volume System, heating energy remained low overall, but did drop appropriately for the 20% glazing case. Cooling energy increased slightly.

Benchmark Variable Two, the addition of high efficiency ballasts to Variable One, produced results that made sense, but did not track well with the Benchmark values. No specific value is given in the Benchmark data set for reductions to lighting power density due to high efficiency ballasts. Ten percent was chosen as a reasonable value based on experience. This reduction was reflected in lighting energy use, and in slight changes to the heating and cooling energy use. The large changes shown by the Benchmark values are not likely to occur due to high efficiency ballasts only, and may be indicative of an error in the Benchmark data set. This possibility is being investigated by BDTC.

The Benchmark exercise would have been more useful had the ASEAM loads results been in an annual format by end-use. This would have been useful in examining reasons for the flatness of responses to the change in glazing area for Variable One. In general, ASEAM tends to underestimate heating energy use compared to the Benchmark data set, but is within the range for cooling energy use. Fan energy use significantly exceeded the Benchmark Data Set ranges for the VAV system runs.

Donald L. Anderson

DESIGN TOOL EVALUATION REPORT
SUMMARY FORM

SUMMARY NUMBER: Completed By: William A. Gruel

CATEGORY: ENERGY PERFORMANCE ANALYSIS

DESIGN TOOL TITLE: CALPAS3, Version 3.13
Residential and Small Commercial Energy Performance Simulation Program

CONTACT: Charles S. Barnaby
BSG
415/843-7600

DEVELOPER:
Berkeley Solar Group (BSG)

FORMAT:

- Manual ☐
- Calculator ☐
- Microcomputer ☒
- Mini/Mainframe ☐

ABSTRACT: CALPAS3 is an hourly computer simulation program which analyzes the energy performance of passive solar/conventional residences and small commercial buildings. This private domain design tool can be used on an IBM Personal computer, although CALPAS3 is also available for minicomputers (BSG permits timesharing on their minicomputer to run CALPAS3 also).

An important attribute of CALPAS3 is its simplicity. A user can expect to be running the program in a single day. Of further assistance is the well organized, 200-page Users Manual.

The CALPAS3 program is based largely on accepted ASHRAE algorithms. Hourly radiant/convecting and conductive heat balances are performed for each surface of each zone simultaneously.

One primary zone may be modeled as well as a thermally coupled sunspace zone (if applicable). The building loads include exterior skin loads, infiltration losses, internal gains, solar gains, thermal mass effects, and ventilation loads. Various space temperature control strategies may also be implemented (CALPAS3 does not address HVAC systems or plants, except for permitting the use of HVAC system seasonal efficiencies).

Finally, weather data files for over 250 locations are available for CALPAS3. Furthermore, CALPAS3 is not capable of performing economic evaluations. The program can however, set up to output hourly, daily, monthly and yearly space loads and space conditions.

SYSTEM REQUIREMENTS: (for computer based tools)

- Display: Monochrome Monitor
- Printer Required: Helpful
- Disks Required: Yes
- Memory Size Required: 256 KBYTES
- Other Hardware: IBM Personal Computer (an 8087 Math Coprocessor Chip is helpful)
- Operating System: MS or PC DOS 2.0 or later
- Language: FORTRAN
- Other Software: Editor (User's Choice)

DESIGN TOOL EVALUATION REPORT
KEY CHARACTERISTICS LIST

Name of Design Tool: CALPAS3, Version 3.13 (Microcomputer Version)

Design Tool Category: Numerically based annual energy performance tool

Primary Application of Tool:

- Building Design Phases ☑
  - — Programming ☑
  - — Schematic ☑
  - — Design Development ☑
  - — Construction Documents ☐
- Research ☐
- Education ☐

Applicable Building Type:

	HTG	CLG	DHW	LTG	Misc.	Other
• Single Family Residential	☑	☑	☐	☐	☑	☐
• Multi-Family Residential	☐	☐	☐	☐	☐	☐
• Small Commercial	☑	☑	☐	☐	☑	☐
• Large Commercial	☐	☐	☐	☐	☐	☐

Form of Tool Availability:

- Manual/Hand Method ☐
- Programmable Calculator ☐
- Microcomputer ☑
- Mini/Mainframe Computer ☐

Conventional HVAC Simulation Capabilities:

- Seasonal/Annual Efficiencies ☑
- Dynamic Equipment Simulation ☐
  (Specify major types: _____)

Alternate Energy Simulation Capabilities:

- Active Solar ☐
  - — Space Heating ☐
  - — DHW ☐
  - — Industrial Process Heat ☐
- Passive Solar ☑
  - — Space Heating ☑
  - — Space Cooling ☑
  - — DHW (thermosyphon) ☐
- Other (specify _____) ☐

List Price: $ 795.00 (As of February, 1985) Completed By: William A Grad

DESIGN TOOL EVALUATION REPORT
USER UTILITY — CHARACTERISTIC CHECKLIST

A. PRIMARY APPLICATION (Y / N)
- 1. Design Phases ✓ / —
  - Programming ✓
  - Schematic ✓
  - Design Development ✓
  - Construction Documents ✓
  - Post Construction ✓
- 2. Research — / —
- 3. Education — / —

B. BUILDING TYPE

	HTG	CLG	DHW	LTG	MISC	OTHER
1. Single Family Resid.	✓	✓	—	—	✓	—
2. Multi-Family Resid.	✓	✓	—	—	✓	—
3. Small Commercial	✓	✓	—	—	✓	—
4. Large Commercial	—	—	—	—	—	—

C. AVAILABILITY
- 1. Origin
  - Public Domain —
  - Private Domain ✓
  - Private/Public —
- 2. Format
  - Manual —
  - Programmable —
  - Microcomputer ✓
  - Mini/Mainframe —

D. COST OF USE (Includes documentation & five weather files)
- 1. Basic Purchase Price $ 795
- 2. Documentation cost (if separate) $25 - each manual
- 3. Weather data cost (if separate) $5-each file
- 4. Hardware required IBM PC & 8087 Math Coprocessor Chip
- 5. Software/operating system req. MS or PC DOS & Editor
- 6. Evaluator Profile first time user of tool

	<1 hr	<4 hr	<1 day	<1 wk	<1 mth
7. Install and Debug					
Initial Installation	—	—	✓	—	—
Debug	—	—	—	—	—
8. Learning Costs					
Setup/Familiarization	—	—	✓	—	—
Training	—	—	—	✓	—
Tool Proficiency	—	—	—	✓	—
9. Operating Costs					
Data Prep for Input	—	—	✓	—	—
Data Input	✓	—	—	—	—

Run time 10 mins. with Coprocessor Chip

- 10. Maintenance Costs
  - Day to Day (ser. bureau) $ N/A /mo.
  - Updates $ 200/yr. after 1st year.
  - Disk Replacement $ _____
  - Other $ Additional Blank Diskette

E. USER INFORMATION (Y / N)
- 1. Documentation
  - a. Format:
    - 1) Individual Manuals ✓ / —
      - a) User ✓
      - b) Technical —
      - c) Programming —
    - 2) Imbedded in Software — / ✓
  - b. Available explanations:
    - 1) Input parameters ✓
    - 2) Output format ✓
    - 3) Method of calculation ✓
    - 4) Sources of methods ✓
    - 5) Computer operations ✓
    - 6) Weather data ✓
    - 7) Common operating errors ✓
    - 8) Error messages ✓
    - 9) Other (specify) _____
  - c. Available examples:
    - 1) Sample problems ✓
    - 2) Input ✓
    - 3) Output ✓
    - 4) Other (specify) _____

E. USER INFORMATION (CONT.) (Y / N)
- d. Document Indexing: ✓ / —
- 2. User Support
  - a. Direct User Support ✓ / —
    - 1) Available from:
      - a) Tool Developer ✓
      - b) Vendor —
      - c) Other (specify) _____
    - 2) Is a fee charged? ✓ / —
    - 3) Method of Inquiry:
      - a) Toll-free number —
      - b) Special format —
    - 4) Is assistance available for ...
      - a) Document clarification ✓ / —
      - b) Startup Questions ✓ / —
      - c) Technical Questions ✓ / —
  - b. Updates ✓ / —
  - c. User Groups — / ✓
  - d. Other (specify) _____
- 3. References
  - a. Source Code provided — / ✓
  - b. Technical sources identified ✓ / —

F. INPUT/OUTPUT (Y / N)
- 1. Input
  - a. Basic Units of Measure
    SI — English ✓ Either —
  - b. Manual Formats
    Tabular ✓ Graphic —
  - c. Computer Formats:
    - 1) Interactive —
    - 2) Batch with editor —
    - 3) Batch without editor —
    - 4) Interactive and batch —
    - 5) Input storage and recall ✓
    - 6) Input summary —
  - d. Special Input Formats ✓ / —
  - e. Processors
    Pre-processing ✓ Post-processing —
  - f. Default Values ✓ / —
  - g. Diagnostic/Error Messages:
    - 1) Numeric error format —
    - 2) Explicit error format ✓
    - 3) Programming errors —
    - 4) Data errors ✓
    - 5) Help menu —
- 2. Output
  - a. Unit Conversion Capability — / ✓
  - b. Predetermined Reporting Formats
    Numerical ✓ Graphical —
  - c. User Selected Formats
    Numerical — Graphical — Both —
  - d. Diagnostic/Error Messages:
    - 1) Numeric error format —
    - 2) Explicit error format —
    - 3) Programming errors —
    - 4) Data errors ✓
    - 5) Help menu —

G. STATUS OF COMPARATIVE TESTING (Y / N)
- 1. Whole building testing ✓ / —
  - Tool to tool —
  - Tool to real building ✓
- 2. Tool component testing ✓ / —
  - Algorithms ✓
  - Lab scale analysis ✓
  - Monitored component —
  - Performance data —
- 3. Comments CALPAS3 revealed favorable predictions in these comparisons.

