PROJECT "REED"
BUILDING PERFORMANCE SIMULATION FOR THE MASSES

Murray Milne, Carlos Francisco Gomez, Don Leeper,
Jennifer Zurick, Ameet Nindra, Jiang Shen, and Yoshi Kobayashi

UCLA, Department of Architecture and Urban Design,
Los Angeles, California, 90095

ABSTRACT

Project REED (Residential Energy Efficiency Design) is a Web-based building performance simulation tool developed under contract to one of the nations largest utilities, to help their 4.5 million ratepayers make energy efficient design decisions for their own particular building in their own particular climate.

SUMMARY

Virtually every decision that homeowners or apartment building managers make about design, operation, and maintenance influences the way their buildings consume energy. But the critical problem is that these ratepayers have no easy way to visualize the relative effectiveness of their various options. Only a tiny fraction of them have the resources to hire professional help, and for most of them, the technical literature is beyond reach. The most important issue for them in any case is not tons of CO_2 or therms of gas or kilowatts of electricity. Their bottom line is money.

REED is an easy-to-use, ratepayer-friendly web-based whole building simulation program that displays graphically the gas and electricity cost of building design or operating decisions. Utility rates for each type of residential service are built in, as well as the hourly climate data for the Typical Meteorological Year (TMY2) in each of the climate zones in the Utility's service area.

REED's expert system creates code-compliant home designs appropriate for each local climate. REED can show how much money ratepayers will save by using energy efficient design options such as better windows, shading, good solar orientation, internal mass, or night ventilation system.

The simulation engine behind this new web site is SOLAR-5, one of the nations most widely used design tools. It has been validated against DOE-2 using the BESTEST procedure.

The software aspects of REED are discussed in this paper, while a companion paper presents the user's perspective and the results of the Usability Test.

1. INTRODUCTION: UNIQUE FEATURES OF THIS NEW SIMULATION TOOL

The research hypothesis of this project asserts that residential utility ratepayers can successfully use this internet-based tool to identify energy efficiency design options specifically calculated for their particular home in their particular climate.

Reaching The Mass Market: Given this Utility's 4.5 million residential ratepayers, the potential for affecting energy conservation is massive. This project takes advantage of the phenomenal excitement and growth of the World Wide Web. With the right interface design, the web has the potential to deliver powerful building performance simulation tools to precisely targeted audiences. Using the Internet means this project can deliver free, user friendly design assistance to this potentially huge residential market. This cost-effective approach can permanently transform the energy consuming behavior of an initially small but rapidly growing share of this Utility's customers.

Program Delivery Mechanism: This project takes advantage of the phenomenal excitement and growth of the Internet. Now with the right interface design, the web has the potential to deliver powerful new building performance simulation tools to precisely targeted audiences. This project's use of the World Wide Web to deliver free, user friendly assistance specifically for this Utility's ratepayers qualifies it as the most innovative market delivery system.

Climate and Rate Database: REED contains a database of all of this Utility's various residential gas rates, as well as the hourly climate data for the Typical Meteorological Year in each of the 12 different climate zones of the 1250 cities in their service area. The database also includes current electricity rates plus the appropriate air pollution data and libraries of building materials emphasizing the type of construction common in Southern California.

Well Developed Code Base Validated against DOE-2: This project takes advantage of a huge amount of existing, well-developed code. The simulation engine inside REED is SOLAR-5, one of the nation's most widely used whole building design tools. SOLAR-5 has been validated against DOE-2 using the BESTEST procedure[5]. In addition to all of the capabilities already built into SOLAR-5.5, a number of new features have been added especially for this application. The standalone version of SOLAR-5.5 can be downloaded at no cost from the web, along with other energy design tools developed at UCLA[4].

Interface Designed for Untrained Users: This new user friendly interactive web site eliminates technical jargon and instead asks questions in plain language that homeowners and apartment managers use. For example, the professional version of SOLAR-5 requires the input of R-values, time lags, and decrement factors of each wall, while this new Internet version simply asks what kind of materials are in the building. Users report that it is straightforward enough so that anyone who knows how to use the Internet can get immediate graphic cost comparisons to help them make energy efficiency decisions about their building. It is designed to be auto-instructional, which means ratepayers can begin producing usable results the first time they use it.

