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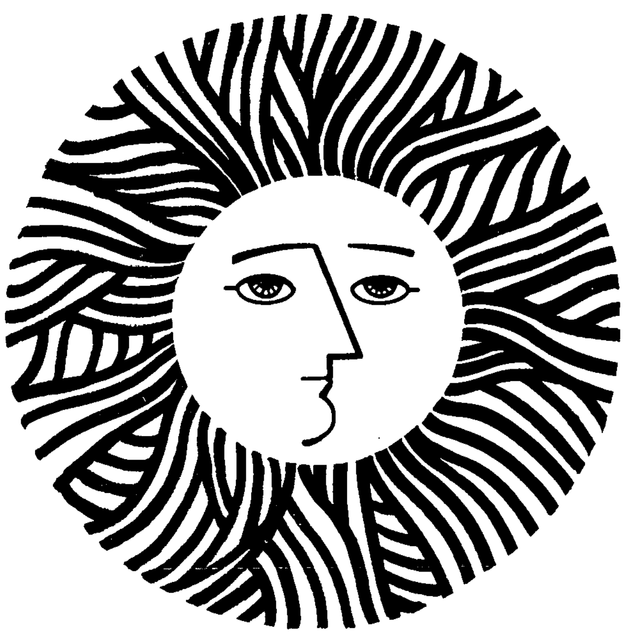

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COMPUTERIZED, INSTRUMENTED, RESIDENTIAL ANALYSIS (CIRA)

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Overview

What do a government official, an architect, an energy auditor, an engineer and a contractor have in common? Sooner or later, they all need to know projected energy use in a given house and sometimes they may need to maximize energy savings in an existing house within the constraints of a given budget.

Several paper-and-pencil procedures exist to do both of these tasks. Unfortunately, they always boil down to lengthy sheets of calculations. You've heard of computer programs developed to ease this task: you like their speed -- it's the inputs you could do without. Describing a building to a computer may require strict adherence to a particular format or the knowledge of a special language. Furthermore, you may lack access to a computer system that runs your favorite building energy analysis program.

Two recent trends appear particularly promising as a way out of the burden of calculating energy use in buildings: the introduction of microcomputers and the development of user-friendly programs. Microcomputers are cheap enough to be affordable by the smallest business, and many different brands are capable of running the same wide selection of programs. User-friendly programs don't expect you to tell them about your building in some rigid format or language; they ask questions in plain English and suggest possible answers -- you just point to the answer you like best.

Computerized, Instrumented, Residential Analysis (CIRA) is a user-friendly program developed for microcomputers. More precisely, CIRA is a collection of programs related to building energy analysis and designed for a wide variety of microcomputers. It couples the state-of-the-art in interactive features with the latest developments in simplified computer models of building energy analysis. For the novice, CIRA will provide exhaustive explanations of everything it needs, while for the experienced user the questions and responses are more terse.

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Below you will find descriptions of how CIRA takes the headaches out of describing the house characteristics needed for energy analysis. For those interested in the more technical aspects of CIRA -- how it figures out heating and cooling energy consumptions or how it determines optimal energy-saving strategies -- we have included a section "Energy Calculations."

Data entry

In developing CIRA, much effort was devoted to facilitating the tedious process of entering the appropriate building data. Prominent among the features that distinguish CIRA from other computer programs are:

Friendliness: The user does not have to learn a language and does not have to remember any commands. CIRA does the work by asking about wall areas and types, heating system specifications, passive solar features, etc.; the user simply answers the questions displayed on a screen.

Helpfulness: If the CIRA novice does not understand some of the questions, such as

"Terrain Class.....?",

he or she can call for help with a simple keystroke, to which the computer responds with a more detailed explanation of the question, together with examples when appropriate.

Multiple choice: If the user understands the question, such as "Window Glazing.....?", but does not remember the possible answers, another keystroke displays a list of options in multiple choice style, in this case

S=Single Pane
D=Double Pane
T=Triple Pane

In fact, this list will appear automatically whenever more than two wrong answers are given.

