Presented at the American Solar Energy Society Conference, Madison, Wisconsin, June 19-21, 2000

ENERGY MORPH, an Animated Design Tool

Murray Milne, Carlos Gomez,
Yoshi Kobayashi, Don Leeper, Jennifer Zurick
UCLA, Department of Architecture
Los Angeles, California 90095
milne@ucla.edu

ABSTRACT

Energy Morph is an new dynamic visual display option that shows SOLAR-5 users an animated picture of the way the energy performance of one building design compares to the next. It is a kind of movie that graphically displays the differences between any two designs according to any of two dozen different measures of performance. Running these little "morph movies" back and forth gives designers a much deeper and far more detailed understanding of how each design performs than could ever be communicated by a barchart, or graph, or table of numbers.

THE DILEMMA:

The numbers are familiar to everyone: Buildings us about a third of our nation's energy and account for about a third of our greenhouse gas emissions.

The principles of how to design energy efficient buildings are well known, but new buildings do not seem to turn out that way. Admittedly the solutions are complex because every building is different, every climate is different, and every utility company's rates are different. But design tools are now available that can make this kind of complexity transparent.

THE GAP

There seems to be a huge gap between what designers say they believe about sustainability and how they practice. A recent issue of GreenClips reported a study assessing design professionals' attitudes toward sustainability. The vast majority believes they have a "moral obligation to offer sustainable solutions to clients, yet only a 37 percent actually do so. The... primary obstacle to sustainable design is too little information. They lack knowledge about the subject, aren't familiar with research that demonstrates its benefits, and believe that sustainability is a low priority with clients. And many also fear compromising their standards by having to sacrifice color, performance, application, or cost for sustainable design."

One way to bridge this gap is to put more powerful tools in the hands of designers. But it can be argued that even our best energy design tools still use the computer like a kind of glorified spreadsheet, printing out static graphs and bar charts. But today's computers have the power for so much more.

Today we find users coming away from the experience of running an energy design tool still unclear or at least unconvinced about what is the right thing to do. True, they can read the numbers on the charts and tables and plots, but on a deeper level they seem uncertain about how well one design works when compared to another. They say it is difficult to understand and to feel confident about whether a new design is really significantly better or worse than the other is.

This paper demonstrates how a design tool that tries to be more visually interesting and engaging, like a video game or a flight simulator, can help designers better understand their building's energy performance.

RIGHT BRAIN THINKING:

Designers tend to be right-brain thinkers, which means they are extremely sophisticated at grasping complex information visually, rather than in the form of numbers or text. SOLAR-5 already produces many kinds of three-dimensional graphic plots showing how the building performs for each hour of each month of the year. Designers can quickly learn to recognize subtle differences in the shape of these plots and to correlate them with differences in the building's design.

Energy Morph adds the new dimension of time/motion to help designers to see the differences in performance between any two successive designs and to understand intuitively whether the building's performance is getting better or worse.

HOW ALL THIS APPLIES TO SUSTAINABLE DESIGN:

SOLAR-5 calculates hourly performance for the full year using hourly TMY2 climate data. It generates 3-D plots of building performance with hours of the day along the right-hand axis, and months of the year along the left-hand axis. The units are given in KBTU/hr heat gain and loss, or KBTUH Output of Heating or Cooling equipment, Air Changes per Hour, and Dollars Cost for Electricity or Gas.

The sample building is a 2880 square foot reading room in a library soon to be built near Los Angeles.

These figures show the graphic images for a number of important concepts of sustainable design:

- Fig.1 shows how automatic daylighting controls save lighting power and the electricity bills for the building;
- Fig.2 shows how night ventilation of a high mass building can reduce air conditioner loads;
- Fig. 3 shows how the orientation of a south-facing window or a skylight influences heat gain;
- Fig. 4 shows how SOLAR-5 can "zoom in" and look at a detailed 12-day picture of performance, in this case showing the heat that flows into and out of the building's internal thermal mass and how that in turn influences indoor air temperature.

