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# Using HEED to Design Energy Efficient Affordable Housing

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ABSTRACT

*Designing energy efficient affordable housing is especially complex because of the limited budget available for "special" features, the tight timelines imposed on the design team, and the many decision makers whose approval is required. The thermal comfort of the residents is rarely considered, and as a result housing may be affordably built but to often proves uncomfortable and expensive to live in. This paper presents some of the unique features of HEED, a Home Energy Efficiency Design tool, that helps address all these issues at the very beginning of the design process,. It also give the architects graphic tools that communicate to the clients, managers and owners the potential impact of design decisions on human thermal comfort and energy costs.*

*Las Brisas is a 96 unit rental project that the Los Angeles Community Design Center is remodeling into affordable housing, with a particular emphasis on energy efficiency. This paper describes the architect's design process and illustrates how HEED's graphic outputs help decision makers understand complex ideas about their building's performance.*

## 1. THE LOS ANGELES COMMUNITY DESIGN CENTER:

The Los Angeles Community Design Center is a non-profit organization which helps to strengthen and revitalize communities by providing affordable, service-enriched housing and architectural, planning and development services to low-income people in underserved neighborhoods. During the 1970's hundreds of community design centers were opened in many American cities across the country. Their purpose was to apply environmental design skills to the problems faced by low-income communities. LACDC was born in this era.

Incorporated in 1972, LACDC has provided comprehensive architectural services and technical assistance to over 500 community groups to build a variety of community-oriented projects, including child care centers, health clinics, senior service centers, playgrounds, shelters for the homeless and permanent affordable housing for low-income people. Over the years LACDC has evolved from a volunteer organization which provided low-cost and pro bono services to groups in low-income communities, to a

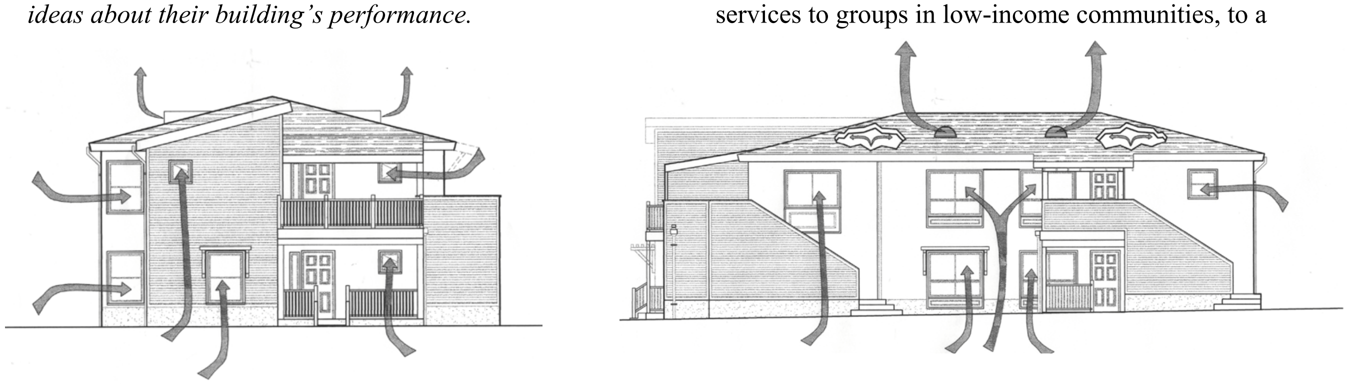

**Fig. 1: South Elevation (left), East Elevation (right)**

professional development and architecture firm with a primary mission to the preserve and produce affordable housing for low-income residents.  Active client participation is a vital part of LACDC's work.

Since 1984, LACDC has completed 50 affordable housing projects totaling over 2,500 apartment units either as sole developer or in partnership with other community-based, non-profit corporations.  Currently, LACDC has acquired ownership interest in 25 properties totaling over 1,300 affordable housing units.