Completed By: William A. Grant

DESIGN TOOL EVALUATION REPORT
TECHNICAL CAPABILITY — CHARACTERISTIC CHECKLIST

	Y	N
A. HEAT TRANSFER		
1. Convection Heat Transfer	✓	—
a. Intra-zonal	✓	
b. Inter-zonal	✓	
2. Conduction Heat Transfer	✓	—
a. Inter-zonal	✓	
3. Radiation Heat Transfer	✓	—
a. Internal Only		
b. Multiple Surfaces	✓	
B. COMPUTATION BASIS AND CALCULATION METHOD	Y	N
1. Computation Basis:		
a. Predominantly First Principle	✓	
b. Predominantly Correlation	—	
c. Hybrid	—	
2. Calculation Method:		
a. Steady-State (UA) Method	✓	
b. Response Factor		
c. Finite Difference	✓	
d. Frequency Domain	—	
e. R-C Network	—	
f. Transfer Function	—	
g. Other _____		
C. TIME STEPS	Y	N
1. 8,760 Sequential Hours	✓	
2. Representative Time Periods	—	
3. Typical Time Periods:		
a. Degree/Day Temperature Bins	—	
b. Variable Degree Hours/Days	—	
4. Hourly Weather — Representative Days	—	
D. BUILDING LOADS AND PROFILES	Y	N
1. Thermal Zoning	✓	
a. Single Zone Only (plus sunspace)	✓	
b. Multiple Zones	—	
2. External Load Factors	✓	—
a. Infiltration Losses	✓	
b. Radiant Heat Losses	—	
c. Envelope Heat Losses	✓	
d. Basement Heat Losses	—	
e. Slab/Slab Edge Heat Losses	✓	
f. Attic/Plenum Losses	✓	
g. Solar	✓	
h. Glazing	✓	
i. Weather Data	✓	
3. Internal Loads/Profiles	✓	—
a. Occupants		
b. Lighting Loads	✓	
c. Process Heat Loads		
d. Ventilation	✓	
e. Internal Load Profiles	✓	
f. System/Plant Profiles	✓	
g. Comfort Models	—	
E. PASSIVE SOLAR SYSTEM SIMULATION	Y	N
1. Passive Heating	✓	—
a. Direct Gain	✓	
b. Mass Wall	✓	
c. Isolate Heat Gain	✓	
2. Passive Cooling	✓	—
a. Natural Ventilation	✓	
b. Evaporative Cooling	✓	
c. Roof Ponds	—	
d. Earth Contact	—	
e. Atria	—	
f. Other _____		
3. Daylighting	—	✓
a. Daylighting Devices	—	
b. Artificial Light Controls	—	
4. Interaction With Conventional HVAC	✓	—
5. Comfort/Overheating Assessment	✓	—
6. Other _____		
F. HVAC SYSTEM SIMULATION	Y	N
1. Seasonal and/or Yearly Efficiencies	✓	—
2. Variable Efficiencies	—	✓

	Y	N
F. HVAC SYSTEM SIMULATION (CONT.)		
3. Conventional HVAC System Types	—	✓
a. Direct-Fire Hot Air Furnace	—	
b. Single Duct Systems	—	
c. Dual Duct Systems	—	
d. Multi-Zone Systems	—	
e. Fan Coil	—	
f. Induction Systems	—	
g. Unit Ventilator	—	
h. Unit Heater	—	
i. Heat Pumps	—	
j. Unitary Clg. w/Separate Heating	—	
k. Heat Recovery Systems	—	
l. Fans/Blower Control	—	
m. Fan/Motor Arrangements	—	
4. Conventional Plant Equipment	—	✓
a. Water Chillers	—	
b. Absorption Chillers	—	
c. Boilers	—	
d. Thermal Storage	—	
e. Diesel Generator/Cogeneration	—	
f. Auxiliaries	—	
g. District Services	—	
h. Evaporative Coolers	—	
i. Other _____		
5. Control Systems/Operating Modes	✓	—
a. Thermostat Setpoints	✓	
b. Thermostat Schedule	✓	
c. Thermostat Types	✓	
d. Controllers	—	
e. Other _____		
6. Domestic Hot Water Systems	—	✓
a. Solar Heated	—	
b. Conventional Heating	—	
c. DHW Variables	—	
7. Active Solar Space Conditioning	—	✓
a. Solar Collectors	—	
b. Thermal Storage System	—	
c. Heat Exchanger	—	
d. Solar Controller	—	
8. Equipment/Component Sizing	—	✓
9. Coupling of Load/System Plant	—	✓
10. Economic Calculations	—	✓
a. Type of Economic Analyses	—	
b. Economic Variables	—	
G. COMPUTATION OUTPUT REPORTS	Y	N
1. Peak Load Determinants:	✓	
a. Building Components	—	
b. Thermal Zones	✓	
c. HVAC Systems		
d. Plant	—	
e. Building	—	
2. Time Variance of Load Determinants:	✓	
a. Hour (or Less)	✓	
b. Day	✓	
c. Month	✓	
d. Season	✓	
e. Year	✓	
3. Temperatures:	✓	
a. Air, Dry Bulb	✓	
b. Air, Wet Bulb (Ambient Only)	✓	
c. Surface		
d. Chilled Water	—	
e. Hot Water/Steam	—	
f. Domestic Hot Water	✓	
g. Storage		
h. Other _____		
4. Site Energy Consumption:		
a. Time of Day Reports	—	
b. Monthly	—	
c. Seasonal	✓	
d. Annual	✓	
5. System and Components	—	✓
6. Energy Systems	—	✓
7. Total Building	✓	—
a. Per Square Foot Basis	✓	
b. By Source and Site	✓	
c. By Energy End Uses	✓	
d. By Units of Consumption	—	

Completed By: William A. Braud

DESIGN TOOL EVALUATION REPORT
NARRATIVE REPORT

Completed By: William A. Israel

DESIGN TOOL TITLE: CALPAS3

PURPOSE OF THE DESIGN TOOL

The primary purpose of the design tool CALPAS3, as stated by the tool developers, is to analyze the energy performance of residences and small commercial buildings, while also being capable of examining the impact of passive solar systems on building energy consumption. A secondary objective of the CALPAS3 program is to provide the user with a quick and simple means for executing energy analyses without intensive education, training, or preparation time.

PART I - USER UTILITY CHARACTERISTICS

A. Primary Application: The CALPAS3 program represents an effective thermal analysis design tool; although its simplicity allows the program to be used for educational purposes also. CALPAS3 complies with California's Title 24 Energy Code.

B. Building Type: The CALPAS3 program can simulate single zone residential and small commercial buildings. However, a sunspace zone may also be modeled whenever applicable. Other passive solar devices can also be simulated. Conversely, CALPAS3 is incapable of modeling domestic hot water systems or HVAC systems (except for allowing seasonal HVAC efficiency inputs).

C. Type of Availability: The CALPAS3 program is available from the Berkeley Solar Group, P.O. Box 3289, 3140 Martin Luther King Jr. Way, Berkeley, California 94703, 415/843-7600. CALPAS3 is a private domain program available for the IBM Personal computer or through timesharing on BSG's minicomputer.

D. Cost of Use: The CALPAS3 microcomputer package costs $795.00 (as of February 1985) and includes the program, a user's manual, five weather files, an introductory class, and one year of support services with updates. The additional purchase and use of an 8087 Math Coprocessor Chip (for $175.00 from BSG) will reduce typical program execution time from one hour, to about ten minutes. Furthermore, a printer is not necessary but can be extremely helpful. The initial setup time, including running sample CALPAS3 input files is roughly one to two days. Additional tool proficiency develops within a week or two, assuming moderate use of the program.

DESIGN TOOL EVALUATION REPORT
NARRATIVE REPORT

E. User Information: A well organized, 200-page user's manual is provided with CALPAS3. Since CALPAS3 is based on easily accessible ASHRAE algorithms, neither a technical manual or a source code is available. The user manual documents the sample files, an introduction to CALPAS3, input preparation and notes, various thermal circuit graphics, command syntax, the execution of CALPAS3, output reports, California's Title 24 compliance, weather files, and miscellaneous information. Direct user support is also available by telephoning BSG during their work hours. They are capable of answering technical questions since they are directly involved in the development of the program.