The following Figures show the performance of one design at the top of the page, and of the second design at the bottom, with two intermediate frames showing how they morph. In the "morph movie" a smooth continuous transition that occurs between these two designs (note that while this paper emphasizes visualization, numerical data is also available):

Scheme 1: Energy Code Basecase: The expert system inside SOLAR-5 creates a simple square building that meets all the minimum requirements of the California Energy Code, including the minimum wall and roof U-values, proscriptive glazing, and maximum number of windows distributed evenly on all four walls.

Scheme 2: Energy Efficient Design: the expert system also automatically created this more sustainable design with the same floor area, but now with a rectangular floorplan facing south with better glazing, window shading, weather stripping to reduce infiltration, photocell controlled lighting, and economizer cooling with night flushing.

Scheme 3: Architect's Best Design: the architect's final design incorporated more elaborate window fins and overhangs, and changed the construction to high thermal mass in slab floors with exposed CMU walls, and added low-E glazing,

Scheme 4: Orientation Test: a copy of Scheme 2 was rotated so the long facade faced west and the external sunshades were removed, all to show the impact of choosing poor orientation and eliminating solar protection.

Scheme 5: No Air Conditioner in Basecase: in a copy of Scheme 1, the air conditioner was eliminated to see how high indoor air temperatures would climb (for example as might happen if there was a power outage). This is a 12-day snapshot that brackets the hottest day of the year to see the actual hour-by-hour behavior of the building.

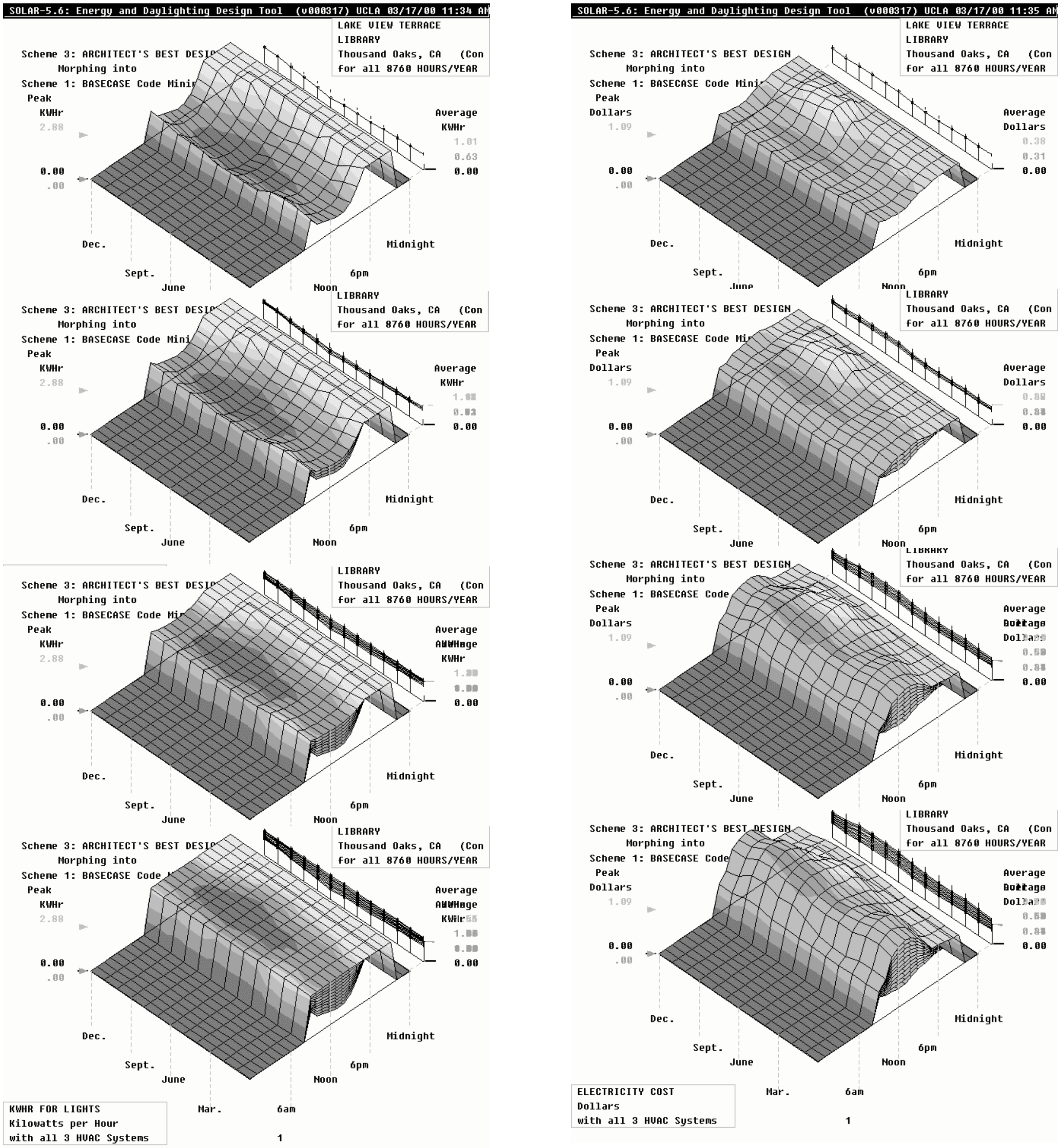
Scheme 6: No Air Conditioner in Improved Design: in a copy of Scheme 3, the air conditioner was eliminated to see how high indoor air temperatures would climb. This also is a 12-day snapshot around the hottest day of the year to be able to see in maximum detail how actual hourly temperatures behave.

