Published in the Proceedings of ASES-2001, the American Solar Energy Society

A DRAG-AND-DROP ENERGY DESIGN TOOL

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ABSTRACT

The objective of this project is to give electric utility ratepayers an easy and intuitive way to accurately describe their home to the computer. This will allow the program to more precisely predict the building's performance and the energy cost savings of the ratepayer's various design or remodeling changes.

Windows are the most critical architectural elements influencing a building's energy consumption, yet they are also the most tedious to describe. Therefore we developed this new graphic user interface (GUI) using intuitively simple "drag-and-drop" data input screens to make it easy (and even fun) for homeowners to provide this critical information.

This new software package incorporates as its computation engine a whole-building hourly heat balance simulation program, Solar-5. It allows homeowner's to easily test various designs alternatives including passive solar options such as window shading, thermal mass, night ventilation, and movable night insulation.

Usability studies conducted with a group of typical ratepayers evaluated the effectiveness of this tool. Among the features they especially appreciate are being able to quickly draw in their own floor plan, drag and drop their actual windows onto each facade, and easily rotate their home to its correct orientation.

1. INTRODUCTION:

Most of the energy that Southern California Edison produces is used by their 4.1million residential customers to heat, light, and cool their homes. How can we enlist this huge and highly diverse population in the task of making their homes more energy efficient?

Almost every decision that homeowners or apartment managers make about the design, operation, or maintenance of their building influences the way it consumes energy. The problem is that they have no easy, intuitive way to visualize the energy implications of all their various choices, or to show how much money they will save with each different choice. This kind of knowledge becomes especially important to ratepayers as electricity costs skyrocket in the face of reduced supply and increased demand. The goal of this project is to give ratepayers an effective reliable way to reduce their increasing energy costs.

This tool is simple enough that anyone who knows how to use a computer can quickly and easily load in their building, and then get immediate graphic information to help make better energy efficiency decisions. The terms and concepts are familiar to anyone who owns a home and pays an electric bill. Thus this new tool speaks the language of ratepayers instead of the technical jargon of architects or energy engineers.

The new Graphic User Interface is written in Java and C++. As its computation engine it uses Solar-5, a popular whole-building hourly heat balance simulation program developed at UCLA. Over the last 16 years Solar-5 has been distributed as freeware and is one of the most widely used energy design tools, especially