The broad range of services provided by LACDC includes architecture and design, financial feasibility analysis for housing projects, financial packaging, the syndication of low income housing tax credits, technical assistance to new and emerging community development corporations, neighborhood planning, and training programs for community groups and residents, and property management of all LACDC developed projects.

1.1 The Las Brisas Project:

The Las Brisas Community Housing Development is part of a comprehensive neighborhood revitalization plan for the city of Signal Hill, California.  The City of Signal Hill used its power of Eminent Domain to gain control over 23 individual four-plex buildings, the great majority of which have suffered the ill affects of absentee landlords who have neglected upkeep at the expense of  the residents.

The new Las Brisas is designed to create an integrated residential neighborhood with rehabilitated apartment units, programmable open space, low-cost childcare opportunities, a multi-purpose community center, well defined public and private spaces, and clear pedestrian and vehicular circulation. This rehabilitation project improves the existing building shells by adding insulation, new windows, earthquake protection, new interior wall surfaces, furnaces, and water heaters. Some units are enlarged with additional bedrooms, stairways, private porches, and storage space.

## 2. *HEED* HOME ENERGY EFFICIENT DESIGN:

HEED is an energy design tool developed with funds from the California Public Utility Commission under the Public Interest Energy Research (PIER) Project. This version was developed especially for the ratepayers of Southern California Edison, but it can be run for any location where TMY2 climate data is available. It is available free of charge on the web at www.aud.ucla.edu/HEED.

Its goal is to help electric customers make energy-efficient design and remodeling decisions for their own homes. Among the features users especially appreciate are the simple way they can draw in floor plans, drag and drop windows onto each facade, and rotate a 3-D image of their building to its correct compass orientation. Clicking the Basic Design icon lets users simply click on various typical building assemblies, or clicking on the Advanced Design icon lets users input each element in detail. The Basic Design output is a bar chart showing the annual energy cost of up to nine different schemes (Fig 3). In Advanced Design the typical graphic output is a 3-D plot of dozens of different aspects of  building performance for each hour of the day in each month of the year (Fig 2).

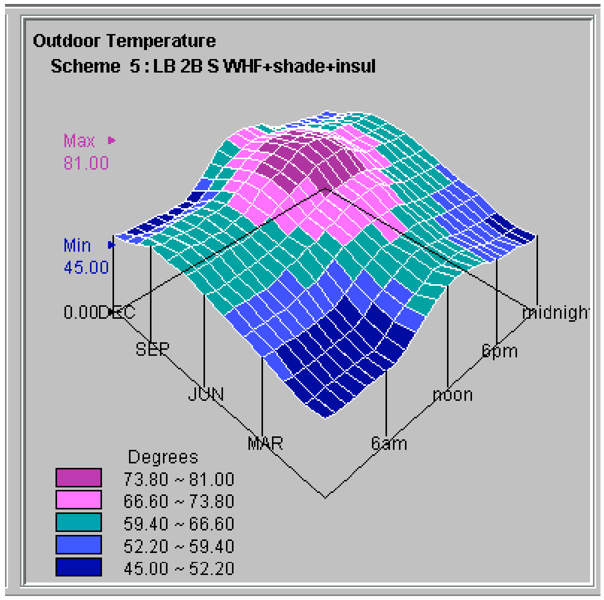


**Fig 2: Typical 3-D plots show performance for every hour (right) in each month (left), for dozens of different variables, in this case for average monthly Outdoor Temperature that peaks at 81 F.**

HEED shows graphically the differences in performance between schemes using various passive solar strategies such as shading, thermal mass, ventilation, envelope insulation, glazing, and orientation. It helps users find the best design by showing graphically how the Total Yearly Energy Cost changes in response to each new design change.

The simulation engine in this energy design tool, Solar-5, calculates an hourly heat balance and integrates loads and system performance calculations. It has been validated against DOE-2 using the BESTEST procedure.  It contains a built-in expert system that automatically designs a basic code-compliant building, and then also designs a second more energy efficient version.