F. Input/Output Data: Special input forms are provided to assist the user with the preparation of input data. With the exception of internal gains, all the input and output data is in English units. SI units are not an option. Data is entered using any microcomputer editor compatible with an IBM. An editor is not included with the program. CALPAS3 does, though, provide default values for most of its input if the user decides to reference them. Furthermore, diagnostic and error messages produced by the program are understandable and quite helpful.

G. Status of Comparative Testing: The results of three different comparisons were presented in a paper entitled "Validation of CALPAS3 Computer Simulation Program". The paper involved an analytical verification, an actual vs. predicted energy consumption comparison, and a test cell comparison. All three comparisons reinforced the accuracy of CALPAS3.

DESIGN TOOL EVALUATION REPORT
NARRATIVE REPORT

PART II - TECHNICAL CAPABILITIES

A. Heat Transfer: The CALPAS3 program simulates conductive and combined radiant/convective heat transfer. Intra-zonal convection heat transfer from multiple surfaces can be modeled by providing the user with the ability to simulate different air film coefficients for ceilings, wall and floors. If a sunspace zone is specified, inter-zonal heat transfer may be modeled.

B. Computation Basis and Calculation Methods: This program relies on first principle calculations for more than 70% of its computation of loads. The algorithms used can be referenced in the ASHRAE Handbooks. CALPAS3 calculates heating and cooling loads based on one-dimensional, steady-state ("UA") heat transfer principles. The exception is the multi-node, implicit finite differencing method, utilized to determine the impact of thermal mass on the building loads. This method has been simplified and applies matrix inversion solutions to maintain a reasonable predictive accuracy.

C. Time Steps: This design tool performs load calculations for each of 8760 sequential hours, thus completing an annual simulation. A system loads calculation is done on a yearly basis and follows the hourly building load computations.

D. Building Loads - and Profiles: CALPAS3 has the ability to model a single, primary zone plus a sunspace zone if applicable. The two zones are thermally coupled by conduction through a mass wall and/or by natural or forced convection.

A variety of external load factors may be simulated. The specification of infiltration losses is limited to the air-change method. Envelope heat transfer, though, may be modeled by the user with such inputs as U-values, surface absorptivity, material conductivity, and material heat capacity. The later two material descriptions are for use with thermal mass elements only. CALPAS3 is not set up to evaluate basement loads. If a basement is to be specified, some assumptions and input manipulation must be made. The program is better set up to model slab-on-grade heat transfer. Monthly ground temperatures may not be entered by the user. CALPAS3 has the ability to simulate any glazing orientation and tilt. The following shading devices may also be employed: fixed overhangs, side fins, and reflective films. Monthly solar gain inputs allow the user to model exterior reflectors to enhance the solar gains into the building. Insulated shutters which can be varied seasonally represent another device of which CALPAS3 can simulate. One slight limitation to this program is it's inability to model glazing units with more than two layers of glass. Furthermore, a user is confined to a list of sixteen (16) various glass types with different shading coefficients from which to choose.

Weather data files are available for CALPAS3 covering over 250 different locations, including sixteen (16) climate zones within California which comply with California's Title 24 Energy Code. The following weather file types are utilized by CALPAS3: TMY, TRY, WYEC, ESOL, ETMY, 1440, MOD, and MKW. Usually only one or two of these files are available for any particular location. Files are provided on a separate diskette from the program diskette.

In modeling internal load factors, CALPAS3 uses a single, constant daily value consisting of occupant, lighting, and process (equipment) gains. Either a pre-defined typical residence or commercial internal load profile can be specified by the user. A user-generated profile may not be inputted.

E. Passive Solar System Simulation: The CALPAS3 program models passive solar heating (e.g., direct gain, mass or Trombe walls, and sunspaces) and passive cooling (e.g., natural ventilation with evaporative cooling). This design tool, however, is incapable of simulating daylighting techniques. Furthermore, interaction between the passive systems and the conventional HVAC systems is not permitted. Returning to passive solar heating, CALPAS3 can model four direct gain configurations including slab-on-grade, floor slab over a rockbed, exterior mass walls, and/or internal mass walls. In addition, mass or Trombe walls may be specified as well as a sunspace (with or without a rockbed). All the passive heating systems mentioned above can be simulated concurrently in a single building. The thermal mass materials specified may include concrete, water, brick, adobe, and any other mass type. Passive cooling, on the other hand, is confined to the modeling of natural or forced ventilation. An evaporative cooler, which cools the vent supply air, may also be employed.

F. HVAC System Simulation: CALPAS3 only allows the use of HVAC system seasonal efficiencies. The program is not set up to simulate individual HVAC systems or their corresponding components. Accordingly, plant equipment as well as DHW systems cannot be modeled. In addition, CALPAS3 is unable to size equipment or to perform economic analyses. However, seasonal thermostat setpoints including heating set-backs may be simulated. Furthermore, if a sunspace is specified, it can have different setpoints from that of the primary building zone. In mid-1985, CALPAS4 should become available. This newer version will be able to model multiple zones and various HVAC systems.

G. Computation Output Reports: At the option of the user, this design tool can output simulation results onto a diskette and/or to a printer. Furthermore, batch files may be set up to execute several simulations sequentially and to output the results after each run. Besides a summary report (showing seasonal and annual energy performances), monthly, daily, and hourly building energy performance reports can be generated by CALPAS3. These reports present energy balances and space conditions for the building, the sunspace, and/or the rockbed whenever applicable. Output is formatted to fit on 8-1/2"x11" sheets of paper.

DESIGN TOOL EVALUATION REPORT
BENCHMARK COMPARISON

The CALPAS3 energy performance results for the 1540 square foot residential building follow similar trends as the Benchmark Case. Only the passive solar category (V3) deviates from the benchmark trends. The results are presented in the graphs and CALPAS3 printouts which follow on the next several pages. It is also important to note that the three variables examined were modeled cummulatively. That is, the variable specifying additional insulation (V1) has also been included in variables two and three. The evaluation procedure did not specifically indicate to do this, but simple thermal analysis showed that the benchmark case trends must have been achieved using the same method. Furthermore, a comparison between the building loads for the increased insulation case (V1) and the respective base case loads reveals an unrealistic reduction in the benchmark building loads. The benchmark heating load dropped 37% while the cooling load fell 21%. Conversely, the heating and cooling loads from the CALPAS3 analysis fell only 16% and 10%, respectively. Again, simple steady-state thermal analysis concerning the impact of additional insulation (in the amounts stated by the evaluation) yielded load reductions much closer to that predicted by CALPAS3. Other unidentified modifications must have been made to the benchmark case with regards to variable one.

Besides the above discrepancies, CALPAS3 energy performance trends compare closely to the benchmark trends with the exception of variable three. The third variable represents a passive solar direct gain approach using thermal mass. The CALPAS3 program results show the thermal mass assisting in reducing the heating requirements and in preventing overheating (and the need for additional cooling) by absorbing the solar radiation entering the residence. Accordingly, CALPAS3 assumes a greater impact from thermal mass on the building's energy performance than that assumed in the benchmark case.

In conclusion, the CALPAS3 program is a viable design tool for modeling the energy performance of residential and small commercial buildings. The future CALPAS4 Program promises to be even better. One last note concerning the benchmark comparison; TMY Weather Data was used in the CALPAS3 runs, while TRY Weather Data was utilized in the benchmark runs. The TMY data has solar data generated by the Berkeley Solar Group. The difference in weather files may account for a certain portion of the deviations in this comparison.

Completed By: William A. Bunk

DESIGN TOOL EVALUATION REPORT
EVALUATOR BIOGRAPHY

WILLIAM A. ZWACK
Associate Engineer

RELEVANT WORK EXPERIENCE

1) W.S. Fleming & Associate, Inc.
536 Seventh Street, S.E.
Washington, D.C. 20003
202/543-7212

Presently an associate engineer involved with various energy related research projects, energy audits, and building energy performance simulations (including DOE-2.1B).

2) Professor David E. Claridge
Department of Civil, Environmental, and Architectural Engineering
University of Colorado at Boulder

Involved as a research assistant on a project concerning the validation of the variable-base degree day method (a method involving a simplified building energy performance procedure).

3) Equifax services, as a contract employee to Detroit Edison

Employed as a National Certified Residential Energy Auditor as per the Federal Residential Conservation Services Program (RCS).

EDUCATION

University of Maryland
Lawrence Institute of Technology
Bachelor of Science Degree in Architecture, 8/82

University of Colorado at Boulder
Master of Science Degree in Building Energy Engineering, 6/84

COMPUTER EXPERIENCE

Computers used: VAX 11/780s, CDC CYBER 720, Data General MV-series, CDC 6000 and 7600, Apple II, and IBM PC.

Languages known: FORTRAN and BASIC

Knowledge and Use of: DOE-2.1B, FCHART, SERI-RES VERSION 1.0, LOTUS 1-2-3, AND Numerous Editing Software

DESIGN TOOL EVALUATION REPORT
SUMMARY FORM

SUMMARY NUMBER: 01A

CATEGORY: Energy Performance and Retrofit Analysis

DESIGN TOOL TITLE: CIRA
Computerized Instrumented Residential Audit
Version 1.0, December 1982.