Dynamic defaults: Frequently, the user may not know the answer to technical questions, such as the R-value of a wall or the solar-gain factor of a window. What is, for example, the R-value of a 2′ x 6′ frame wall whose 5.5 inch cavity is insulated with 4 inches of Vermiculite and one inch of exterior insulating sheathing? CIRA provides the answer, in this case R-16.8, at the touch of another special key. We call the values provided by this keystroke dynamic defaults. Defaults, because they provide the most likely answer when the user hasn′t a clue, and dynamic, because they usually depend on the user's answers to one or more previous questions. Beyond the lay user, the professional can use dynamic defaults to avoid leafing through voluminous handbooks in search of the heat-loss factor for a basement, for example. If asked for help at this point, the computer will describe what method it uses to arrive at a particular default value.

Goof-proofing: Often, the user may want to alter previous input, or correct mistakes, or re-use a house entered earlier, changing only details such as floor area, the city where it is located, and the window size. As soon as another simple keystroke is hit, the computer enters an editing mode, and displays the desired questions and the answers previously given on the screen, along with a request for the new answers. The computer even keeps track of things you may have forgotten in the process: if you change the city from Denver to San Francisco, for example, it will remind you that, as you leave the mile-high city, you may also want to change the altitude.

The computer accepts entries on a wide variety of house components and related features:

- Walls, windows, doors
- Roof and subfloor
- Active and passive solar features
- Heating and cooling system
- Information on how the house is oriented and shielded
- Occupant behavior related to energy use
- Prices for the various fuels used.

Some of these entries may require the use of specialized instrumentation, such as 1) a tape measure to obtain the relevant dimensions of the house, 2) a solar siting meter to measure the degree of obstruction to solar radiation by trees and adjacent buildings, 3) a combustion efficiency meter to measure furnace efficiency, 4) a blower door to pressurize the house, and 5) a few smoke sticks to find where the air leaks are. Incidentally, most of these instruments can be found in the kit of a "house doctor," who searches a house for hard-to-spot energy leaks and fixes the most conspicuous of them during his or her visit. CIRA was designed with the house doctor-approach in mind. The measurements performed by the house doctor feed directly into CIRA which translates them into practical retrofit recommendations. Thanks to dynamic defaults, however, these measurements and the attendant instruments are not indispensable -- CIRA can function as a "stand-alone" diagnostic program. After all questions about the house have been properly answered, the computer will automatically figure monthly and yearly heating and cooling energy consumptions or, on request, recommend several combinations of energy-saving measures suitable for low, medium and high budgets. Every combination (e.g., storm windows, elimination of air leaks, basement insulation) is chosen to produce the highest energy savings for a given budget. Of course, interest and inflation rates, maintenance costs of the installed measures, and projected period of occupancy are taken into account.

Energy calculations

To calculate the energy consumed for any given house, CIRA uses heating and cooling algorithms developed at Lawrence Berkeley Laboratory, Princeton University, National Bureau of Standards, Los Alamos National Laboratory and the University of Wisconsin. A technical report describing the calculation methods in detail is available upon request.* A brief summary follows below.

For each month, an energy balance is calculated separately for day and night. First, a heat-transmission coefficient is calculated, to determine how much heat the house loses per month and per degree of temperature difference between indoors and outdoors. To this coefficient is added the effect of infiltration, computed on a monthly basis using a method developed at Lawrence Berkeley Laboratory. This method uses information on the leakage area of the house, the type of terrain on which it is located, and the type of shielding surrounding the house, all of which is part of the information requested by CIRA. For terrain and shielding classes, CIRA will display descriptive tables on request. Leakage area is generally measured with a so-called "blower door", a fan-like device that creates an over- or under-pressure in the house and measures the amount of air flow through the fan necessary to reach several special levels of pressure. Alternatively, the leakage area can be estimated from information on the air tightness of windows, walls, doors, and all other building components. As usual, dynamic defaults are available to provide what the user may not know.

Of course, like most other aspects of heating and cooling energy requirements, air infiltration depends on the local temperatures and wind speeds. The user, however, never need be concerned with such tedious detail: the name of the nearest city in CIRA's files is all he or she ever will have to know about local weather patterns. And, naturally, the program will prompt for it and display the available options.

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* Write for: R.C. Sonderegger, J.-Y. Garnier, A Simplified Method for Calculating Heating and Cooling Energy in Residential Buildings, Lawrence Berkeley Report LBL-13508 (to be presented at the Third Intl. CIB Symposium on Energy Conservation in the Built Environment, Dublin, Ireland, March 30 - April 1, 1982.)