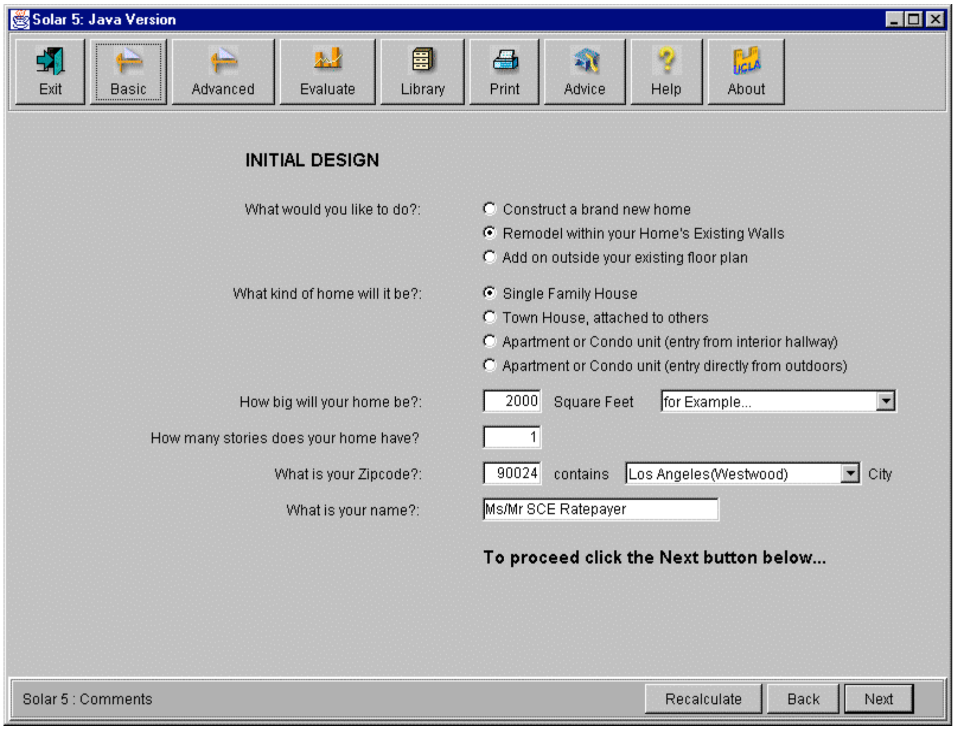

Fig.1: INITIAL DESIGN: On this initial screen the ratepayer answers just five questions about the building type, size, and location of their home. From this data, Solar-5's built-in expert system designs two different reference homes called "Scheme 1 Meets Energy Code," and "Scheme 2, More Energy Efficient."

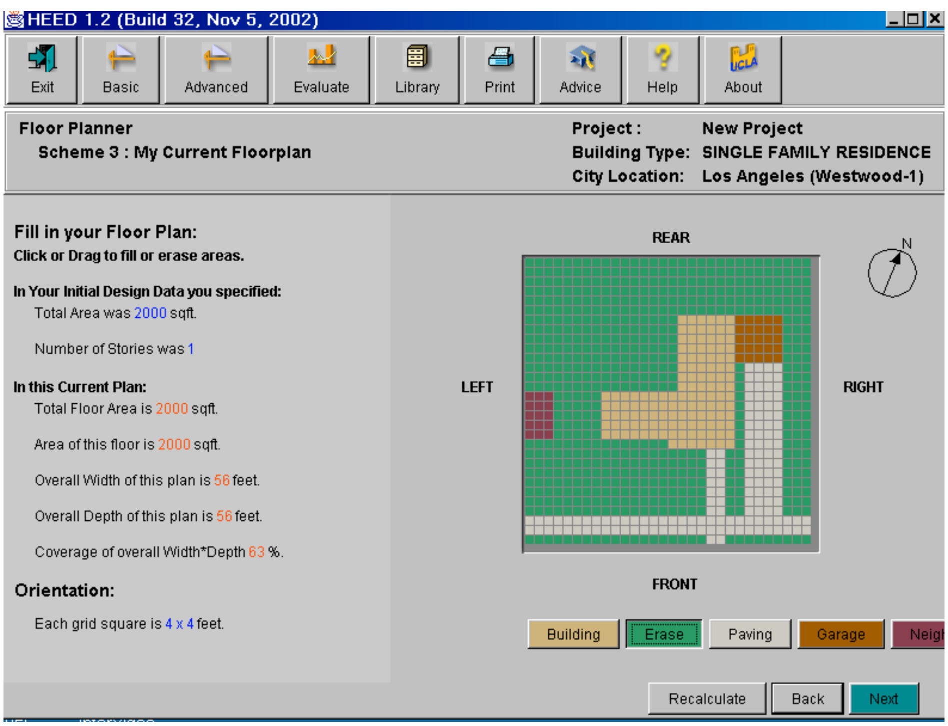

Fig. 2: FLOOR PLANNER: On this screen, the homeowners have adjusted the outline of their house with the mouse until the same 2000 square feet area is distributed into two wings. As they make changes, the left hand panel calculates on the fly all the dimensions like Total Floor Area, Overall Width, and Overall Depth.

among architects and students of architecture. Solar-5 uses TMY2 climate data to calculate a whole-building heat balance for each hour of the year. It integrates loads and system performance and can calculate floating indoor air temperatures. It has been validated using the BESTEST procedure which shows it produces the same results as DOE-2, BLAST, and four other models.