DEVELOPER: Lawrence Berkeley Laboratory
Energy and Environment Division

■ **CONTACT:** Peter Cleary
LBL

FORMAT:

- Manual ☐
- Calculator ☐
- Microcomputer ☑
- Mini/Mainframe ☐

ABSTRACT: CIRA is an energy-prediction and retrofit analysis tool for residential buildings. The building shell components, HVAC system characteristics, passive and active solar systems, and internal loads are inputted into CIRA in a menu-driven, multiple choice question/response format, with dynamic default values available for many questions. The building is simulated with monthly average weather data (available for 150 cities). Conduction heat loads, solar loads, infiltration loads, sky radiation losses, and temperature control strategy are accounted for in the simulation.

The program completes the energy use calculations in about two minutes, and then tabular results are displayed. If desired, the user can then iterate as necessary, using various tradeoffs, adjusting base load, infiltration etc. to actual conditions and re-run energy use calculation. The retrofit calculations take 15-20 minutes, in which over 100 retrofit items are evaluated. The retrofit results show changes in energy end use, paybacks, maintenance costs, etc. which are helpful in evaluating the most attractive retrofit options.

SYSTEM REQUIREMENTS: (for computer based tools)

- **Display:** Monochrome, 40 column
- **Printer Required:** Yes, if printed output is desired
- **Disks Required:** 1 or 2 (450K bytes total)
- **Memory Size Required:** 64K RAM
- **Other Hardware:** Microcomputer
- **Operating System:** CP/M
- **Language:** BASIC-80
- **Other Software:**

Lawrence Berkeley

DESIGN TOOL EVALUATION REPORT
KEY CHARACTERISTICS LIST

Name of Design Tool: CIRA

Design Tool Category: Numerically based annual energy performance tool

Primary Application of Tool:

- Building Design Phases ☑
  - — Programming ☐
  - — Schematic ☐
  - — Design Development ☑
  - — Construction Documents ☐
- Research ☐
- Education ☐

Applicable Building Type:

	HTG	CLG	DHW	LTG	Misc.	Other
• Single Family Residential	☑	☑	☑	☑	☑	☐
• Multi-Family Residential	☑	☑	☑	☑	☑	☐
• Small Commercial	☐	☐	☐	☐	☐	☐
• Large Commercial	☐	☐	☐	☐	☐	☐

Form of Tool Availability:

- Manual/Hand Method ☐
- Programmable Calculator ☐
- Microcomputer ☑
- Mini/Mainframe Computer ☐

Conventional HVAC Simulation Capabilities:

- Seasonal/Annual Efficiencies ☐
- Dynamic Equipment Simulation ☑
  (Specify major types: Oil/gas boilers & furnaces, heatpumps)

Alternate Energy Simulation Capabilities:

- Active Solar ☑
  - — Space Heating ☑
  - — DHW ☑
  - — Industrial Process Heat ☐
- Passive Solar ☑
  - — Space Heating ☑
  - — Space Cooling ☐
  - — DHW (thermosyphon) ☐
- Other (specify _____) ☐

List Price: $ 240 ($100 additonal for uncompiled source code and listing)

Lawrence V. Roy

DESIGN TOOL EVALUATION REPORT
USER UTILITY — CHARACTERISTIC CHECKLIST

A. PRIMARY APPLICATION [Y] [N]
1. Design Phases ✓ —
   - Programming
   - Schematic ✓
   - Design Development ✓
   - Construction Documents —
   - Post Construction ✓
2. Research — —
3. Education — —

B. BUILDING TYPE

	HTG	CLG	DHW	LTG	MISC	OTHER
1. Single Family Resid.	✓	✓	✓	✓	✓	—
2. Multi-Family Resid.	✓	✓	✓	✓	✓	—
3. Small Commercial	—	—	—	—	—	—
4. Large Commercial	—	—	—	—	—	—

C. AVAILABILITY
1. Origin
   - Public Domain ✓ — Private/Public —
   - Private Domain —
2. Format
   - Manual — — Microcomputer ✓
   - Programmable — — Mini/Mainframe —

D. COST OF USE
1. Basic Purchase Price $ 240 ($100 additional for source code)
2. Documentation cost (if separate) $ —
3. Weather data cost (if separate) $ —
4. Hardware required Microcomputer/CRT/Printer
5. Software/operating system req. CP/M
6. Evaluator Profile Experienced user

	<1 hr	<4 hr	<1 day	<1 wk	<1 mth
7. Install and Debug					
Initial Installation	✓	—	—	—	—
Debug	—	—	—	—	—
8. Learning Costs					
Setup/Familiarization	—	✓	—	—	—
Training	—	—	✓	—	—
Tool Proficiency	—	—	—	✓	—
9. Operating Costs					
Data Prep for Input	✓	✓	—	—	—
Data Input	✓	—	—	—	—

Run time 15 hrs. (min.)

10. Maintenance Costs
    - Day to Day (ser. bureau) $ N/A /mo.
    - Updates $ No further updates available
    - Disk Replacement $ Not available
    - Other $ N/A

E. USER INFORMATION [Y] [N]
1. Documentation
   a. Format:
      1) Individual Manuals ✓ —
         a) User ✓ — Combined
         b) Technical
         c) Programming Source Code ✓
      2) Imbedded in Software ✓ —
   b. Available explanations:
      1) Input parameters ✓
      2) Output format ✓
      3) Method of calculation ✓
      4) Sources of methods ✓
      5) Computer operations ✓
      6) Weather data ✓
      7) Common operating errors ✓
      8) Error messages ✓
      9) Other (specify) —
   c. Available examples:
      1) Sample problems —
      2) Input ✓
      3) Output ✓
      4) Other (specify) —

E. USER INFORMATION (CONT.) [Y] [N]
   d. Document Indexing: ✓ —
2. User Support
   a. Direct User Support — ✓
      1) Available from:
         a) Tool Developer —
         b) Vendor —
         c) Other (specify) —
      2) Is a fee charged? — —
      3) Method of Inquiry:
         a) Toll-free number —
         b) Special format —
      4) Is assistance available for ...
         a) Document clarification — ✓
         b) Startup Questions — ✓
         c) Technical Questions — ✓
   b. Updates — ✓
   c. User Groups — ✓
   d. Other (specify) —
3. References
   a. Source Code provided ✓ —
   b. Technical sources identified ✓ —

F. INPUT/OUTPUT [Y] [N]
1. Input
   a. Basic Units of Measure
      SI — English — Either ✓
   b. Manual Formats
      Tabular — Graphic —
   c. Computer Formats:
      1) Interactive ✓
      2) Batch with editor —
      3) Batch without editor —
      4) Interactive and batch —
      5) Input storage and recall ✓
      6) Input summary ✓
   d. Special Input Formats — ✓
   e. Processors
      Pre-processing — Post-processing —
   f. Default Values ✓ —
   g. Diagnostic/Error Messages:
      1) Numeric error format —
      2) Explicit error format ✓
      3) Programming errors —
      4) Data errors ✓
      5) Help menu ✓
2. Output
   a. Unit Conversion Capability ✓ —
   b. Predetermined Reporting Formats
      Numerical ✓ Graphical —
   c. User Selected Formats
      Numerical — Graphical — Both ✓
   d. Diagnostic/Error Messages:
      1) Numeric error format —
      2) Explicit error format —
      3) Programming errors —
      4) Data errors —
      5) Help menu —

G. STATUS OF COMPARATIVE TESTING [Y] [N]
1. Whole building testing ✓ —
   - Tool to tool ✓
   - Tool to real building ✓
2. Tool component testing ✓ —
   - Algorithms ✓
   - Lab scale analysis —
   - Monitored component
   - Performance data ✓
3. Comments —

