

Effect of Shading Devices on Residential Energy Use in Austin, Texas

by

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EXECUTIVE SUMMARY

This report presents the results of an analytical study of the effect of shading devices on the annual heating, cooling, and total energy use, on summer peak electric demand, and on energy cost savings in single-family residences in Austin, Texas. With an hourly building energy analysis model, savings were simulated for interior and exterior shading devices. No analysis of the costs of installing and operating these devices was made.

Results are presented in terms of annual heating and cooling energy use and energy costs, with each shading device in place, as compared to baseline reference cases for three prototypical residences. The devices are ranked in terms of energy cost savings. **While the five best-performing devices have annual cooling energy savings ranging up to 32%, the annual energy cost savings (at 1985 Austin utility rates) range from 5 to 14%.** Another significant result is the multiple-regression correlation of normalized annual heating and cooling energy savings with Shading Coefficient (SC) and U-value. By means of this correlation the results of the study can be applied to any single-family residence in Austin.

Performance Analysis of Shading Device

Shading devices of three basic types were analyzed in this study:

- reflective and tinted glazing (including films)
- interior devices (louvered blinds, draperies and curtains, planar roller or hanging shades, and shutters)
- exterior devices (solar screens, awnings, overhangs, and the effects of recessed windows and vegetation)

A data base of the thermal/optical characteristics (principally Shading Coefficient and U-value) of these devices, which was developed from manufacturer's and technical literature, is included in Appendix A of this report.

Direct and diffuse solar gains were analyzed using the standard heat gain methodology for fenestrations developed by ASHRAE, The American Society of Heating, Refrigerating, and Air-Conditioning Engineers. This methodology was implemented in the DOE-2 building energy analysis computer program that was used for the simulations. Each interior shading device was characterized by a Shading Coefficient and a U-value; where applicable, these values were scheduled to represent managed (operable) devices. The exterior devices were characterized by Shading Factors (time-averaged Shading Coefficients) calculated external to the simulation program; however, at each simulated hour the program calculated the shading pattern on the glazing and calculated the transmitted solar gain.

Parametric Analysis of Prototypical (Baseline) Residences

The set of three prototypical residences was representative of small, medium, and large houses, as well as a range of building age, thermal integrity, and occupant energy use patterns. A nominal baseline (gas heating, single-pane glazing, and nominal shading from eaves and neighboring buildings) was established to represent the most likely configuration for each of the three houses. However, to test the sensitivity of the shading device effects to key features of the baseline models, baseline variants were developed for an all-electric house, a house with double glazing, and one with no eaves or neighbors (bare case). These baseline variants were run only for selected shading strategies.

Residence 1, representative of pre-1964 vintage, was a single-story, two-bedroom house of 1,008 ft representing old frame construction. It has an R-19 ceiling, R-11 floor, and R-2 (uninsulated) walls, and room air conditioners (EER = 6.55). **Residence 2 was a single-story, four-bedroom, 1,543-ft house of 1964-73 vintage.** It was moderately insulated with R-19 ceiling and R-11 walls, and had a 2.5-ton central air conditioner of EER = 7.78. **Residence 3 was a 2,782-ft, two story, four bedroom house** representative of new, large home construction. Thermal integrity was high with R-19 ceiling, R-11 walls, and tight construction. Two central air conditioners (1.5-ton and 3-ton units) had EERs of 7.92. The Residence 2 and 3 prototypes were calibrated and validated by comparing DOE-2 simulated monthly and annual electric and gas use with metered data.

Sensitivity cases were run for the nominal baselines to establish the maximum effect of the use of shading devices and to determine the sensitivity of energy use to building orientation and to the distribution of shading on each facade. The results showed that if all solar gains were eliminated (zero Shading Coefficient) the annual energy cost decreases 7-9%. Thus, the insulation value of a shading device can be significant, even in the cooling-dominated Austin climate. Sensitivity tests for building orientation and distribution of shading shed that these variations had minimal effect on annual energy use, energy cost, and summer peak demand.

Results of the baseline variant sensitivity runs showed that the double-pane baseline has slightly lower energy use (5-7% lower) and energy cost (3-5% lower) than the nominal baseline case. In contrast, the annual energy costs for the bare baseline slightly exceed (by about 3%) those for the nominal baseline. This difference indicates the magnitude of the effect of nominal eaves and neighbor shading.

Results of Shading Strategy Analysis

Performance Relative to Nominal Baseline Residences

Comparisons of performance relative to the nominal baseline residences show that for all three residences the interior strategies (including solar screens) consistently outperform the exterior strategies in terms of the energy cost savings. The likely reason for this finding is that the exterior devices, assumed to be in place year round, provide no U-value improvement while they reduce beneficial wintertime solar gains. Thus awnings

should be removed in the wintertime to be effective. However, despite the very modest annual energy savings of the exterior devices, they do significantly reduce summer peak loads more than 7% in the largest house.