A file of zipcodes for the Southern California Edison (SCE) service territory correlates city names with residential electric rates data, as well as the corresponding California Energy Commission climate zone.

Thus, SCE residential ratepayers can use this program to accurately identify cost effective energy efficiency options that are specifically calculated for their own unique building in their own particular climate.

2. WHAT THIS PROGRAM LOOKS LIKE

The following images demonstrate what it would be like for an SCE ratepayer to use this new energy design tool. This particular example took about half an hour to run.

2.1 Initial Design

On this first screen (Fig. 1) the homeowners, "Ms/Mr SCE Ratepayer," answer just five questions about their type of home, its size, and location. From this data, the built-in expert system designs two different reference homes:

Scheme 1 is called "Meets Energy Code": This reference design just barely meets the California Energy Code for Low-Rise Residential Buildings (Title 24, Package B). It has a square floor plan with a raised floor over a vented crawl space, and the maximum number of windows uniformly distributed on all four walls using code minimum glazing.

Scheme 2 is called "More Energy Efficient": It is has a rectangular floor plan with a slab on grade and most of the windows on the south wall, optimally shaded, and double glazed, plus the home has a whole-house fan (or optimum natural ventilation).

2.2 Floor Planer

On this screen (Fig. 2) the homeowners have started Scheme 3, "My Current Floorplan," and have drawn in with their mouse the outline of their actual house. Here the same 2000 square feet of floor area are distributed into two wings. As the homeowners make changes to their floorplan, all the dimensions like Floor Area, Overall Width, and Overall Depth are calculated on the fly and displayed in the left hand panel.

2.3 Orientation

This new floor plan is now shown in 3-D, overlaid on a compass (Fig. 3) . They can grab their house and rotate it around so that the front faces in the correct direction. In this particular case, it was finally adjusted to face about 15 degrees East of due South. To help homeowners figure out which direction their house faces, this compass also shows the directions of sunrise and sunset in the summer and winter plus on the equinox.

2.4 Window Layout

On this screen (Fig. 4) the homeowners can click and drag each individual window to its correct location on its correct facade. On a previous screen the homeowners were asked to describe the various types of windows in their home. Up to 14 different kind of windows or skylights can be input, but this particular house uses only five types. Homeowners can easily measure their windows with a yardstick, and clicking on the "Help" icon explains how to use a match flame to see if they have dual pane glass or low-E coatings (i.e., if there are four reflections it is double pane, if one reflection is much brighter it is low-E coated).

The little compass on the upper right shows that the user has clicked their house around to look at the left side where they have two pairs of sliding glass doors facing into their back yard. The previous Orientation screen showed that this Left Side wall faces roughly west.

It is very important for the homeowners to accurately place each window on the wall because it gives them a visual check to be sure they have not left any windows out or made them the wrong size. Encouraging them to make each facade look exactly like their actual house has another benefit because it reassures them that the computer is actually modeling their own particular building, and thus they will have more confidence in the energy cost figures when they are calculated.

2.5 Other Building Construction Decisions

There are many other aspects of a home's construction that can be input by simply clicking on 'radio button' lists (see Fig. 5). For example, in this case they can

