RESEARCH AND IDEAS

The Powerful Benefits of Architectural Shading (Revisited)

If there were no such thing as air conditioning or electric fans, designers and builders would be forced to rediscover (and actually *use*) the great passive cooling techniques of old. Most of these ideas are highly intuitive — at least to people who live in hot climates — and pretty simple to employ. For example, if at all possible, why not locate a new house in the cool shade of surrounding trees or other houses? And if site shading wasn't available, wouldn't it be smart to build porch roofs and trellises to shield windows and walls from direct solar gain? Pretty simple stuff, eh? Yet many designers and builders still reject such methods because it seems simpler to just slap another ton of mechanical air conditioning into place and call it done.

But all that is going to change, in one way or another, because the chronic power shortages that are plaguing California and other Western states are forcing government officials and code writers to tighten the screws, and much of that new pressure to cut peak air conditioning loads is going to be applied to builders (see *EDU*, January 2001).

From that perspective, we find a lot to be learned in the new field research done by Sara Farrar-Nagy and Ren Anderson of the National Renewable Energy Laboratory (NREL — Golden, Colorado) and Paul Reeves of the Partnership for Resource Conservation. Their study, called *Impacts of Shading and Glazing Combinations on Residential Energy Use in a Hot Dry Climate,* is one of the best we've seen in exploring the performance and interaction of spectrally selective glazing, architectural shading, site shading, and building orientation.

Designers and builders will be interested to know that in the prototype studied — a 1,170-ft^2 ranch built in Tucson, Arizona — architectural shading has a much greater impact on reducing daily cooling use than upgrading the windows with spectrally selective glass. In fact, the researchers found that architectural shading reduces the home's annual cooling requirement by about 23%, regardless of the glazing type. Site shading from adjacent houses and spectrally selective glazing raises the total savings in cooling energy to about 30%, compared to a house without such features.

The House in Question

The primarily purpose of the NREL field study was to assess various solar load control strategies. Secondarily, the researchers wanted to verify computer modeling software to see how well it estimates the impact of design changes — especially those related to shading — on cooling energy use.

The test house, located in a high-density residential development in Tucson, is a high-efficiency prototype that was built in conjunction with the Department of Energy's Building America program. It is flanked on either side by two-story houses that provide a lot of beneficial site shading. The house itself features:

- Walls and roof framed with structural insulated panels (R-27 and R-41, respectively)
- A crawlspace that is sealed, insulated, and conditioned
- Spectrally selective glazing in the windows and sliding glass doors
- High-efficiency air conditioning
- A combination water/space heating system
- Solar water heating

It should be noted that the Tucson house has a lot of window area for its size — 272 ft^2 in all. Four sliding glass doors that face the side patio make up 80% of the glazing. These are partially shaded by a patio overhang that is 24 feet long, 6 feet wide, and 10 feet high. An open horizontal trellis that supports vegetation shades the front elevation of the house. These architectural shading features are shown in the computer rendering in Figure 6. Keep in mind that the home's tight, well-insulated envelope and large ratio of windows-to-floor

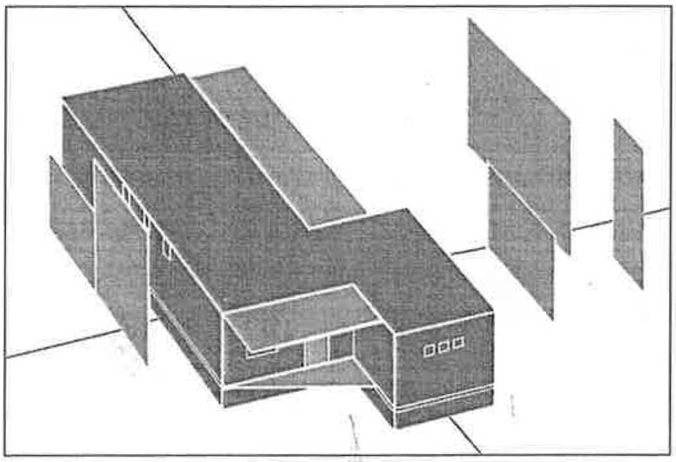

Figure 6 — Simulated view of the Tucson house from the southwest, showing how the trellis and porch overhang provide shade. The trellis, with growing vegetation, was modeled with an average transmittance of 50%, while the side patio overhang is completely opaque. The windows and sliding glass doors in the house are both tinted at the same level, but with different types of spectrally selective coatings. The solar transmittance of the windows and doors is 0.28 and 0.36, respectively. Note also that the fence and walls of the neighboring houses are modeled, with solar reflectances ranging from 0.26 (fence) to 0.42 (wall of adjacent house).

area cause the windows to have a relatively larger impact on heating and cooling than would be the case in most Tucson-area houses.