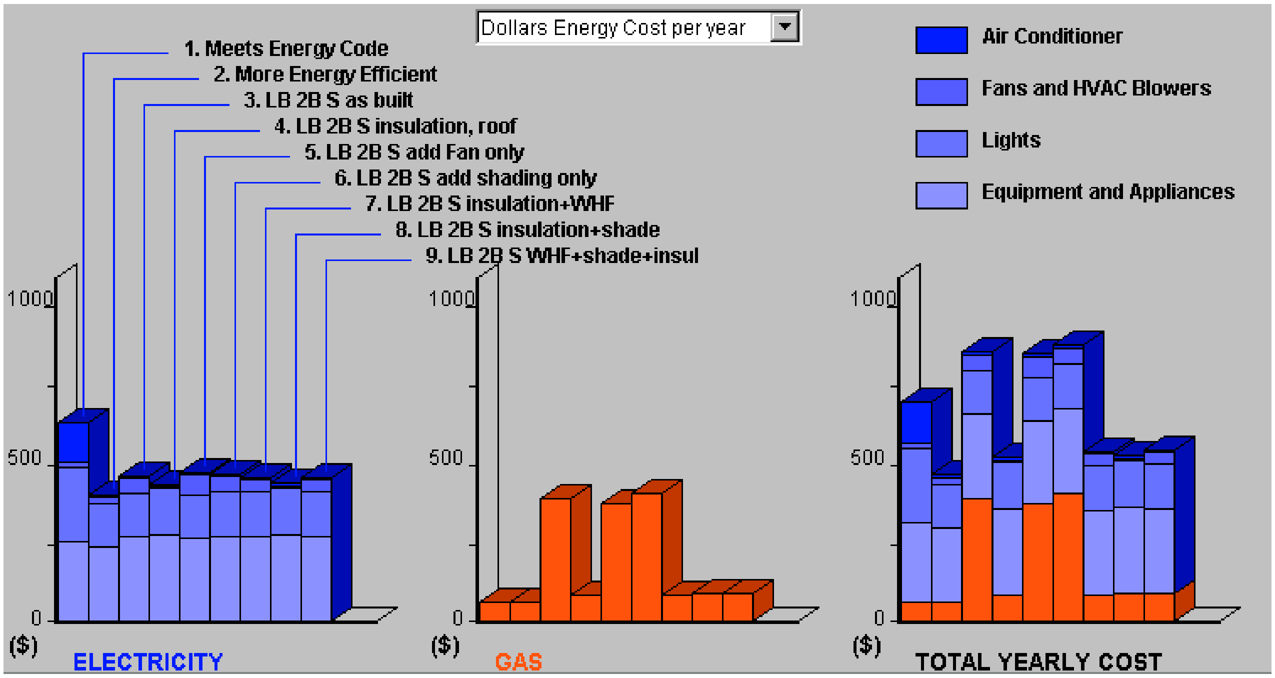


**Fig 3: This bar chart shows that the three schemes (3, 5, and 6) in which insulation was not brought up to code, have the greatest Total Yearly Cost (right) which is due entirely to Gas heating cost (center).**

Together these two basecase schemes serve as checkpoints against which the user can compare their own building's performance. The current Southern California Edison 5-tier utility rates are built in, as well as the hourly TMY2 climate data for each climate zone in the SCE service area. Clicking the Advice icon offers suggestions for designing energy efficient buildings in each of these climate zones. Clicking on the Help icon tells how to use HEED.

## 3. ENERGY ISSUES IN AFFORDABLE HOUSING

The LACDC's projects benefit individuals and families whose incomes fall below 50% of area median income. At Las Brisas, monthly rents start at $499 for a two bedroom, and go up $645 for three bedrooms. Conscious of the limited income of residents, the LACDC has made it a priority to make units more energy efficient, comfortable, and affordable to live in.