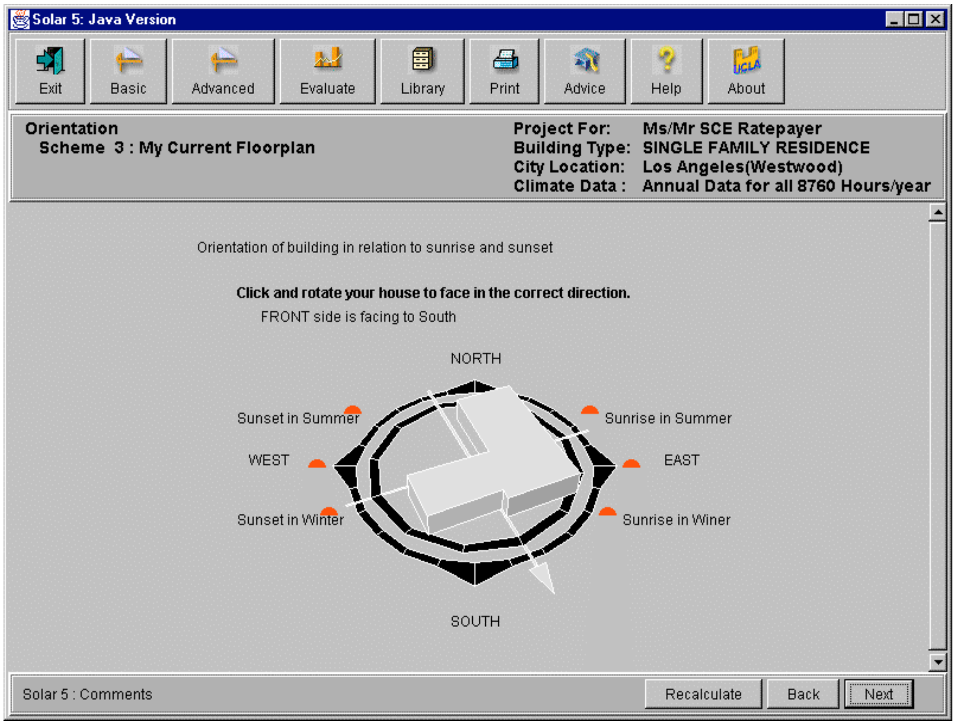

Fig.3: ORIENTATION: Once the floor plan has been defined, the homeowners can click and drag the front of the house around to face in the correct direction, in this case making it face about 15 degrees East of due South.

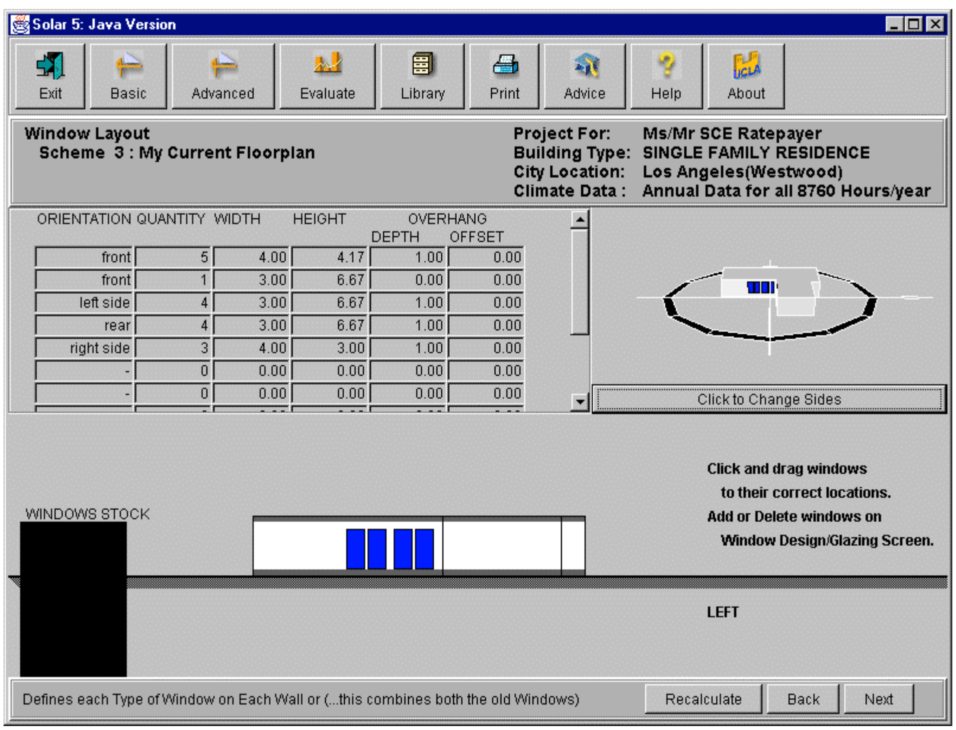

Fig. 4: WINDOW LAYOUT: Here the homeowners can drag and drop each window into its correct location, which helps them visually check that the each facade has the correct number of windows of the correct size.

described their exterior walls as “Stucco on Wood Studs with Plaster Board Interior.”