Measurements and Simulations

The NREL research team was able to directly measure the home's cooling load without the system losses associated with the conventional air-conditioning system. They did this by deploying a portable 5-ton water chiller outside the house, with insulated water piping installed in a temporary opening and a fan coil unit located inside the house. This independent cooling system (referred to as "co-cooling") enabled the direct measurement of the cooling load of the shell.

The researchers also built opaque exterior shades to block all beam radiation from entering the windows. This enabled them to measure the maximum influence that window solar gains would have on the home's cooling load. Using a spectroradiometer, the team also measured window transmittance and the solar reflectance of surrounding surfaces, including a concrete block fence, patio floor, and the stuccoed walls of the adjacent houses (see Figure 6). These measured results were used to verify and modify the team's modeling software, so that the home's annual energy usage could be predicted with more accuracy and a broader range of solar load control strategies could be assessed.

Impacts of Shading on AC Loads

The refined modeling software predicted that the Tucson house will require 3,285 kilowatt-hours (kWh) of cooling energy and 71 therms of heat energy per year. As shown in Figure 7, architectural shading is a very important feature in reducing cooling loads. In fact, Farrar-Nagy, Anderson, and Reeves conclude that the architectural shading on this house reduces its annual cooling requirement by 23%, regardless of whether spectrally selective glazing is used.

This is not to say that spectrally selective glass is not a good idea — it does reduce solar gain and cut the home's air conditioning load. But the shading combination reduces daily cooling use by 9.4 kWh (23%) while the reduction due to upgrading the windows is only 4.4 kWh (11%). Thus, if a designer had to choose just one feature based on energy savings alone, shading would win out. Unhappily, the report doesn't tell us how much the shading and glazing features cost, so we can't compare the cost per kWh saved. But even if cost data were available, how do you screen out the aesthetic and comfort values associated with having a patio overhang or an ivy-covered trellis?

Figure 8 shows annual cooling and heating costs as a function of glazing type, two types of shading, and the orientation of the front of the house. As built, the house faces south, which places most of its windows towards the east. As shown in Table 2, this orientation, combined with the shading and spectrally selective glass, produced a 26% reduction in total energy costs. (The heating penalty caused by the loss of solar gain in the winter is slight, because the total amount of heating energy required — just 70 therms a year — is so small.

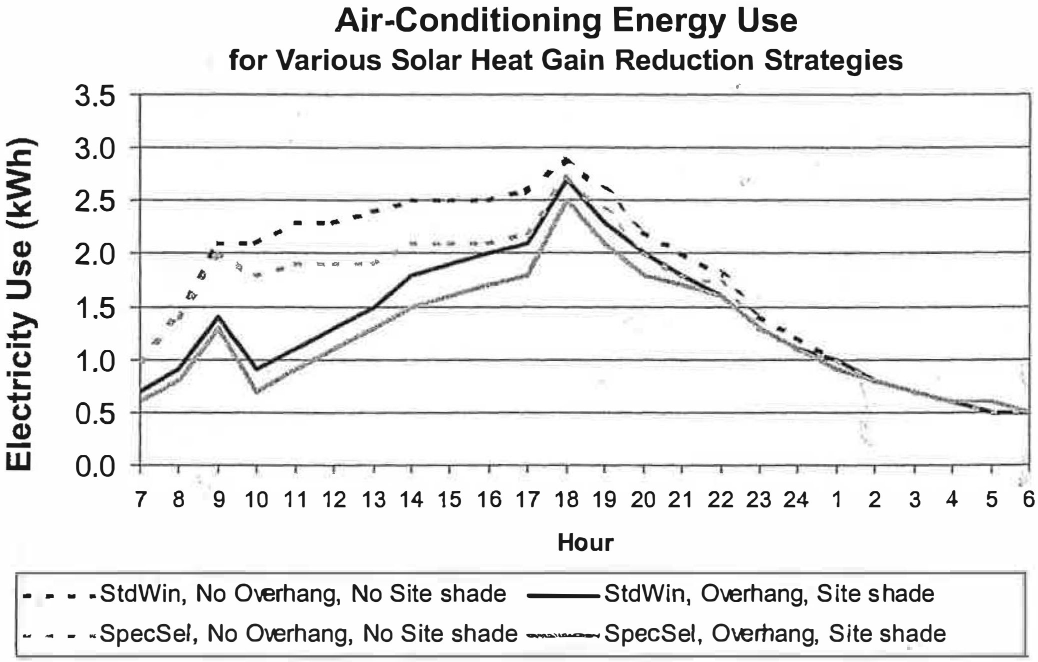

Figure 7 — Daily air conditioning load profiles comparing windows with standard glazing (StdWin), with and without shading, and spectrally selective windows (SpecSel), with and without shading. If site shading were not taken into account, annual cooling energy would have been overestimated by 6%-24%, depending on glazing type, overhang, and orientation.