ACKNOWLEDGEMENTS: This work and the development of our other Energy Design Tools was made possible through grants from the UCLA Academic Senate, and the University of California Energy Institute. Library design by James Weiner, Fields Devereaux Architects and Engineers.

REFERENCES: "Study Shows Gap Between Designers' Beliefs and Practices", GreenClips electronic Newsletter, 138, February 23, 2000 an excerpt from Interiors, Jan 00, p 28, by Neil Frankel.

SOFTWARE AVAILABILITY: The "morph movies" described in this paper are produced by the latest version of SOLAR-5, a whole-building energy design tool that can be downloaded at no cost from UCLA's Energy Design Tool Web Page (www.aud.ucla.edu/energy-design-tools).

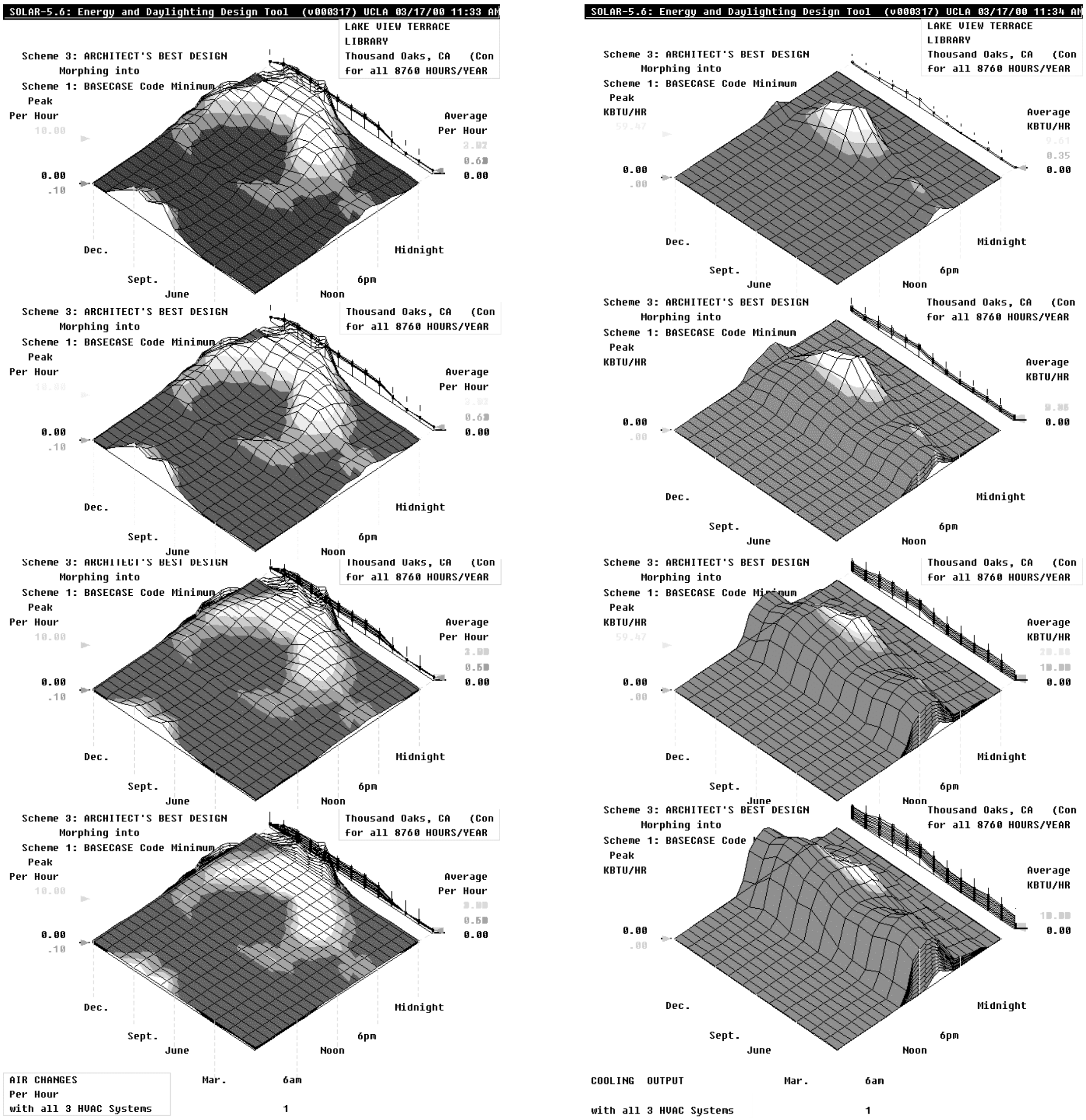
Scheme 3: Architect's Best Design



Scheme 1: Basecase Code Minimum

Fig. 1: ENERGY AND COOLING SAVED BY AUTOMATIC DAYLIGHTING CONTROLS: These two sets of frames from the "morph movies" illustrate (on the left) the electricity used for lighting in this library. The Architect's Best Design at the top shows the classic 'sun bowl' shape of a building with adequate glazing and a good photocell controlled dimming system. At the bottom is the flat power consumption plot of a building with no lighting controls. The total cost of electricity for the Best Design (right top), includes lights, equipment, and a small bump in summer afternoons for air conditioning. Contrast this with the Code Minimum Building (bottom right) which shows the electricity costs for the additional lighting plus the added air conditioning to remove the additional heat.