Built-in Expert System: An expansion of the existing SOLAR-5 Expert System gives guidance on energy design and maintenance alternatives that are appropriate for the local Southern California climates, economy, and construction practices. Given only the user's location and the size of their house, the Expert System creates two building designs that serve as reference points for the user's own design alternatives. The first design is called the Basic Energy-Code Building, and the second design is the Best Practices Home.

HELP and ADVISE: Users explicitly asked for more guidance in making better energy efficient design decisions. They appreciated the option of clicking the HELP button or any of the hypertext links for assistance with any of the terms or concepts they did not understand. Clicking the ADVISE button gives them design guidelines for their specific climate. Also REED takes advantage of periods when the client is waiting for the server to calculate and reply, by displaying messages on energy efficient design strategies. It may turn out that while many ratepayers might not be able to actually implement any of the design revisions they test, this hidden educational agenda could be the longest lasting benefit.

2: SYSTEMS DESIGN: TECHNICAL ISSUES

A number of complex technical barriers were overcome in completing this project:

Server: The Utility required that REED be launched from their corporate server, but actual development was conducted separately on another server at UCLA. Fortunately, the Utility and the UCLA Department of Architecture both run the same type of servers, Sun UNIX hardware and the Solaris 2.x operating system and Netscape Enterprise Server 3.x web server.

Migrating the Beta version of REED to the Utility Company server proved to be quite straightforward after resolving some initial differences due to the two sites using slightly different revisions of Solaris (2.6 vs. 2.7) and Netscape Enterprise Server (3.1 vs. 3.5).

Systems Design: The REED system consists of three components, the client-side Graphic User Interface (GUI) written in JavaScript, the SOLAR-5.5 simulation engine written in FORTRAN (the kernel), and the server-side interface between the two written in JAVA and C++. The difficult technical problem of how to get FORTRAN and JAVA to talk to each other was solved by developing Java code to read and rewrite SOLAR-5's standard ASCII data files.

The interface between the two is a direct mapping of the FORTRAN kernel's data files into Java classes with get and set methods defined for each field in the files, as well as a run method to invoke the FORTRAN kernel on the server.

The Kernel: After the user's input data has been stored as files in a binary either-endian format on the server, the SOLAR-5 kernel is invoked. First it creates an instance of a Java class called S5KJNI, which stands for Solar5 Kernel, Java Native Interface. This class is responsible for loading a shared library called libS5K.so. It is also responsible for maintaining a set of Java String variables that tell the kernel the location of user's input data and the TMY weather data file. This class is used to make a call to a non-java native function called S5KMain(). This function is actually a C++ function that translates the Java string variables into C strings. It uses these strings as command line parameters to invoke the actual calculation kernel, s5k, as a system command.

The kernel starts up, reads the current input files, calculates, writes the output data files, and exits. The FORTRAN kernel is linked to the Java server as a Java native method call.

Remote Method Invocation: By far the most difficult technical problem in this project was the question of how remote users could launch and execute the kernel on the Utility's server. Java contains this capability under the title of Remote Method Invocation (RMI). For the REED project this is achieved by downloading a small applet to the client that provides JavaScript access via Java RMI to the server application.

RMI was chosen to simplify the communication between client and server. The fact that the server is remote is for the most part transparent to the client. The server hardware hosts both the web server and the RMI server.

Because of the large amount of data being transferred between the client and server, RMI is a natural choice. The alternative of using the web's CGI (Common Gateway Interface) would be extremely undesirable. A Sockets implementation has been discussed but would involve re-inventing (and debugging) much of what RMI already provides.

The Browser Wars: The dilemma is that although Netscape 4.x supports the standard version of Java with RMI, all versions of Internet Explorer do not. Due to the differences in Internet Explorer's implementation of Java and JavaScript we were unable to get the RMI interface working from Internet Explorer.