Solar gains are computed by taking into account weather-averaged solar radiation in the city chosen by the user, the shading effects of trees, nearby buildings and overhangs, and the optical characteristics of windows and walls. The shading effects of overhangs and the reflection of glazed surfaces are modeled by using correlation methods developed at Los Alamos National Laboratory. The solar gains, together with other internal gains and radiation losses to the sky, are used to compute an effective outdoor temperature, which is usually higher than the monthly average temperature. The monthly values of effective outdoor temperature, indoor thermostat setting, and heat-transmission coefficient are used to compute monthly heating and cooling loads for day and night. These loads are corrected if night and day thermostat settings are different. Seasonal heating and cooling efficiencies are figured for each month based on 1) heating and cooling loads, 2) specifications of the heating and cooling equipment, 3) part-load efficiencies, and 4) ambient-dependent output capacities. Finally, heating and cooling loads and efficiencies are combined to arrive at monthly energy consumptions for heating and cooling.

The heating and cooling consumptions calculated by this load module were compared with those of the DOE-2.1 program for seven different cities and two thermostat schedules. In general, discrepancies between the two programs were found to be on the order of $\pm 10\%$.

Viewing the results

After the minute or so that it takes to perform the heating and cooling calculations, CIRA displays monthly values and yearly totals (or means, where appropriate) of several quantities, such as:

- Daily and nightly heating and cooling energy consumption
- Daily and nightly heating and cooling loads
- Air infiltration
- Solar gains
- Dollar expenditures for heating and cooling
- Average and effective daily and nightly outdoor temperatures

These results can be displayed either in tabular form or graphically, depending on the user's wishes. By pressing the appropriate key from a menu displayed at the top of the screen, the user may also plot any arithmetic combinations of these figures (e.g., the sum of daily and nightly heating and cooling expenditures). For users with special needs, CIRA can be easily modified to display other types of output as, for example, infra-red radiation loss to the sky, or the percent change in energy consumption for every percent change in infiltration, in solar gains, or in similar parameters.

Energy-saving retrofits

For energy auditors and energy policy makers, the technical details about yearly energy consumption may be of less interest than determining the most cost-effective strategy to save energy. That is, for a given budget, what is the most energy-saving combination of retrofits or, what is the highest retrofit budget for which the dollar savings still exceed the expenditures (including maintenance costs)? CIRA is able to answer both of these questions in a mostly automated process consisting of two stages: the selection of retrofits, and their economic optimization.

Retrofit selection

The retrofit selection occurs as follows: First, CIRA scans an extensive list on a disk containing several hundred retrofit options and their respective costs per unit, as well as their figures of thermal merit (typically, added thermal resistance, decreased solar gain, decreased leakage area, improved efficiency). CIRA will display only those items appropriate to the structure in question; that is, cellulose insulation for cavity walls, not for solid masonry walls, and sliding storms for double-hung windows, not for casement windows.

This reduced selection of retrofits is shown on the screen for each house component (walls, windows, etc.). Costs for do-it-yourself and contractor installation are displayed for each retrofit selected. At this stage, the user may discard any unacceptable item (for example, aluminum insulating blinds in the bedroom).

Econonmic optimization

At the end of this retrofit selection process, the computer determines the best combination of retrofits for the whole house within the constraint of one or several given budgets. This process involves multiple yearly energy calculations, and may take from a few seconds to a few minutes, depending on the size and complexity of the house, the climate and the number of retrofits involved. Dollar and energy savings are shown for each combination of retrofit options based on the expected period of occupancy for the house under consideration. On request, the program can display monthly payment schedules for bank loans covering the cost of the retrofits. These schedules will be computed for the house under consideration, and will also display the dollar amount of tax credits and tax deductions available.

Microcomputer requirements to run CIRA

Currently, CIRA can be run on any microcomputer with the following specifications: 1) a Z-80 or Intel-8080 microprocessor, 2) a CP/M* operating system, 3) at least 56 kilobytes memory, 4) a minimum of 360 kilobytes floppy disk space and 5) a small printer. Small modifications may be necessary to accommodate special terminals. At the time of this writing (October 1981) a complete system with these specifications, including a terminal or a keyboard and monitor, can be purchased for around $4,000.

For more information on CIRA, additional descriptive material, or availability, please write to:

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* CP/M is a trademark of Digital Research, Inc., P.O.Box 579, Pacific Grove, CA 93950.