Because of the high cost of initial installation and operation, air conditioners are not included. As a result, summer indoor temperatures in some units in past/older affordable housing projects routinely reach into the 90's. Exterior sun shades are allowed but the building management division views them as a potential maintenance problem. At Las Brisas, the presence of asbestos will require removal of all interior plaster, allowing for easy introduction of wall insulation before new finishes are installed.

Using HEED, the architects found that many different passive design strategies could be quickly tested with the existing building shells in the specific local climate. The evolution of two selected units will illustrate how HEED allowed the architects to evaluate the impact of alternative designs on the two issues deemed most important: cost savings and indoor air temperature.

HEED gave the architects a tool that not only helped them design more energy efficient units, but at the same time produced graphics that helped communicate the result of each design to various decision makers. Beyond telling the developers and property managers that the units would be more comfortable and energy efficient, HEED made it possible to quantify exactly how much could be gained. As the project design evolved and project financing began to solidify, it was possible to evaluate where the owner could get the most 'bang for their buck'.

## 4. DESIGNING IN COMFORT AND ENERGY EFFICIENCY

The 23 existing buildings in the Las Brisas neighborhood are identical four-plex buildings with stucco over uninsulated wood framing. The ground floor units have slab on grade, while the second floor had plywood flooring, and an uninsulated attic space.

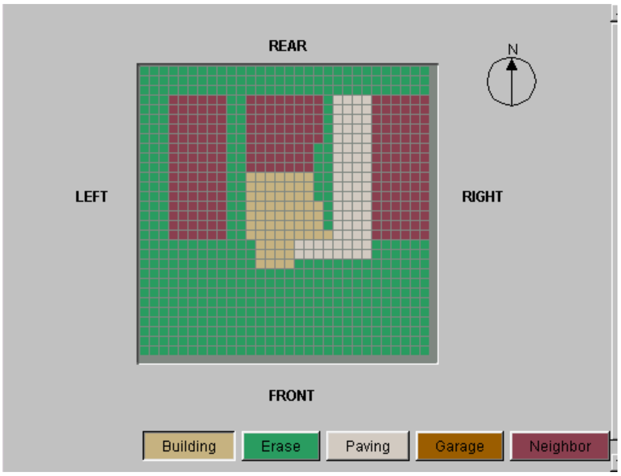


**Fig 4: Using HEED the architects can draw in the footprint of each unit (center) surrounded by lighter colored paving and darker neighboring units.**

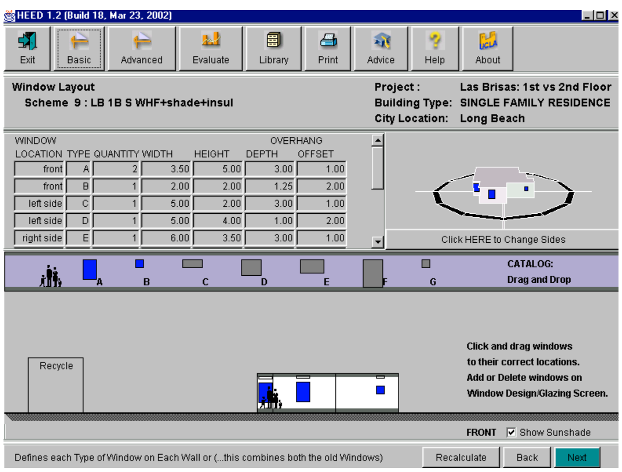


**Fig. 5: The architects can click and drag windows to their correct location on each elevation.**

Using HEED, two basecase schemes are automatically created: 1. Meets the Energy Code, and 2. More Energy Efficient (see Fig 4.). Their Total Yearly Cost (excluding cooking and water heating) were $650 versus $400 respectively. Next the architects tested seven different design alternatives. The third scheme was the 'as-built' condition. Schemes 4,5,anad 6, added either insulation, a whole-house fan, or additional shading. Then schemes 7 and 8 combined insulation with the whole-house fan or with additional shading, and finally scheme 9 combined all three.