At present, we detect for clients using Internet Explorer and run instead the static Demo. At the end we state that the full interactive version requires RMI compatible browsers such as Netscape 4.5 and above, with a hyperlink to Netscape's free download site. However, this download takes more than half an hour on a standard phone line so we do not expect many IE users to switch. Assuming this incompatibility is not resolved soon for IE users, we propose to deal with this problem by rewriting everything into JAVA and offering a non-browser based version (see below).

Firewall: Initially, because of its server firewall, no one inside the Utility's Intranet could see or test REED as it was developing on UCLA's Internet based server. Now however the Beta version of REED is up and running inside the firewall on the Utility's server, and soon ratepayers will be able to access REED on another server that is located outside the firewall. Because the Utility's officially supported browser is Internet Explorer, in order to run the full interactive version of REED the Utility employees will have to install their own copy of Netscape 4.5 or above.

Methods for connecting to an RMI server from behind a firewall are documented. However, this will be the Utility's choice to implement.

Future Issue I: Avoiding the Browser Wars: At present the best strategy seems to be to completely re-write the current JavaScript GUI as a non-browser based client-server Java application. Thus it will run on the Internet, without the use of any browser. This neatly solves the problem of older and incompatible versions of browsers and their support for different versions of HTML, JavaScript, Java, and RMI. Unfortunately this will add another level of complexity for ratepayers less experienced in Internet use.

New information indicates that the latest release of IE, Internet Explorer 4.0.1 SP 1, does work with RMI but we have not been able to verify this yet.

Future Issues II: Stand Alone Version: Our next task is to develop a basic stand-alone version of REED that can be downloaded and run on the client's own machine. Initially it will be the equivalent of the version that is already on the web. This will also solve the web browser problem by removing both the browser and the Internet from the equation. It also allows some features to be added that are normally prevented in browser applet based applications (such as reading and writing project files locally on the client system).

The use of RMI for the client-server interaction allows a stand-alone (i.e. serverless) version of the application to be built with only minor modifications to the source code (provided that a suitable FORTRAN compiler is available to recompile the kernel for each platform to be supported).

Future Issue II: The Full Professional Version: It would be impractical to try to run the full professional version over the web. It will contain all of SOLAR-5.5's multiple graphic outputs and detailed input capability, plus new features developed as a result of this project. Eventually we hope to offer it as a later upgrade, but clearly the full professional version will have a new order of magnitude of issues to contend with.

3. SIMULATION ENGINE: A BRIEF HISTORY OF SOLAR-5

The simulation engine driving this new Internet tool is an enhancement of a widely used Energy Design Tool developed at UCLA that is popular among architects and students of architecture. Over the past 20 years SOLAR-5 has been developing as a user-friendly microcomputer program that helps users design more energy efficient, sustainable buildings. By now thousands of people have designed buildings using the current public release version, SOLAR-5.5, and its predecessors.

SOLAR-5 uses an iterative hourly thermal balance method. Like many simulation models today it uses TMY2 climate data to calculate performance for all 8760 hours in the year. It is fast enough to give results within seconds in order to maintain the momentum of the interactive trial-and-error type decision making dialogue with the user.

In the REED project a new user-side interface has been written to speak the language of ratepayers and homeowners, while the original server-side GUI that speaks the technical language of architects has been disabled.

SOLAR-5's built-in Expert System has been modified to also create a basic minimal code-compliant building (Scheme 1), in addition to its traditional function of creating a good passive solar energy efficient building (Scheme 2) which is usually about 30% better. The performance of these two designs serves as benchmarks against which users can judge the performance of their own design. SOLAR-5 depends on its expert system and its carefully designed interactive dialogue to guide the user to provide progressively more detail. Experience with REED shows that most users have a difficult time bettering the performance of the Expert System's best design.