Lawrence V. Gloy

DESIGN TOOL EVALUATION REPORT
TECHNICAL CAPABILITY — CHARACTERISTIC CHECKLIST

	Y	N
A. HEAT TRANSFER		
1. Convection Heat Transfer	—	✓
a. Intra-zonal	—	
b. Inter-zonal	—	
2. Conduction Heat Transfer	✓	—
a. Inter-zonal	—	
3. Radiation Heat Transfer	✓	—
a. Internal Only	✓	
b. Multiple Surfaces	—	
B. COMPUTATION BASIS AND CALCULATION METHOD	Y	N
1. Computation Basis:		
a. Predominantly First Principle	—	
b. Predominantly Correlation	—	
c. Hybrid	✓	
2. Calculation Method:		
a. Steady-State (UA) Method	✓	
b. Response Factor	—	
c. Finite Difference	—	
d. Frequency Domain	—	
e. R-C Network	—	
f. Transfer Function	—	
g. Other _____		
C. TIME STEPS	Y	N
1. 8,760 Sequential Hours	—	
2. Representative Time Periods	—	
3. Typical Time Periods:		
a. Degree/Day Temperature Bins		
b. Variable Degree Hours/Days	✓	
4. Hourly Weather — Representative Days	—	
D. BUILDING LOADS AND PROFILES	Y	N
1. Thermal Zoning	✓	
a. Single Zone Only	✓	
b. Multiple Zones	—	
2. External Load Factors	✓	—
a. Infiltration Losses	✓	
b. Radiant Heat Losses	✓	
c. Envelope Heat Losses	✓	
d. Basement Heat Losses	✓	
e. Slab/Slab Edge Heat Losses	✓	
f. Attic/Plenum Losses	✓	
g. Solar	✓	
h. Glazing	✓	
i. Weather Data	✓	
3. Internal Loads/Profiles	✓	—
a. Occupants	✓	
b. Lighting Loads	✓	
c. Process Heat Loads	✓	
d. Ventilation	—	
e. Internal Load Profiles	✓	
f. System/Plant Profiles	✓	
g. Comfort Models	✓	
E. PASSIVE SOLAR SYSTEM SIMULATION	Y	N
1. Passive Heating	✓	—
a. Direct Gain	✓	
b. Mass Wall	✓	
c. Isolate Heat Gain	✓	
2. Passive Cooling	—	✓
a. Natural Ventilation	—	
b. Evaporative Cooling	—	
c. Roof Ponds	—	
d. Earth Contact	—	
e. Atria	—	
f. Other _____		
3. Daylighting	—	✓
a. Daylighting Devices	—	
b. Artificial Light Controls	—	
4. Interaction With Conventional HVAC	✓	
5. Comfort/Overheating Assessment	—	✓
6. Other night/day solar gain distribution		
F. HVAC SYSTEM SIMULATION	Y	N
1. Seasonal and/or Yearly Efficiencies	—	✓
2. Variable Efficiencies	✓	—

	Y	N
F. HVAC SYSTEM SIMULATION (CONT.)		
3. Conventional HVAC System Types	✓	—
a. Direct-Fire Hot Air Furnace	✓	
b. Single Duct Systems	✓	
c. Dual Duct Systems	—	
d. Multi-Zone Systems	—	
e. Fan Coil	—	
f. Induction Systems	—	
g. Unit Ventilator	—	
h. Unit Heater	✓	
i. Heat Pumps	✓	
j. Unitary Clg. w/Separate Heating	—	
k. Heat Recovery Systems	—	
l. Fans/Blower Control	—	
m. Fan/Motor Arrangements	—	
4. Conventional Plant Equipment	✓	—
a. Water Chillers	—	
b. Absorption Chillers	—	
c. Boilers	✓	
d. Thermal Storage	—	
e. Diesel Generator/Cogeneration	—	
f. Auxiliaries	—	
g. District Services	—	
h. Evaporative Coolers	—	
i. Other _____		
5. Control Systems/Operating Modes	✓	—
a. Thermostat Setpoints	✓	
b. Thermostat Schedule	✓	
c. Thermostat Types	—	
d. Controllers	—	
e. Other _____		
6. Domestic Hot Water Systems	✓	—
a. Solar Heated	✓	
b. Conventional Heating	✓	
c. DHW Variables	✓	
7. Active Solar Space Conditioning	✓	—
a. Solar Collectors	✓	
b. Thermal Storage System	✓	
c. Heat Exchanger	—	
d. Solar Controller	—	
8. Equipment/Component Sizing	—	
9. Coupling of Load/System Plant	✓	—
10. Economic Calculations	✓	—
a. Type of Economic Analyses	✓	
b. Economic Variables	✓	
G. COMPUTATION OUTPUT REPORTS	Y	N
1. Peak Load Determinants:		
a. Building Components	—	
b. Thermal Zones	—	
c. HVAC Systems	—	
d. Plant	—	
e. Building	—	
2. Time Variance of Load Determinants:		
a. Hour (or Less)	—	
b. Day	—	
c. Month	—	
d. Season	—	
e. Year	—	
3. Temperatures:		
a. Air, Dry Bulb	—	
b. Air, Wet Bulb	—	
c. Surface	—	
d. Chilled Water	—	
e. Hot Water/Steam	—	
f. Domestic Hot Water	—	
g. Storage	—	
h. Other _____		
4. Site Energy Consumption:		
a. Time of Day Reports	—	
b. Monthly	—	
c. Seasonal	—	
d. Annual	—	
5. System and Components	—	✓
6. [illegible] Systems	✓	—
[illegible] Building	✓	—
[illegible] Square Foot Basis	—	
[illegible] Source and Site	—	
c. [illegible] Energy End Uses	✓	
d. By Units of Consumption	✓	

Lawrence V. Ory

DESIGN TOOL EVALUATION REPORT
NARRATIVE REPORT

DESIGN TOOL TITLE: CIRA (Computerized Instrumented Residential Audit).

PURPOSE OF THE DESIGN TOOL: The primary purpose of the design tool CIRA is to simulate and project energy use and costs for residential buildings, and project energy/cost savings for about 100 retrofit items.

PART I - USER UTILITY CHARACTERISTICS

A. PRIMARY APPLICATION: CIRA can be used in the design phase of new residences, and in projecting energy use and savings for existing residences with various retrofit measures.

B. BUILDING TYPE: CIRA can model only residential buildings, which include both single and multifamily dwellings. The model building is treated as a single zone, and the tool can simulate energy performance with a wide variety of HVAC systems, shell characteristics, and passive and active solar systems. Primary energy loads are shell dominated.

C. TYPE OF AVAILABILITY: Presently, CIRA is sold (in an 8-bit, CP/M version- 8" disks) only to firms which will in turn market CIRA. It is available from Lawrence Berkeley Laboratory at the University of California. However, a modified version of CIRA called "EEDO" (which is a 16-bit, IBM PC/compatible, 5 1/4" disks) is now being marketed by Burt Hill Kosar Rittelmann Associates in Butler, PA., and is available to both the public and private sectors.

D. COST OF USE: The basic cost of CIRA, which includes the program disks and manual, is $240. The uncompiled source code disks and source code listing can be purchased for an additional $80 and $20, respectively. EEDO is available with all of the above for $495. A microcomputer (64K RAM, 32K free after operating system/BASIC is loaded) with CRT terminal is required to run CIRA, and a printer (with 132 columns for retrofit output) is necessary if printed output is desired. The tool can be learned and used within a day or so, and the user can become proficient with the tool in less than a week.

E. USER INFORMATION: The CIRA manual is over 600 pages long, and is well organized and easy to read and understand. It is separated into an overview section, input and output sections, engineering methods section, economic optimization section,

Lawrence V. Gay

organizational glossary, question library, retrofit library, weather library, and utility program section. Sample input and output are provided, as are many helpful explanations. However, a sample problem is not included. A sample problem would help clarify the entire input/output procedure and would aid in understanding how the results can be applied. The output contains very useful data for analyzing the energy use, costs, savings etc. of the residential building. The length of time to read the documentation and become familiar with the material contained is less than a day. No further user support is available for the program.

F. INPUT/OUTPUT DATA: For data input, CIRA uses a question/response user-friendly format. The user can define his own properties and characteristics, or dynamic default values can be selected. The input procedure is clear and easily comprehended, and helpful information is available for each input (the help explanations are imbedded in the software). A particularly interesting feature of CIRA is that actual utility data can be inputted so that the impact of retrofit options can be more accurately determined. Output is in numerical tabular form. Energy use profiles can be graphed if desired by user. Input and output can be in either SI or English units. Weather data is assigned by CIRA automatically based on the nearest major city (to the building being inputted) selected by user. CIRA weather data (available for 150 cities) is based on TRY, TMY, and RCTZ tapes.

G. STATUS OF COMPARATIVE TESTING: CIRA energy use predictions have been compared to those of the DOE 2.1 program for 7 different cities and 7 different thermostat schedules. Discrepancies between the 2 programs were found to be ± 10%. CIRA predictions were also compared with actual energy use in 22 houses in 3 locations and showed good agreement. Some tool correlations and outputs such as variable-base degree days, and part load efficiencies have been compared against actual data and found to be in good agreement.

PART II - TECHNICAL CAPABILITIES

A. HEAT TRANSFER: CIRA simulates conduction and radiation heat transfer. An overall heat conduction coefficient is calculated for the building based on the sum of U-values and areas of the various building shell components. Infiltration, solar gains and sky radiation losses are calculated, in addition to day/night distribution of the solar gains.

B. COMPUTATION BASIS AND CALCULATION METHODS: The design tool calculates energy loads for each month based on variable-base degree days and cooling degree days calculated from effective

monthly temperatures. A combination of empirical correlations, standard mathematical calculation methods, and algorithms are used in determining the energy loads.

C. TIME STEPS: Complete load calculations are performed for each month in an annual simulation. System and plant calculations are performed subsequent to loads.

D. BUILDING LOADS AND PROFILES: CIRA models the entire house as a single zone with its specified characteristics and components.

A variety of situations can be modeled for external load factors. Infiltration losses can be specified based on leakage area. However, one shortcoming of the program (which has been modified in EEDO) is that infiltration losses cannot be inputted based on air changes per hour. Envelope heat losses are accounted for by calculations of U-value, absorb tivity, etc. Basement and slab losses are accounted for (based on algorithms not steady-state conduction), as are losses from the attic space. Solar gains are simulated for the four cardinal directions and horizontal surfaces, and various shading and glazing characteristics can be specified.