4.1 Added Insulation:

Installing new dual pane windows and adding insulation to the walls and attic spaces helped bring these buildings up to code, but also dramatically reduced annual gas heating costs (Fig. 4). The three uninsulated schemes averaged about $800 Total Yearly Costs, while the last three insulated schemes averaged about $500 Yearly.

Because of the added savings for the resident's utility bills, this design option was deemed to be a priority by the architects and developers.

4.2 Whole-House Fans

The original buildings were built very close together. In the courtyards, they are twenty feet apart, while in the side yard there is only eight feet of separation. The architects felt that this would allow for only minimal natural ventilation. Whole-house fans were introduced as a solution to try to bring indoor air temperatures into a more comfortable range. Traditional whole-house fans vent directly into an attic. While this works at the second floor units, at the ground floor units a whole-house fan appropriate for plenum installations was used. In this application the fan is mounted to the exterior face of the building and connects to an air-intake shutter and then to a plenum that is fed by a grill in the interior hallway.

HEED demonstrated that fans were one of the most important features for improving indoor comfort. It also allowed the architects to demonstrate that whole house fans introduced natural cooling at extremely economical costs (it costs just $ 36 per year to run this whole house fan). Using HEED's graphic plots, the architects were able to make a convincing argument that more than any other feature, whole house fan would help keep indoor air temperatures comfortable during the hottest months of the year

4.3 Exterior Shading:

From the onset, increasing exterior window shading to the south and west elevations was thought to be the key to reducing indoor air temperature. Using HEED, the architects found that average monthly temperatures peaked at 88.27 F with window shades (Scheme 7), compared to only 84.23 F with a whole house fan (Scheme 8). Notice that the unit with the whole-house fan cooled off more quickly in the evening, compared to the unit with the extra shading (Fig. 7).