Unique Features of SOLAR-5.5: This project takes advantage of a number of the unique advantages of SOLAR-5 compared to other Energy Design Tools:

- The Expert System creates a unique building for each building type, size, and climate zone in this Utility's service territory.
- It is one of the fastest of all the whole-building energy design tools.
- It has been shown to produce results matching those of DOE-2 in about 97% of the buildings tested (using the Bestest Procedure developed for DOE by the National Renewable Energy Laboratory).

What the Current Full Professional Version Can Do: Currently the full professional DOS stand-alone version of SOLAR-5.5 can handle everything from small single-zone residential buildings, to large commercial buildings with up to eight separate zones. It works equally well for new construction, retrofit, or building maintenance decisions for either commercial or residential building types.

It is available on the UCLA Energy Design Tools web site, free for the taking. Almost 2,000 copies were downloaded in the last two years, which makes one of the most widely used of all the Energy Design Tools. Because the cost of distribution is zero, and the cost of development has already been paid by prior research grants, it is logical that we give it away as a strategy to eliminate any barriers to widespread use. This means that it is now instantly available to anyone anywhere in the world.

4. USABILITY TEST:

To test the acceptability of REED to typical ratepayers who were likely to visit this web site, a formal usability experiment was conducted in one of the client's computerized classrooms. Fourteen representative ratepayers were recruited by an independent service. Given no prior instruction they were asked first to run a small standard test home, then to input their own home and run through any design alternatives they choose that might improve its performance. Written questionnaires were used at each stage. Afterwards an informal group de-briefing session helped to uncover their collective opinions and to articulate any remaining issues.

The full description of this Usability Test is reported elsewhere[1], but in summary the research team was surprised to discover that the judgement of the users was unanimously positive. Some example quotes said "this was fun to use", "I learned a lot", and "it was great to be able to load in my own home and see how it performed compared to various alternatives". Additional responses revealed:

- They liked the idea of making one change and then quickly seeing whether it performed better or worse. They were also eager for more information and guidance in the form of advice about which are the best options.
- They reported willingness to make design changes to their house that only slightly improved performance because of the other non-monetary benefits like greater comfort (i.e. reduced drafts) or aesthetics (i.e. image or 'look').
- They seemed unimpressed by the power of the simulation engine or by the fact that it was calculating their building for all 8760 hours per year.

Why the Experience of Using this Tool is So Effective: This study shows that this user-friendly interactive graphic program can illustrate concepts for ratepayers with much greater clarity then is possible with traditional engineering or accounting approaches. The conscious participatory act of deciding which options to try and the pleasure of finding positive results makes the experience much more alive and compelling. With the opportunity to acquire this kind of knowledge, this Utility's customers are in a much better position to make informed judgements about the energy efficient design and operation of their homes.

5. WHAT IT IS LIKE TO USE REED:

A typical beginning session of REED starts with defining a few basic parameters like location (zipcode) and size (square footage), from which the Expert System creates the two reference schemes; a Basic Energy-Code Home.

Scheme 1, Basic Energy-Code Home, requires only fourinputs from which the Expert System designs the first reference building: the type of construction, the kind of home, the location (zip code), and the floor area (square feet). When the REED server obtains this information, it invokes the kernel, which creates a square home with an equal number of windows on all sides that meets the minimum legal code requirements. The kernel then calculates the simulation of its annual performance on the server.

Scheme 2, Energy Efficient Home, is automatically created by the kernel's Expert System. It will have a rectangular floor plan with shorter walls facing west and longer walls facing south. Depending on climate it might also have a high mass interior and most of the windows facing south. The kernel again calculates the simulation of its annual performance on the server.

Scheme 3, Your First Design, invites the user to change any variables they wish to better represent their home. If this is a Remodel, most of the effort usually goes into representing the existing home; this often means selecting options that are worse than what the Expert System created for the Energy Efficient Home (these are shown in boldface). Shown here are only a few of the design options available in REED. In the full professional stand-alone version, there will be full access to the total array of design variables.