Weather data for 12 cities is internally stored, and the user can input weather data (supplied in CIRA manual) from any of 150 other cities. The weather data is derived from hourly records of dry bulb and wet bulb temperatures. wind speed, and cloud cover from TRY, TMY, and RCTZ tapes. The weather data input procedure has been simplified somewhat in EEDO.

For modeling internal load factors, CIRA has the ability to account for sensible and latent gains from people. various household appliances (i.e. washer/dryer, hot water heater, refrigerator. range). and lights. These gains are used as "free heat" to the space. Internal profiles as well as system/plant profiles are based on average monthly gains.

E. PASSIVE SOLAR SYSTEM SIMULATION: CIRA has the ability to simulate trombe walls. water walls. and greenhouses. CIRA calculates a solar savings fraction and solar gains to the space for the passive solar systems.

F. HVAC SYSTEM SIMULATION: Residential heating/cooling systems such as oil and gas-fired furnaces and boilers, heat pumps, central A/C systems, wood stoves, electric baseboard, etc. can be simulated. Simplified steady-state efficiencies and COP values are specified by user for the simulation. CIRA calculates part-load efficiencies for the heating and cooling systems and applies these to the energy consumption calculations. Day and night thermostat settings are specified for winter and summer. Active solar space heating and solar domestic water heating systems can also be simulated.

Economic calculations are based on fuel prices, escalation rates, maintenances costs, etc. which are specified by the user (default values can also be selected). Various costs for retrofit items can also be specified by user.

G. COMPUTATION OUTPUT REPORTS: CIRA energy use output includes monthly and yearly total energy end use and costs, along with many useful variables such as solar gain, day/night energy use, infiltration, etc. Output data can be plotted at user's request.

CIRA retrofit output includes a listing of the retrofit items, their installed cost. and net changes in energy use. One shortcoming of this section is that retrofit items cannot be deactivated/activated easily to eliminate long lists of retrofit items the user may not be interested in. However, the retrofit section allows the user to edit retrofit item costs, correlations, etc. when out of CIRA with a word processing program.

H. BENCHMARK COMPARISON: We simulated the benchmark residential building using both a gas furnace/central air conditioning system and a heat pump conditioning system. The results yielded net heating and cooling loads on the building, as well as heating, cooling, and domestic hot water energy consumption with each of the two conditioning systems. Then, two independent retrofit modifications were made and simulated. In the first case, more insulation was added to the shell, and in a second case, a third of the glass area was redistributed from the north face to the south face. Our results followed the patterns expected. By changing the building from a moderately insulated one to a heavily insulated one, the heating and cooling uses decreased by about 15%. Redistributing more glass to the south face added more passive solar gains, which in turn reduced the heating energy loads and consumption by about 6%.

Our results agreed with the benchmark ranges (developed by others) in some instances, and disagreed in other instances. The cooling energy consumption (and loads) and domestic water energy consumption generated by CIRA fell into the expected ranges of the benchmark cases. However, the heating consumption and loads varied in several instances. Our base cases for the heating load and consumption were lower than the benchmark range, and the changes in heating load and energy consumption due to increased insulation levels and redistributed glass area were not as large as the benchmark ranges suggested.

The benchmark comparison was made for the residential building only, since CIRA is not intended for use on commercial buildings.

Lawrence Livermore Lab

DESIGN TOOL EVALUATION REPORT
SUMMARY FORM

SUMMARY NUMBER:

CATEGORY: ENERGY PERFORMANCE ANALYSIS

DESIGN TOOL TITLE: SERI-PES
Solar Energy Research Institute Residential Energy Simulator, Version 1.0

DEVELOPER: Larry Palmiter and Terry Wheeling
The Ecotope Group
2328 East Madison
Seattle, WA 98112

■ **CONTACT:** Ron Judkoff
SERI
1617 Cole Blvd.
Golden, CO 80401
(303)231-1090

FORMAT:

- Manual ☐
- Calculator ☐
- Microcomputer ☐
- Mini/Mainframe ☒

ABSTRACT: SERIRES is supplied as 2 programs: (1) an interactive editor that is used to construct and perform checks upon the input file, and (2) the hourly loads simulation program.

Very general systems simulation capability exists, with any number of thermal zones. Connections between zones include constant convective conductances and/or pure conduction surfaces. Each surface may have up to six material layers with or without thermal capacitance. Solar gain is calculated very generally, on any number of surfaces of arbitrary orientation. Sophisticated solar transfer algorithms exist for glazings (arbitrary number of panes and orientation). However, the internal solar transfer is limited to a constant percentage between zones. Fairly general shading capability exists for overhangs of arbitrary orientation and size, with a very nice skyline profile option. The earth contact modelling is very crude, though.

System components include Trombe walls (with thermocirculation), rockbins, fans, and glazings and mass surfaces of arbitrary size and orientation. Control is very general, effected by predetermined schedules allowing such options as: setup, setback, night insulation, seasonal shading devices, etc.

Only thermal loads are calculated, so no HVAC system simulation capability is available. This limits the applicability to residential, and small industrial and commercial buildings with simple heating and cooling plants.

The outputs are user controlled, with the freedom to select a wide variation in output detail. All in all, the design package is very nice, indeed.

SYSTEM REQUIREMENTS: (for computer based tools)

- Display: 80 column, monochrome
- Printer Required: Yes-line
- Disks Required: Standard disk packs
- Memory Size Required: 121,000 60 bit words
- Other Hardware:
- Operating System: Independent of Operating System
- Language: FORTRAN '77
- Other Software:

DESIGN TOOL EVALUATION REPORT
KEY CHARACTERISTICS LIST

Name of Design Tool: SERIRES

Design Tool Category: Numerically based annual energy performance tool

Primary Application of Tool:

- Building Design Phases ..... ☒
  - — Programming ..... ☒
  - — Schematic ..... ☐
  - — Design Development ..... ☒
  - — Construction Documents ..... ☐
- Research ..... ☐
- Education ..... ☐

Applicable Building Type:

	HTG	CLG	DHW	LTG	Misc.	Other
• Single Family Residential	☒	☒	☐	☒	☒	☐
• Multi-Family Residential	☒	☒	☐	☒	☒	☐
• Small Commercial	☒	☒	☐	☒	☒	☐
• Large Commercial	☐	☐	☐	☐	☐	☐

Form of Tool Availability:

- Manual/Hand Method ..... ☐
- Programmable Calculator ..... ☐
- Microcomputer ..... ☐
- Mini/Mainframe Computer ..... ☒

Conventional HVAC Simulation Capabilities:

- Seasonal/Annual Efficiencies ..... ☐
- Dynamic Equipment Simulation ..... ☐
  (Specify major types: _____)

Alternate Energy Simulation Capabilities:

- Active Solar ..... ☐
  - — Space Heating ..... ☐
  - — DHW ..... ☐
  - — Industrial Process Heat ..... ☐
- Passive Solar ..... ☒
  - — Space Heating ..... ☒
  - — Space Cooling ..... ☐
  - — DHW (thermosyphon) ..... ☐
- Other (specify _____) ..... ☐

List Price: $ From $900 to $1150, depending on buyer's status

DESIGN TOOL EVALUATION REPORT
USER UTILITY — CHARACTERISTIC CHECKLIST

A. PRIMARY APPLICATION [Y] [N]

1. Design Phases — X / —
   - Programming — X
   - Schematic
   - Design Development — X
   - Construction Documents — —
   - Post Construction
2. Research — X / —
3. Education — X / —

B. BUILDING TYPE

	HTG	CLG	DHW	LTG	MISC	OTHER
1. Single Family Resid.	X	X	—	X	X	—
2. Multi-Family Resid.	X	X	—	X	X	—
3. Small Commercial	X	X	—	X	X	—
4. Large Commercial	—	—	—	—	—	—

C. AVAILABILITY

1. Origin
   - Public Domain — X
   - Private Domain — —
   - Private/Public — —
2. Format
   - Manual — —
   - Programmable — —
   - Microcomputer
   - Mini/Mainframe — XX

D. COST OF USE

1. Basic Purchase Price $ ABOUT $1000
2. Documentation cost (if separate) $ Included
3. Weather data cost (if separate) $ 60
4. Hardware required Large mini or mainframe
5. Software/operating system req. FORTRAN '77
6. Evaluator Profile New User

	<1 hr	<4 hr	<1 day	<1 wk	<1 mth
7. Install and Debug					
Initial Installation	—	—	XX	—	—
Debug	XX	—	—	—	—
8. Learning Costs					
Setup/Familiarization	—	—	XX	—	—
Training	—	XX	—	—	—
Tool Proficiency	—	—	XX	—	—
9. Operating Costs					
Data Prep for Input	—	XX	—	—	—
Data Input	XX	—	—	—	—

Run time 8 ~~hrs~~ XXX min.