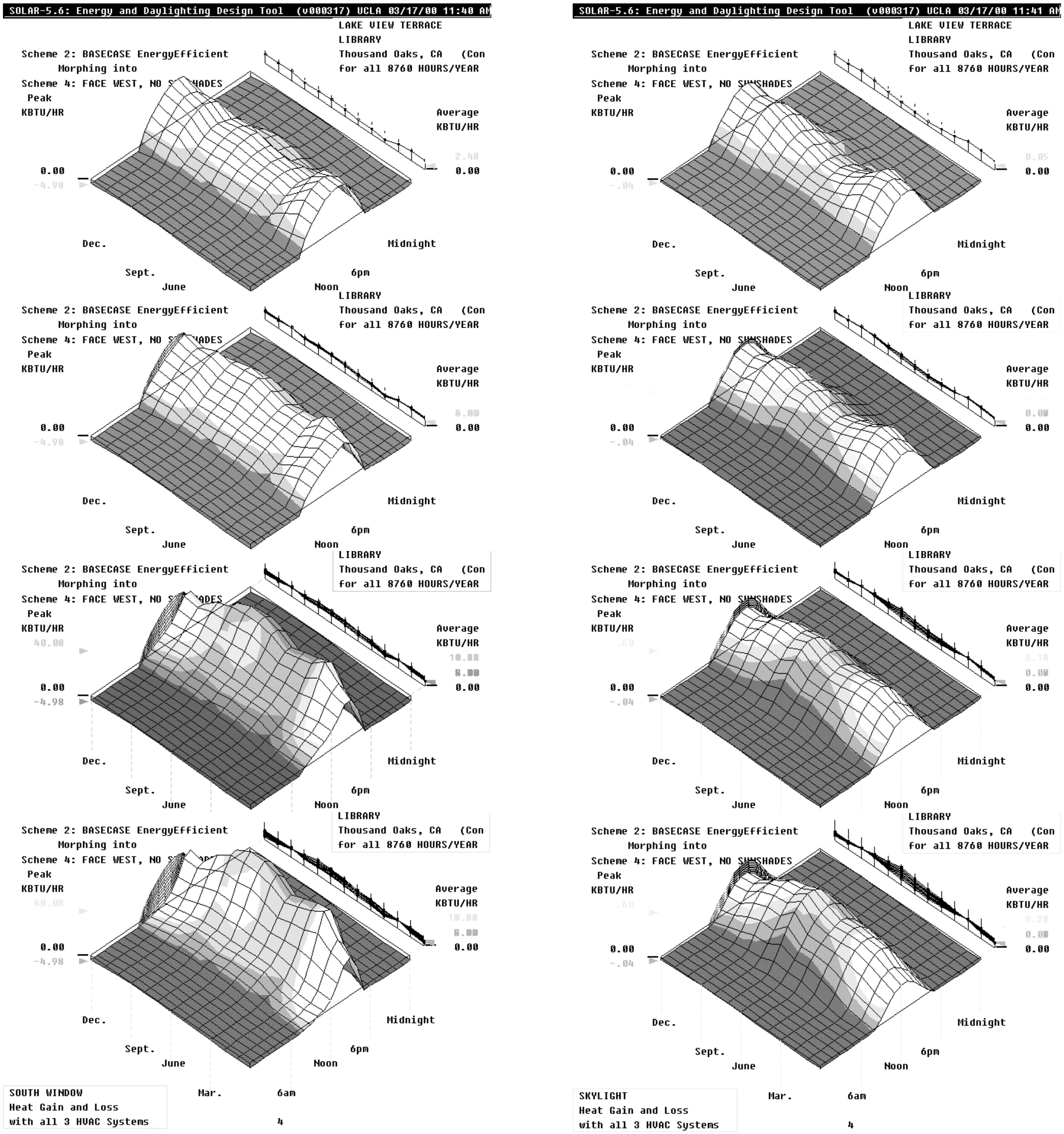
Scheme 3: Architect's Best Design



Scheme 1: Basecase Code Minimum

Fig 2: NIGHT VENTILATION IN HIGH MASS BUILDINGS: These frames from the "morph movie" show (on the left top) the Architect's Best Design that automatically brings in up to 10 air changes per hour especially at night in the late summer, compared to the Basecase Code Minimum building (at the bottom) that is completely flat with only the code minimum of .5 air changes. Fans managed by a smart economizer controller could create the carefully managed ventilation pattern in the top building. This translated to an Air Conditioner Output for the Basecase Code Minimum building (lower right) that runs almost all day long for all year long. Compare this to the Best Design (top right) in which the air conditioning load is clearly much less, in fact in many months it hardly runs at all. (Note: this striking improvement illustrates one of the reasons why it is hoped this Library will earn a LEEDS Platinum Rating).