Bar Charts are displayed after the performance of each scheme is calculated. The Summary Chart: Annual Energy Cost will be automatically displayed for up to 9 different schemes. The comparative cost of only the three initial schemes is shown here. When the user places the cursor over any of the bars its dollar amount pops up. A Performance Summary Table can be printed out that shows comparative cost savings due to energy efficient design decisions. In this case the ratepayer can see that their first design, Scheme 3 costs more to operate than Scheme 2, so probably they will be motivated to try to design other better alternatives that will come closer to the reference Scheme 2.

Performance Summary Table: Annual Energy Costs

	Gas	Electricity	Total
Scheme 1: Basic Energy-Code Home	$66	$1982	$2048
Scheme 2: Energy Efficient Home	$63	$1228	$1291
Scheme 3: Your First Design	$129	$1416	$1545

Energy Savings Resulting From these Changes: This simple example shows that a ratepayer in Southern California could save about $757 per year by designing an Energy Efficient Home compared to a home that just met the Basic-Energy Code Home. But when they loaded in their own building, their annual savings difference dropped to $503.

At various points in the process, while waiting for responses from the server, REED shows the ratepayer guidelines about how to design more energy efficient homes in their specific climate. The HELP and ADVISE buttons are also available, as are a great number of hypertext links back into the HELP file. Thus the user should begin to develop better ideas about how to make their home more energy efficient.

6. FOOTNOTE ON GLOBAL WARMING AND THE KYOTO ACCORDS

As a footnote, although it is unknown at this moment how the Kyoto Accords will ultimately be enforced, it is generally agreed that buildings account for about a third of the problem. The professional stand-alone version of SOLAR-5 can display the comparative performance of each different design in terms of air pollution emissions. For example, it can show how many tons of Carbon Dioxide would NOT be emitted into the atmosphere as a result of any individual design or maintenance decision, such as adding an awning or insulating the attic or updating a furnace. It can also calculate the pounds of avoided air pollution for five other contaminants: sulphur oxides, nitrogen oxides, particulate matter, volatile organic compounds, and carbon monoxide.

7. CONCLUSION: A COMMENT ON THE POTENTIAL IMPACT OF THIS TOOL

We roughly estimate that a third of all this Utility's ratepayers have Internet access in their home. To be conservative we assume that only once every five years each of them will make a major decision about the operation of their residence, maintenance, design, or even rental or purchase. This means that every year there will be a new population of a quarter of a million ratepayers in a position to use this tool to save money on their utility bill.

Reaching this population of potential energy savers will be relatively straightforward via the Utility's newsletter that comes with each bill, their regular radio and direct mail promotions, and their existing web sites. So clearly, the potential is there.

Acknowledgements:

REED would not have been possible without the positive support of the Utility's management team headed by Lance DeLaura, along with Wayne Tanaka and Melissa Cuaycong. We especially appreciate the help of Doug Wong, their system manager and webmaster.

The SOLAR-5 kernel was initially developed with the support of the UCLA Academic Senate, plus additional support by the US Department of Energy. It is copy-

Footnotes:

1. This paper is one of two describing REED. The companion paper explains the project from the user's point of view, especially how they learn the impact of various aspects of energy efficient building design. It also describes what was learned from the Usability Test: "A Free Internet-Based Simulation Tool for Energy Efficient Home Design", SOLAR-99, the American Solar Energy Society Conference, Portland, Maine, June 12-16, 1999

2. The Current Status: As of the date of writing of this paper (February 28, 1999) the Beta version of REED is running under Netscape 4.5, and the Usability Study has been completed. The Marketability Study Report will be completed at the end of March, 1999. Pending final debugging and validation studies, plus addition of any of the proposed new features will determine the final public release date.

3. The full stand-alone DOS based professional version is available on the UCLA Energy Design Tools web site[4], free for the taking. Almost 2,000 copies were downloaded in the last two years, which makes it one of the most widely used of all the Energy Design Tools. Because the cost of distribution is zero, and the cost of development has already been paid by prior research grants, it is logical that we give it away as a strategy to eliminate any barriers to widespread use. This means that it is now instantly available to anyone anywhere in the world.