10. Maintenance Costs
    - Day to Day (ser. bureau) $ 1.00 /mo.
    - Updates $ n/a
    - Disk Replacement $ n/a
    - Other $ none

E. USER INFORMATION [Y] [N]

1. Documentation
   a. Format:
      1) Individual Manuals — X
         a) User — —
         b) Technical — —
         c) Programming — —
      2) Imbedded in Software — X
   b. Available explanations:
      1) Input parameters — X
      2) Output format — X
      3) Method of calculation — X
      4) Sources of methods — X
      5) Computer operations — —
      6) Weather data — X
      7) Common operating errors — —
      8) Error messages — X
      9) Other (specify) _____ — —
   c. Available examples:
      1) Sample problems — XX
      2) Input — XX
      3) Output — XX
      4) Other (specify) _____

E. USER INFORMATION (CONT.) [Y] [N]

   d. Document Indexing: — XX / —
2. User Support
   a. Direct User Support — XX / —
      1) Available from:
         a) Tool Developer — —
         b) Vendor — —
         c) Other (specify) ~~SERI~~ _____
      2) Is a fee charged? — — / XX
      3) Method of Inquiry: Phone
         a) Toll-free number — —
         b) Special format — —
      4) Is assistance available for ...
         a) Document clarification — XX / —
         b) Startup Questions — XX / —
         c) Technical Questions — XX / —
   b. Updates — — / XX
   c. User Groups — — / XX
   d. Other (specify) _____
3. References
   a. Source Code provided — — / XX
   b. Technical sources identified — XX / —

F. INPUT/OUTPUT [Y] [N]

1. Input
   a. Basic Units of Measure
      SI — English — Either X
   b. Manual Formats
      Tabular — Graphic —
   c. Computer Formats:
      1) Interactive — X
      2) Batch with editor — X
      3) Batch without editor — —
      4) Interactive and batch — X
      5) Input storage and recall — X
      6) Input summary — X
   d. Special Input Formats — X / —
   e. Processors
      Pre-processing X Post-processing —
   f. Default Values — X / —
   g. Diagnostic/Error Messages:
      1) Numeric error format — —
      2) Explicit error format — X
      3) Programming errors — X
      4) Data errors — X
      5) Help menu — X
2. Output
   a. Unit Conversion Capability — X / —
   b. Predetermined Reporting Formats
      Numerical X Graphical —
   c. User Selected Formats
      Numerical X Graphical — Both —
   d. Diagnostic/Error Messages:
      1) Numeric error format — —
      2) Explicit error format — X
      3) Programming errors — —
      4) Data errors — —
      5) Help menu — —

G. STATUS OF COMPARATIVE TESTING [Y] [N]

1. Whole building testing — X / —
   - Tool to tool — X
   - Tool to real building — X
2. Tool component testing — X / —
   - Algorithms — X
   - Lab scale analysis — X
   - Monitored component — X
   - Performance data — —
3. Comments See attached comments in body of evaluation.

DESIGN TOOL EVALUATION REPORT
TECHNICAL CAPABILITY — CHARACTERISTIC CHECKLIST

	Y	N
A. HEAT TRANSFER		
1. Convection Heat Transfer	XX	—
a. Intra-zonal	XX	
b. Inter-zonal	XX	
2. Conduction Heat Transfer	XX	—
a. Inter-zonal	XX	
3. Radiation Heat Transfer	XX	—
a. Internal Only	—	
b. Multiple Surfaces	—	
B. COMPUTATION BASIS AND CALCULATION METHOD	Y	N
1. Computation Basis:		
a. Predominantly First Principle	—	
b. Predominantly Correlation		
c. Hybrid	XX	
2. Calculation Method:		
a. Steady-State (UA) Method	XX	
b. Response Factor	—	
c. Finite Difference	XX	
d. Frequency Domain		
e. R-C Network	XX	
f. Transfer Function	—	
g. Other _____		
C. TIME STEPS	Y	N
1. 8,760 Sequential Hours	XX	
2. Representative Time Periods	—	
3. Typical Time Periods:	—	
a. Degree/Day Temperature Bins		
b. Variable Degree Hours/Days	—	
4. Hourly Weather — Representative Days	—	
D. BUILDING LOADS AND PROFILES	Y	N
1. Thermal Zoning	XX	
a. Single Zone Only	—	
b. Multiple Zones	XX	
2. External Load Factors	XX	—
a. Infiltration Losses	XX	
b. Radiant Heat Losses		
c. Envelope Heat Losses	XX	
d. Basement Heat Losses	XX	
e. Slab/Slab Edge Heat Losses	XX	
f. Attic/Plenum Losses	XX	
g. Solar	XX	
h. Glazing	XX	
i. Weather Data	XX	
3. Internal Loads/Profiles	XX	—
a. Occupants	XX	
b. Lighting Loads	XX	
c. Process Heat Loads	XX	
d. Ventilation	—	
e. Internal Load Profiles	XX	
f. System/Plant Profiles	—	
g. Comfort Models	—	
E. PASSIVE SOLAR SYSTEM SIMULATION	Y	N
1. Passive Heating	XX	—
a. Direct Gain	XX	
b. Mass Wall	XX	
c. Isolate Heat Gain	XX	
2. Passive Cooling	—	—
a. Natural Ventilation	—	
b. Evaporative Cooling	—	
c. Roof Ponds	—	
d. Earth Contact	—	
e. Atria	—	
f. Other _____		
3. Daylighting	—	—
a. Daylighting Devices	—	
b. Artificial Light Controls	—	
4. Interaction With Conventional HVAC	—	—
5. Comfort/Overheating Assessment	—	—
6. Other _____		
F. HVAC SYSTEM SIMULATION	Y	N
1. Seasonal and/or Yearly Efficiencies	—	XX
2. Variable Efficiencies	—	XX

	Y	N
F. HVAC SYSTEM SIMULATION (CONT.)		
3. Conventional HVAC System Types	—	XX
a. Direct-Fire Hot Air Furnace	—	
b. Single Duct Systems	—	
c. Dual Duct Systems	—	
d. Multi-Zone Systems	—	
e. Fan Coil	—	
f. Induction Systems	—	
g. Unit Ventilator	—	
h. Unit Heater	—	
i. Heat Pumps	—	
j. Unitary Clg. w/Separate Heating	—	
k. Heat Recovery Systems	—	
l. Fans/Blower Control	—	
m. Fan/Motor Arrangements	—	
4. Conventional Plant Equipment	—	XX
a. Water Chillers	—	
b. Absorption Chillers	—	
c. Boilers	—	
d. Thermal Storage	—	
e. Diesel Generator/Cogeneration	—	
f. Auxiliaries	—	
g. District Services	—	
h. Evaporative Coolers	—	
i. Other _____		
5. Control Systems/Operating Modes	XX	—
a. Thermostat Setpoints	XX	
b. Thermostat Schedule	XX	
c. Thermostat Types	—	
d. Controllers	—	
e. Other _____		
6. Domestic Hot Water Systems	—	XX
a. Solar Heated	—	
b. Conventional Heating	—	
c. DHW Variables	—	
7. Active Solar Space Conditioning	—	XX
a. Solar Collectors	—	
b. Thermal Storage System	—	
c. Heat Exchanger	—	
d. Solar Controller	—	
8. Equipment/Component Sizing	—	
9. Coupling of Load/System Plant	—	XX
10. Economic Calculations	—	XX
a. Type of Economic Analyses	—	
b. Economic Variables	—	
G. COMPUTATION OUTPUT REPORTS	Y	N
1. Peak Load Determinants:	XX	
a. Building Components	XX	
b. Thermal Zones	XX	
c. HVAC Systems	—	
d. Plant	—	
e. Building	XX	
2. Time Variance of Load Determinants:		
a. Hour (or Less)	XX	
b. Day	XX	
c. Month	XX	
d. Season	XX	
e. Year	XX	
3. Temperatures:		
a. Air, Dry Bulb	XX	
b. Air, Wet Bulb	—	
c. Surface	XX	
d. Chilled Water	—	
e. Hot Water/Steam	—	
f. Domestic Hot Water		
g. Storage	XX	
h. Other _____		
4. Site Energy Consumption:		
a. Time of Day Reports	—	
b. Monthly	—	
c. Seasonal	—	
d. Annual	—	
5. System and Components	—	XX
6. Energy Systems	—	XX
7. Total Building	XX	—
a. Per Square Foot Basis	—	
b. By Source and Site		
c. By Energy End Uses	XX	
d. By Units of Consumption	XX	

DESIGN TOOL EVALUATION REPORT
NARRATIVE REPORT

DESIGN TOOL TITLE: SERI-RES

PURPOSE OF THE DESIGN TOOL: The primary purpose of the design tool, as stated by SERI, is to be used as a general purpose thermal analysis simulation program for residential buildings of the passive solar type. However, the program can be used for other building types as well, when the HVAC equipment does not interact with the building in a highly nonlinear fashion.

PART I - USER UTILITY CHARACTERISTICS

A. PRIMARY APPLICATION: The primary application of the design tool is to simulate building loads for residential type buildings. As only building loads are the object of simulation, no HVAC equipment/building interactions are possible. There is no capability in SERIRES to handle the situation when equipment efficiencies are highly dependent upon equipment output.