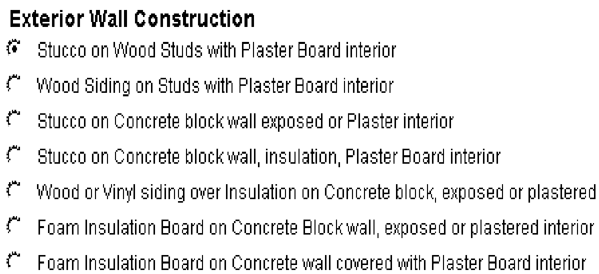

Fig. 5: Typical List of Exterior Wall Construction Options

If homeowners are unsure about what is in their walls or ceilings, clicking on “Help” gives them a list of various suggestions about how to find out, plus definitions of many terms. Notice, however, that these are not technical architectural or engineering terms, but are the kind of things that most homeowners would know or could easily determine about their own home.

Similar lists are also provided for:

- Insulation
- Roof Construction
- Floor Construction
- Glass Type
- Infiltration and Weather Stripping
- Ventilation (and free Economizer Cooling)
- Furnaces
- Air Conditioners

2.5 <u>Energy Costs:</u>

Each time the ratepayers finish describing their home, its performance is calculated for all 8760 hours in a year, and a set of bar charts are displayed showing the annual cost of Electricity, Gas, and the Total Yearly Cost (Fig. 6).

The first bar in each set is for “Scheme 1, Meets Energy Code,” the reference design that the expert system automatically created for this 2000 square foot house in Westwood. The second bar shows how much less energy is used by the “Scheme 2, More Energy Efficient” version of the same house In most cases, depending on where the ratepayers live and what type of house they have, the expert system will create a Scheme 2 design that uses about a third less energy.

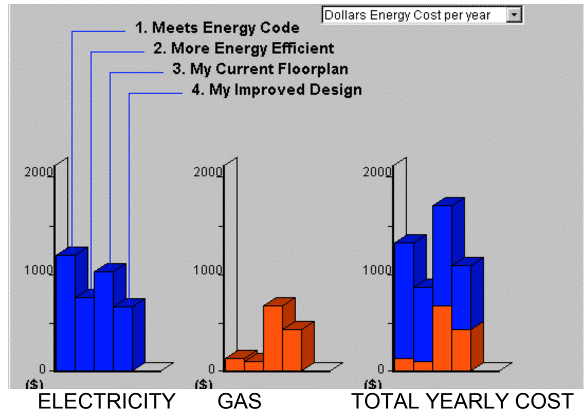

Fig. 6: Energy Cost Bar Charts. In each of these three sets (Electricity, Gas, Total), the right hand bar shows the Dollars Energy Cost per Year for of Scheme “4. My Improved Design”.

The third bar in each set shows the Energy Cost of Scheme 3, their own building that they called “My Current Floorplan.” This was where they drew in their “L” shaped floor plan, rotated it to the correct orientation, laid out their windows, and checked off the other attributes of its construction. Notice that it uses much more Total Yearly Energy then any of the other designs.

Finally the right-most bar shows what happened when they copied their “Current Floorplan” into Scheme 4 that they called “My Improved Design”, and made four changes:

- Insulated their attic
- Added an 8 foot patio cover above their sliding glass doors in the back yard
- Weather striped and caulked their windows and doors
- Added a whole-house fan

When they clicked on the Total Yearly Cost bar for Scheme 3, they found it costs them about $1691 per year for heating, cooling and lighting. Clicking on the Scheme 4 bar shows it uses only $1087, for an annual savings of over $600.