4. Access to the REED web site will be announced on the UCLA Energy Design Tools web page:

http://aud.ucla.edu/energy-design-tools

The latest stand-alone version of SOLAR-5, and all the other design tools developed at UCLA can also be downloaded at no charge from the same web site.

5. SOLAR-5.4 has been validated against results produced by DOE2.1E, BLAST3.0 and SERRIES/SUNCODE 5.7 using the HERS BESTEST procedure developed by Ron Judkoff and Joel Neymark of the NREL (November, 1995). This procedure involves tests run on a battery sixty-six building designs in two climates, Las Vegas and Colorado Springs. Because SOLAR-5 does not model basements or sunspaces, six of these building designs could not be run. Of the remaining buildings SOLAR-5.4 produced results falling within the BESTEST acceptance range in 100% of the cases. Hernando Miranda, <u>Validation of a Building Energy Computer Design Tool</u>, Volume I and II, Master of Arts in Architecture Thesis, UCLA School of Architecture, 1998.

6. The name of the Utility that supported this project, under the auspices of the California Board for Energy Efficiency, is not mentioned here in order to avoid commercial references. However, because this simulation tool is offered at no charge to all their rate payers, and to interested professionals from outside their service territory, this prohibition might not be necessary in future versions of this paper.

Figure 1: REED Demo
The following is a screen capture of the demo built into REED.

Welcome to

REED: Residential Energy Efficiency Design Tool

If you are thinking about building a new home or remodeling your existing home, we can help you make good energy efficiency decisions.

You only need to answer a few questions, and we will show you which design options are best for your climate.

What would you like to do:

- ○ Construct a brand new home
- ○ Remodel within your homes existing walls

Scheme 1: Basic Energy-Code Home

What kind of home will it be: (Click on the Button)

- ○ Single Family House
- ○ Town House, attached to others
- ○ Apartment or Condominium unit

Type in where it will be Located:

[ ] Zip Code

[Enter Your Zip Code above ▾] City

(For Advice on how to design a home specifically for this climate, click the ADVISE box on the Left.)

How Big you would like your New Home to be?

[ ] Square Feet(You can choose from the box below, or type in the number to be accurate.)

In California the square footage of typical home is:

400	Single Apartment
600	1 Bedroom Apartment
800	2 Bedroom Apartment
1000	Small 1 Bedroom House
1200	Small 2 Bedroom House
1400	Medium 2 Bedroom House
1600	Medium 3 BR./Den
2000	Large 2 BR./Den
2600	Large 3 BR./Den
3200	Luxary 4 BR. house

Scheme 1: Basic Energy-Code Home

The above information is now being sent to the Residential Energy Efficient Design (REED) project computer.

It is creating for you a Basic Home that just barely meets the minimum requirements of the California Energy Code. For example it will have a square floor plan with equal amounts of glass on all four sides, the thinnest legally allowed insulation, and heating and cooling equipment with the lowest allowed efficiency. This will be a typical California stucco home with a flat roof and a wood floor with a vented crawl space underneath.

This takes time because REED is calculating the performance of this building for every hour of every day the year using climate data for your city.

computing...

Scheme 2: Energy Efficient Home

REED is now automatically creating a second Home of the same floor area that also meets the minimum requirements of the California Energy Code, except that it has a rectangular floor plan, with most of the glass now facing south for good winter passive solar gain, and shading to protect the glass from the summer sun. It also has a slab floor for "thermal mass", to store up this heat so it can help keep temperatures higher at night. During the Summer this home uses a fan to bring in air at night to cool down this "thermal mass" to help hold down temperatures during hot days.

Finally REED will show you bar-charts of the total annual costs of the GAS for heating these two different homes, and the cost of ELECTRICITY for cooling and lighting them, and the TOTAL annual cost of each. (Note that these costs do NOT include the cost of gas used for COOKING, or for WATER HEATING, or for CLOTHES DRYING, because they are not affected by building envelope design decisions.)

computing...