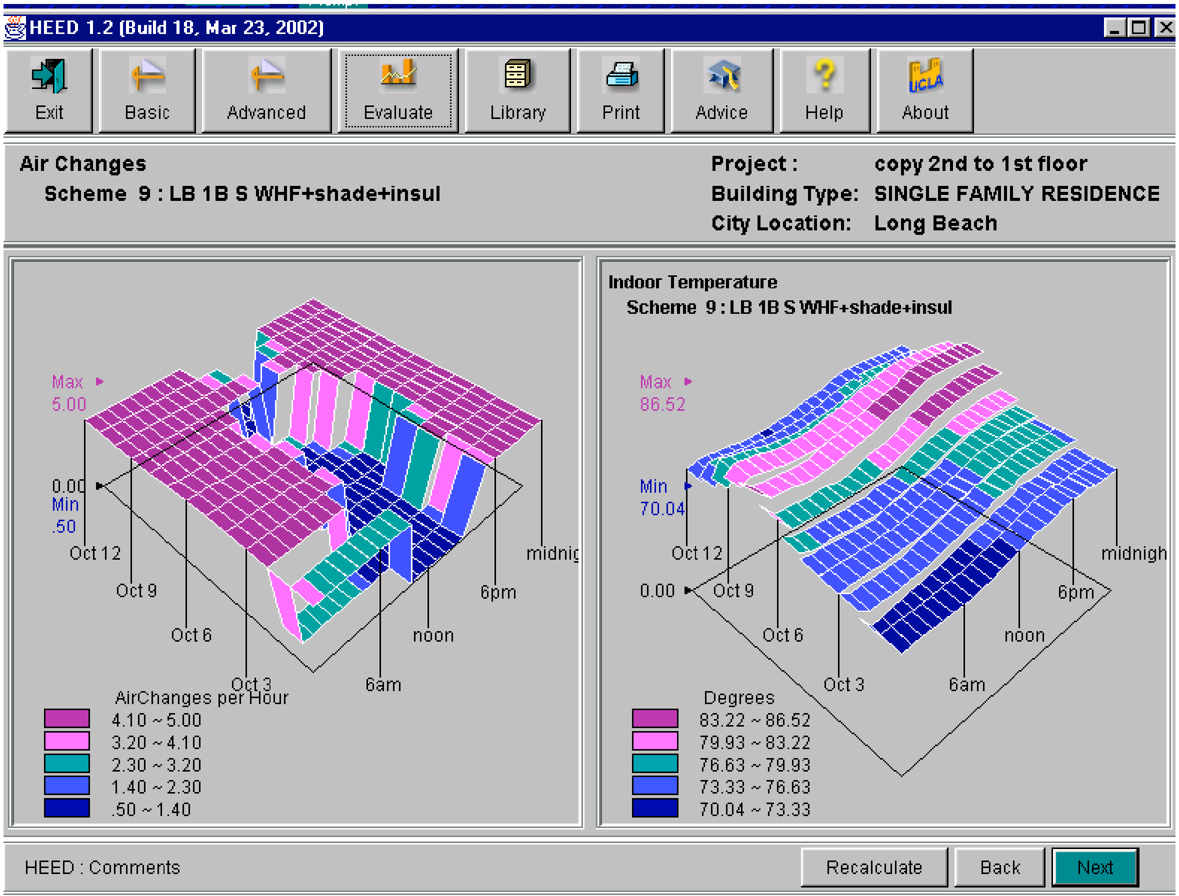


**Fig. 6: Looking at the hottest 12 days of the year, when outdoor temperatures reached 98 F, this side-by-side plot shows that the whole-house fan running at 5 air changes per hour (left) could reduce the peak indoor temperature to 83.52 F. in the first floor unit (right).**

Through this trial and error process with HEED, the architects realized that although important for the Las Brisas building types, exterior shading did not make quite as much impact on indoor air temperature as first thought. HEED helped the architects place a dollar value on the introduction of exterior shading in relationship to other building features. The architects still feel this is an important feature, but overall, the developer, and the occupants, might not get as much 'bang for the buck' from exterior shades as they will from other features being considered.

4.4 Final Overall Performance:

The fact that air conditioners were eliminated from this affordable housing project, means that energy cost is not a good measure of design quality, because the best three schemes use about the same amount of energy for furnace, lights, fans, and appliances (Fig 3). Thus peak indoor air temperatures were the only objective way to identify the best design (Fig. 6 and 7).

The final overall design used code levels of wall and attic insulation, a whole-house fan, and additional shading. With this design the final peak average indoor air temperature was 83.24 F in the upper unit and 76.45 F in the lower unit. On the worst peak hour of the year when it was 98 F outdoors, the upper unit peaked at 91.47 F and the ground floor unit peaked at 86.52 F. While all these temperatures are still uncomfortable, there is a significant improvement between indoors and out. Added to this is the additional psychological cooling effect of increased air velocity with the whole-house fan.

The upper unit behaves like a low-mass building, with very little thermal storage and only a few hours of time lag between the peak outdoor and peak indoor air temperatures. The lower unit with its slab on grade behaves more like a high mass building, with much more thermal capacity to store up nighttime 'coolth', and a longer time lag between peak outdoor and indoor air temperatures. This longer time lag gives the fan more time to bring in cooler outdoor air to cool down