The annual energy cost savings for the top strategy (solar screens with the best properties) range from 10 to 14% (\$140-\$240/year) [calculated at 1985 energy prices your savings will be higher depending on the increase in electric costs since 1985]; the comparable savings for the top exterior device (3-foot awning with side fins) are only 2%. The relative rankings are generally independent of residence size and thermal integrity, although the greatest relative savings occur for Residence 3.

In terms of annual energy cost savings, the best five strategies are:

- **Best Available Solar Screen (SC = 0.14)**
- Reflective Film (SC = 0.23)
- Best Drapery/Curtain (SC = 0.15)
- Worst Available Solar Screen (SC = 0.44)
- Operable Blinds with Closed Position at 45 (SC = 0.51)

Although annual cooling energy savings for these top strategies range from 22 to 32%, and summer peak reductions range from 4 to 22% for the 2,782 square foot house, the annual energy cost savings range only from 10 to 14% for the three residences. Annual cost savings include the net effect of cooling and heating load tradeoffs and the differential effects of gas and electricity utilization efficiencies and prices.

Among the interior strategies, the operable drape/curtain with the worst available properties and tinted windows rank the lowest, saving only 1 to 3% in annual energy costs. The 1-foot overhang and the 6-inch recessed windows rank lowest among the exterior strategies, saving energy costs of at most 0.3%.

Performance Relative to Baseline Variants

When selected shading strategies were simulated for Residence 2, but with electric space heating (either resistance or heat pump) and electric resistance water heating instead of gas space and water heating, the performance ranking and relative savings did not change significantly, with one exception: the Worst Solar Screen was replaced by the Planar Shade in the top five performers. Because interior strategies provide an extra measure of window insulation, more of them rank above the 50th percentile in performance for the all-electric baseline as compared with the mixed-fuel (nominal) baseline.

Similarly, with the bare baseline variant (no eaves or neighbor shading) the annual energy cost rankings of the strategies analyzed are unchanged compared to those for the nominal baseline. However, the presence of the nominal shading diminishes the effect of the shading devices on energy cost, so that houses with completely unshaded fenestration experience 2 to 5% greater energy cost savings with shading devices than houses with nominal shading to begin with.

The annual energy cost of strategies applied to double-pane windows is less than that for single-pane windows; the difference is most pronounced for Residence 3. However, because the relative reduction in heating and cooling energy differs for the single- and double-pane baselines, some shading devices perform better when applied to double-pane windows than when applied to single-pane windows.

Selected shading strategies were compared with a 30% reduction in infiltration and the installation of clear storm windows. The results showed that these alternative strategies are more effective in reducing annual energy costs than is the 3-foot awning with sides, but they are only half as effective as the Best Solar Screen. **The solar screens are three times as effective as the alternative strategies in reducing summer peak demand.**

Finally, the effect of shading device management is illustrated by comparing results for the operable mode versus those for the closed mode (device in place during all hours). The results indicate that this extreme approach (closed mode) increases energy cost savings by a factor of two over the managed mode savings.

Generalized Annual Correlations with Shading Parameters

To permit the application of the annual heating and cooling energy savings of

any shading device to any single-family residence in Austin, correlations of normalized (by glazing area) heating and cooling energy savings were developed as a linear function of Shading Coefficient and U-value of the device for the Austin climate. Interior and exterior device results were regressed separately; for the exterior strategies the season-weighted Shading Factor was used instead of the Shading Coefficient. R-squared values of 0.95-0.98 indicated a satisfactory fit between the correlations and the simulated results. This generalized correlation allows the prediction of annual heating and cooling energy savings for a residence of any size in Austin.

Conclusions

The most significant conclusions of this study are that:

1. **The top strategy in terms of energy performance and energy cost savings is the Best Solar Screen (SC = 0.14). Although the annual cooling energy savings were 32% for this device, the annual energy cost savings were 14%, the summer peak load reduction was 22%.**
2. As a group the interior strategies (which include solar screens) perform better, with very few exceptions, than the exterior strategies. The reason is that the interior strategies not only provide effective solar gain control, but also improve the U-value of the window. Thus even for the cooling-dominated climate of Austin, heating load reductions through fenestrations are important to overall energy savings.
3. Annual heating and cooling energy savings, normalized by glazing area, correlate well with the weighted Shading Coefficient and U-value of a shading device, allowing a generalized method for predicting the annual energy savings for a residence of any size and thermal integrity in Austin.