B. BUILDING TYPE: Both heating and cooling loads can be simulated for single and multifamily dwellings of the residential type, and for small commercial and manufacturing buildings. Lighting loads and internal loads can be simulated separately with a daily or weekly/weekend schedule. No capability exists for simulating either DHW or Space Heating active solar systems. The code is designed to accurately handle solar gain to the space. Thus, particular emphasis has been placed upon buildings of the passive solar type.

C. AVAILABILITY: The code exists in the public domain and is available from the National Software Data Center, Argonne National Laboratory, Argonne, IL 60439. A substantial minicomputer or a mainframe computer is required to run the code.

D. COST OF USE: The purchase price is about $1000, and includes the User's Manual, and (on magnetic tape) the source code for the input editor, the source code for the loads program, example input files, and example output files. TMY weather data are required as input to the loads program, but this may be circumvented with data of the same scope.

This evaluation was performed by a new user who was very experienced with building performance simulation codes and computer operating systems. Yet, strenuous efforts were still required to install the code, mainly because random access I/O files are used by the program. Such files are unable to be accessed by some operating system's utilities. Thus, one entire day was required for installation. Debugging proceeded rapidly thereafter, requiring only about one hour, and consisted mostly of effecting proper I/O connections. About one entire day was required for setup and familiarization, primarily because the

manual is poorly written. An additional half day was required in training to become familiar with the input editor, while one additional day is necessary to attain proficiency.

About one half day was required to generate (by hand) the input information to be supplied during the input phase of use. About one hour of time was required to input this information required for the generation of a completely new input file, but changes could be made speedily thereafter. It is noted that these times will vary depending upon complexity of the particular simulation, and system response time. As the files to be dealt with are fairly large, it is recommended that they be stored on tape rather than disk. However, this decision is system dependent, as costs and ease of tape access vary.

E. USER INFORMATION: All of the documentation supplied as part of the package comes in one manual, which is conveniently stored in a 3 ring binder. The manual contains detailed information on the following topics: (1) input variables, (2) output format, (3) mathematical and physical bases of discretization and solution, (4) error messages (in the comprehensive chapter on the input editor), and (5) the required format(s) for the weather data input.

There are also two sample input problems provided, with complete input and output for each problem. However, this information is presented with no attempt to lead the reader through the problems.

Direct user support by telephone is available on a personal basis from Ron Judkoff at SERI, for which no fee is charged. Presently, there are relatively few problems with the code, so this is possible now. In the future, as the user community grows, this situation may change. Ron will attempt to answer any question put to him, including technical questions, start-up questions, and document clarification.

No updates are yet available, as there is only one version of the code. There is no formal user's group. However, the FORTRAN '77 source code is included as part of the package, and the manual includes ample references to the technical literature.

F. INPUT/OUTPUT: A seperate, interactive, preprocessing editor exists wherein data may be input in either English or Metric units. Input data files may be stored for later recall and modification, and libraries of material properties and building components may be generated and saved. The editor has many internal default values, provides a clear explanation of the specific input required (including units and field size), and performs a variety of error checking including data value errors, format errors, and programming errors. The loads program will accept weather data in either English or Metric units. Output

can be generated in either system of units, also. The amount and format of the output may be specified, but only tabular output is available.

G. STATUS OF COMPARATIVE TESTING: SERIRES has been tested extensively versus other passive solar system simulation codes through participation in the Systems Simulation and Economic Analysis (SSEA) exercises. It has also been validated versus test cell and residential data collected at SERI. This testing includes whole building performance, subroutine performance, and component performance.

PART II - TECHNICAL CAPABILITY

A. HEAT TRANSFER: Convection heat transfer within a zone (surface to air), and between zones (air to air) is modelled with constant conductances input by the user. Conduction heat transfer is modelled between zones by specification of 1-dimensional nodal points with or without thermal capacitance. The separate material properties for each material must be input also. Shortwave radiation heat transfer is modelled very accurately until it enters the building. The user is then required to distribute it to surfaces, the air, and loss using constant percentages. There is no capability to simulate longwave radiation heat transfer anywhere in the code.

B. COMPUTATION AND CALCULATION METHOD: The bases for the calculations represent a mix between a correlational approach and a fundamental approach. The user has a variety of options to pursue, including selection of a steady-state R value, an RC network using finite difference, or a combination of the two.

C. TIME STEPS: The period of simulation may be chosen, but is usually an entire year. Time steps are constant as calculated by the input editor for stability, but must be less than or equal to 1 hour.

D. BUILDING LOADS AND PROFILES: Any number of thermal zones may be specified (up to system memory and acceptance of execution time), as the building description is based upon a building block approach. Transfer coefficients may be defined to include infiltration, conduction to the ambient, losses to the ground, losses to an attic zone, and losses through glazings. Solar gain is modelled very accurately, but solar loss is only included as a user input fraction of the solar gain. Internal loads may be defined on a daily or a weekly/weekend schedule to represent occupant load (sensible and latent), process load, and lighting load. No comfort models or HVAC equipment models are available.

DESIGN TOOL EVALUATION REPORT
NARRATIVE REPORT

E. PASSIVE SOLAR SYSTEM SIMULATION: The program was designed primarily to simulate passive solar systems in the heating mode, and is quite general in this respect. Direct gain, sunspace, thermal storage wall, and isolated gain systems may be simulated. No daylighting or passive cooling system simulation capabilities are available. No assessment of comfort is possible, and no HVAC system simulation is possible.

F. HVAC SYSTEM SIMULATION: As the program deals only with the building load, no HVAC equipment models are available. All HVAC system sizing must be done off-line by hand. However, the program does include separate heating, venting and cooling thermostat setpoints which may be input on a daily or weekly/weekend schedule.

G. COMPUTATION OUTPUT REPORTS: The output is very general if one is willing to wade through the extreme detail generated. In this fashion, it is possible to determine the peak loads for the building, and for individual components and zones. Similarly, one can select any or all outputs (temperatures, and energy/heat flows) hourly, daily, monthly, or annually. Dry bulb temperatures are available for the zones, surfaces, and storage components. A breakdown of energy consumption by end use is also output.

H. BENCHMARK COMPARISON

A. RESIDENTIAL HOUSE

The primary point to be made is that SERIRES does not calculate any equipment loads whatsoever, but only calculates the thermal loads of the building. Therefore, all system loads have been hand calculated by the evaluator.

The following parameters were used in the simulation and are given here as they exerted a significant influence upon the results:

Wall solar absorptivity = 0.6
Roof solar absorptivity = 0.8
Overhang horizontal projection = 1.5 ft.
Overhang height above top of window = 1.5 ft.
Average window height = 3 ft

The second point to be made is that the parameters were varied in a sequential fashion (not in a parallel fashion). This means that V2 had the parameters from V1, and that V3 had the parameters of V2 (which had the parameters of V1). Explicitly, each run was not an excursion on the base building, but an excursion on the previous run.

Finally, SERIRES has no capability to calculate DHW performance. Therefore, this section of the results are left blank.

The results shown are in fair agreement with those shown as shaded bars. However, the cooling loads predicted by SERIRES tend to be slightly lower than those shown on Figure R1. This is possibly due to the assumption of an overhang in the present simulation.

The energy consumption figures plotted on Figures R2 and R3 were obtained by dividing the building loads by the averagy efficiency or the average COP, whichever was appropriate. No account was taken for parasitic losses, and this would tend to raise the present results to the point of falling within the shaded areas.

B. COMMERCIAL BUILDING

The following parameters were assumed for the present calculations:

Wall solar absorptivity = 0.6
Roof solar absorptivity = 0.8
No overhang

Also, it was unclear what to do with the lighting load. It was specified as 2.25 W/ft_2, and in combination with the equipment load of 0.75 W/ft_2, resulted in a load of 3.0 W/ft_2 (=10.24Btu/ft_2-hr). This load was taken as independent of the occupancy as a dependence on the occupancy was not indicated in the instructions. Additionally, unless selected groups of workers were gone from specific rooms in which the lights were always extinguished during the unoccupied hours, this load would persist. Therefore, the full lighting and office equipment loads were applied during all occupied hours. It is evident that the results shown for comparison made the opposite assumption. The present results, therefore, tend to be about 20% higher in the cooling loads than the shaded results. This has also resulted in a decrease in the annual heating load as shown on Figure C1.

Finally, the second modification was specified as the installation of energy efficient ballasts (not light bulbs). There are 2 grades of energy efficient ballasts - the better grade saves about 5-10% of the lighting energy. Therefore, 10% was taken as the upper limit for the results calculated herein. The present results are seen to be much higher, for this reason, in case V2.

It is evident that the shaded results for case V2 assumed that both the lights and the ballasts were on the energy efficient variety, which tends to save from 20% to 30% of the lighting energy.

Again, the system energy loads were obtained by dividing the building loads by the efficiency or COP, whichever was appropriate. As the cooling results started from a higher point and the heating results started from a lower point, it is not surprising that they so remained.

The fan energy was computed by applying the "rule of thumb" that parasitic losses tend to average around 15% of the total system energy. Actually, agreement is surprisingly close in this regard.

Finally, the electric peak demand was calculated in a fashion similar to the electric consumption, and 15% additional was added in for the inclusion of parasitic losses.