The homeowners are encouraged make a copy of their best scheme and test various other building design alternatives. The bar charts can show the comparison of up to nine different schemes at once.

2.6 <u>Advanced Data Input and Evaluation Plots</u>

Advanced, more technically oriented users, who wish to define their building in greater technical detail, can click on the "Advanced" icon which will offer access to a drop-down list of text-based input screens familiar to those who have used prior versions of SOLAR-5.

Both advanced and beginning users may wish to click on the "Evaluation" icon to see a drop-down list of over two dozen graphic outputs, including 3-D graphic plots familiar to users of prior versions of SOLAR-5.

2.7 Help and Advice:

When users clicks on the "Help" icon, they are offered an extensive new context specific help function. The drop-down menu offers definitions and practical information for residential energy consumers.

If the users click on the "Advice" icon they are offered advice and suggestions for the best strategies to save energy in their own specific climate zone for their particular building type.

3. WHY THE EXPERIENCE OF USING THIS DESIGN TOOL IS SO EFFECTIVE

Our usability studies have shown that interactive graphic programs like this can illustrate concepts for homeowners with much greater clarity then is possible with number-based input and output modes of traditional engineering or accounting approaches. Because it is open-ended, homeowners are pleased to be able to define their own unique problems and explore the results at their own pace and in as much depth as they choose. Because of the highly graphic (right-brain) nature of the various outputs, users not only visually grasp concepts faster and in greater detail, but they also come to understand intuitively the dynamic nature of how their building responds over time.

4. PERSUADING HOMEOWNERS TO ACT:

The task now is to persuade homeowners to actually take action to reduce their home's energy consumption. In this particular case pointing out that they will save $50 every month on their utility bills should be impressive. It will also help to remind them that their house will be more comfortable and less drafty. At this point homeowners also need lists of home improvement web sites, 800 numbers for contractors associations, and Yellow Pages categories where they will find the products and services they need. This is also where the various Utility incentive programs can be explained.

The SCE customers who stand to gain even more from this type of software are managers of large apartment complexes and hotel operators. They usually have a good understanding of their utility costs, and once they clearly see the magnitude of the money they can save, they have the management leverage to insure that these changes actually get made. (In fact the first year energy cost savings from the re-design of two or three large apartment complexes or hotels would equal the entire cost of this research project.)

Once ratepayers have downloaded this software from the web, it will be possible to later query them to determine the actual energy savings they were able to predict and to find out what action they plan to take

5. HOW THIS DESIGN TOOL CAN HELP SOLVE CALIFORNIA'S ENERGY PROBLEMS:

The changes made to this typical 1970's tract home (in the example above) reduces its consumption by 2.3 kW on its peak air conditioning hour of the year. Thus if 1449 ratepayers made similar changes, it would save the source energy equivalent to the output of a 10 mW generator. This number represents less than 0.035% of SCE's residential ratepayers (3.5 in 10,000). Thus it would seen that with a reasonable amount of marketing, even more ratepayers could be enlisted to use this tool to help them make energy efficiency improvements to their homes. Clearly this approach could significantly reduce California's summer peak load problems.

TECHNICAL BACKGROUND:

This new software, tentatively called HEED, Home Energy Efficient Design, is the latest generation of the Design Tool Development work that has been underway at UCLA for over 16 years. It is based on the continuing evolution of Solar-5 a whole-building hourly heat balance model. This current work for SCE involves the development of a new GUI that is written in Java and C++ and is intended to be downloaded from the web or to be distributed via a CD-ROM (similar to SCE's current EnergyDesignResources CD). It has evolved from previously published work for a different client, written in JavaScript that could be run interactively over the internet.

ACKNOWLEDGEMENTS:

The authors wish to thank Marion Brown, Gregg Ander, and Paki Muthig of Southern California Edison, and Malcolm Lewis, President of Constructive Technologies Group, for their support.