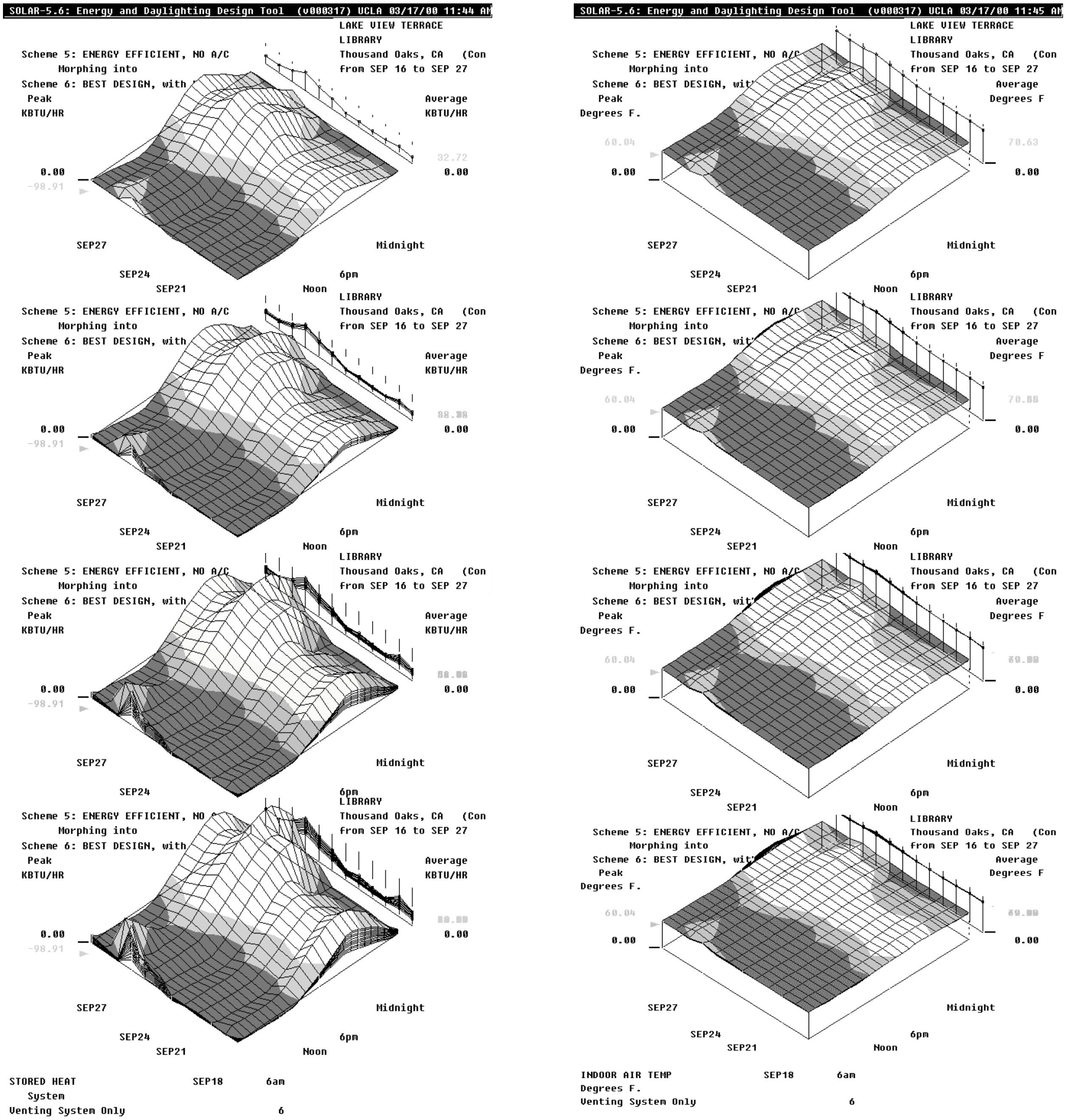
Scheme 2: Energy Efficient Design



Scheme 4: Energy Efficient Rotated to face West

Fig 3: THE IMPACT OF ORIENTATION ON WINDOW GAIN: The south-facing windows, at the top of the "morph movie" on the left, exhibits the classic 'saddle shape' plot that shows why south windows are wonderful passive solar collectors, actually gaining much more heat in the winter than in summer. By the time this window is rotated to face West (bottom) it exhibits the classic 'heat mountain' shape with too much gain on summer afternoons, and almost no gain in winter when it is needed. The "morph movie" on the right shows what happens when a skylight is tilted from horizontal to vertical. The flat up-facing skylight (bottom) shows the classic "heat mountain" shape of summer overheating, but as it tilts up to face south (top) it gradually becomes more 'saddle shaped'

Scheme 5: No Air Conditioning in the Low-Mass Basecase



Scheme 6: No Air Conditioning in the Architect's Best Design

Fig. 4: HOW INDOOR AIR TEMPERATURES RESPOND TO ELIMINATING AIR CONDITIONING: The "morph movie" on the left, for the hottest 12 days of the year, shows the picture of how heat flows into and out of the buildings internal thermal mass. The bottom shows heat flow into the much more massive Best Design. On the right the peak indoor air temperature reaches 101 degrees in the less massive building (top) while in the more massive "best design" on the bottom shows almost no temperatures differences between day and night (it peaked at 81degrees).