Scheme 3: Your First Design

Let's start with the design you chose **Scheme 3: Your First Design**. The features of *Scheme 2, Energy Efficient Home* are shown in **bold**. Click on your desired features below if you want to revise:

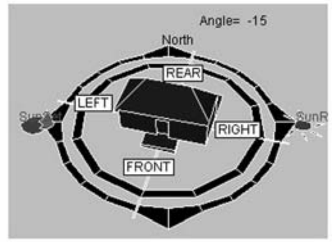
Floor Plan Shape:(First rotate the compass to show the orientation of the front of the house.)

2400 Total Square Footage (This can only be changed in Scheme 1.)

[66.67] East-to-West Overall Dimension (ft.)

[36] North-to-South Overall Dimension (ft.)

[1] Number of Floors



Exterior Wall Construction (Typical):

- ⦿ **Stucco on Wood Studs with Plaster Board interior**
- ○ Wood Siding on Studs with Plaster Board interior
- ○ Concrete Block wall exposed both sides
- ○ Concrete Block wall exposed exterior, Plaster Board interior
- ○ Stucco on Concrete Block, Plaster Board interior
- ○ Foam Insulation Board on Concrete Block wall, exposed on interior
- ○ Foam Insulation Board on Concrete wall covered with Plaster Board interior

Roof Construction (Typical):

- ○ No heat loss through roof because upstairs is a heated dwelling
- ⦿ **Flat Built-up Roof on wood joists Plaster Board ceiling**
- ○ Light Colored Flat Roof, joists, Plaster Board ceiling
- ○ White Reflective Flat Roof, joists, Plaster Board ceiling
- ○ Asphalt Shingles on ply, Vented Attic, Plaster Board ceiling
- ○ Light colored Shingles, Vented Attic, Plaster Board ceiling
- ○ Clay or Concrete tiles over Vented Attic with plaster Board ceiling
- ○ vaulted ceilings

Glass Type (Typical):

- ⦿ **Single sheet of glass (no longer allowed by the Energy Code in many places)**
- ○ Double Pane Window glass
- ○ Double Pane Windows with Low Emissivity coating
- ○ Double Pane with Low Emissivity coatings, Argon gas filled

Window Sizes **(You can add up to six combinations of windows and walls.):**
You can type-over any data you wish to change;
Use the blank line to add different kinds of windows to the same wall;
You can delete windows by entering 0 under the Number of Windows.

Window Faces	Number of Windows on All Floors	Window Width in Feet	Window Height in Feet	Sunshade Overhang Depth
Front	19	3	4.17	2.81
Left	2	3	4.17	0
Rear	4	3	4.17	0
Right	2	3	4.17	0

Furnace:

- ○ Older Low Efficiency Furnace (72% Annual Fuel Utilization Efficiency: AFUE)
- ⦿ **Standard Energy Code Minimum Furnace (78% Annual Fuel Utilization Efficiency: AFUE)**
- ○ High Efficiency Condensing Furnace (88% Annual Fuel Utilization Efficiency: AFUE)

[CLICK HERE to calculate this Design]

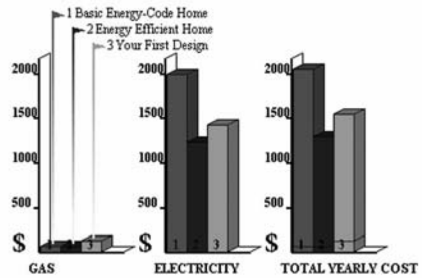
Scheme 3: Your First Design

computing...

Scheme 3: Your First Design

The REED Project has now simulated the Performance of this Home.

Summary Chart: Annual Energy Cost



(To see the actual dollar amount, put the cursor on any bar.)
Scheme 3, **Your First Design, shows that your yearly** Total Energy **cost is:**

- $503 less than Basic Energy-Code Home
- $254 more than Energy Efficient Home

Your did QUITE WELL, but you could improve this design.

Would you like to try to:

- ○ Go on to a new Scheme to improve this design
- ○ Revise a prior Scheme design
- ○ Stop here.