In a less efficient house located in a colder climate, the heating penalty related to shading would obviously be more severe.) The table shows that the maximum amount of energy savings — a whopping 37% — would be achieved if the house faced west, which would orient most of its windows to the south. Conversely, an eastern orientation would place the windows to the north, in which case the shading and glazing features would save only 19%.

Obviously, the combination of site shading, architectural shading, and spectrally selective glass will save the owner of this house a lot of money over the years. But there are important benefits for the local electric utility as well. The shading and glazing features in this house reduce the afternoon peak electricity demand by 0.4 kWh (14%) and the daily total electricity used for air conditioning by 12.4 kWh (30%), compared to the same house with no shading and standard double pane windows.

There are further implications here for designers who want to correctly size air conditioning equipment and accurately estimate utility bills. For example, without the beneficial site shading from neighboring houses, the air conditioning load in the Tucson house would be 10% higher. Take away the overhang and the trellis, and it would shoot even higher. Hopefully, some of the modeling refinements that Farrar-Nagy, Anderson, and Reeves achieved in this field study will quickly find their way into design and heat-load calculation tools.

For more information, the full report is available from the America Council for an Energy-Efficient Economy (ACEEE) as part of their *2000 Summer Study Proceedings*. The price for the 10-volume printed set is $220 including postage. The price for the CD-ROM (which features Adobe Acrobat software for both Mac and PC platforms) is $120 including postage. Contact ACEEE publications at: Tel: (202) 429-0063; Fax: (202) 429-0193; E-mail: ace3pubs@ix.netcom.com.

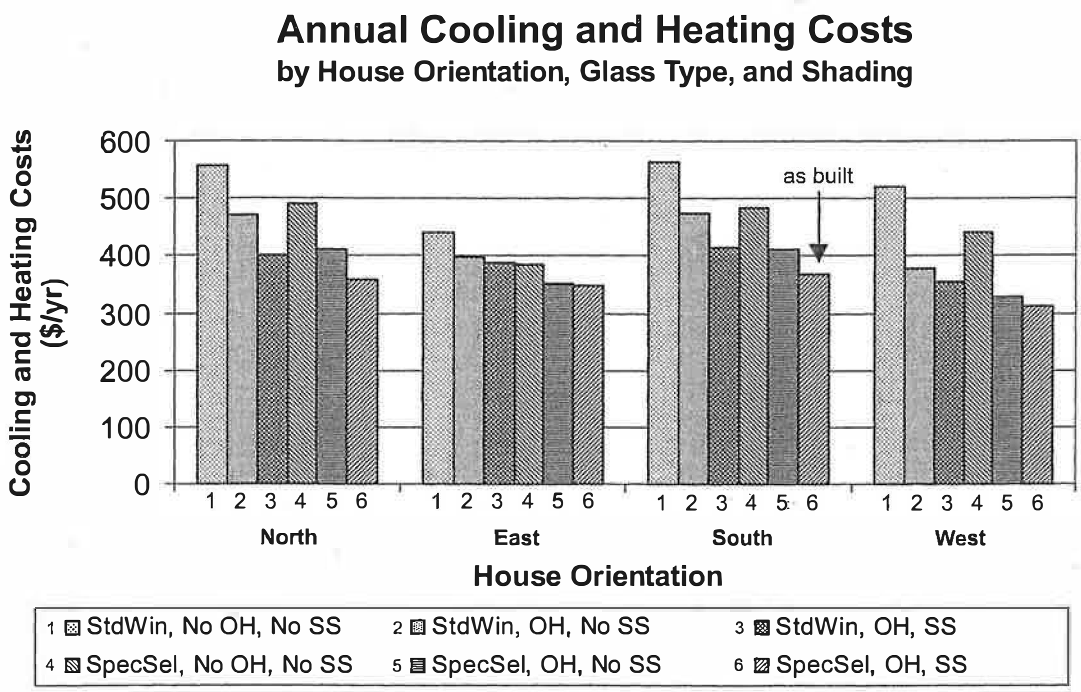

Figure 8 — Annual cooling and heating costs as a function of glazing type, two types of shading, and orientation of the front of the house. (StdWin = standard glazing. SpecSel = spectrally selective glass. OH = overhangs. SS = site shading.)

Table 2 — Reduction in Cooling and Heating Costs for a Subset of Combinations*

Solar Load Control Strategy	Front Orientation			
	North	East	South	West
Overhang	18%	10%	17%	28%
SpecSel	12%	12%	13%	14%
SpecSel + Overhang	27%	19%	26%	37%

* Base case is standard glass with site shading.