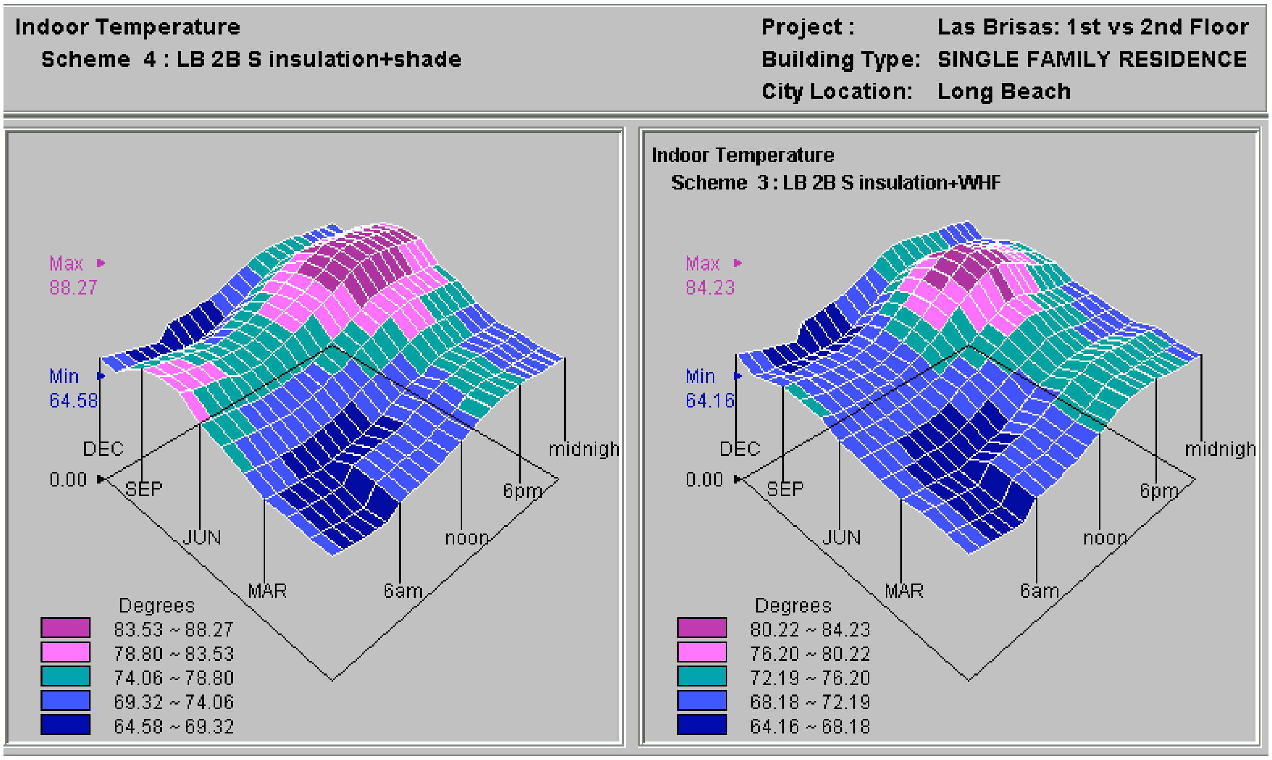


**Fig. 7: Even in the well insulated second floor unit, the annual peak temperature reached 88.23 F. with the increased shading option, but 84.23 F. with the whole-house fan option.**

the interior thermal mass. Thus the peak temperatures are much lower in the ground floor unit.

## 5. THE ARCHITECT'S CONCLUSIONS:

The architects state that in the end HEED not only helped them test their assumptions about the impact of each element, but also helped define the relative value of each in terms of human comfort (indoor air temperature) and economic impact (on residents' utility bills). Initially, exterior window sun shades were thought to be the key to controlling heat build up for Las Brisas; insulation was thought to be important not only in keeping the building warm, but also in keeping it cool, and whole house fans were deemed an important feature, but not necessarily essential.

In the end, although each of the features proved important, the combination of insulation with a whole house fan was deemed most essential. Window shading, though still valued and proposed as a part of final the project, is not as essential (as long as insulation and whole house fans are used), and might even be less important than trying to introduce additional mass into the second floor units (such as lightweight concrete floor covering). During the initial design process, the architects quickly changed combinations to zero in on the winning combination. As the project moves forward through the bidding process and possible adjustments are made to the project's overall budget, the architects will be able to keep track of the features that will have the greatest impact.

To make a compelling argument on behalf of what was deemed most important, the architects relied on HEED's graphics, and its analytical tools. These became an integral part of all presentations made to the developers. Not only has HEED allowed the architects of the LACDC to make the case for energy efficiency in the Las Brisas project, it has also helped set a standard for the design and evaluation of all future affordable housing produced at the LACDC.

## ACKNOWLEDGEMENTS:

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HEED is available free at www.aud.ucla.edu/heed