Analysis of Annual and Peak Load Savings of High-Performance Windows for the Florida Climate

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ABSTRACT

Solar gain through clear single glazing typically represents between 20% and 30% of the annual cooling load in Florida homes. In recent years, a series of high-performance windows have become available from manufacturers. Since most of the glazings are designed for enhanced performance in northern climates, many architects, designers, and conservation program managers desire to know how effective such windows might be in a hot climate. Since utilities in Florida are especially concerned with meeting summertime peak loads, we examined how such high-performance glazings might affect building thermal performance, both with respect to annual savings as well as peak cooling loads.

Window options were analyzed using a detailed hourly simulation model of an existing block home located in Orlando, FL. Cases were examined for windows facing each of the cardinal directions. Each window type was compared both to single glazing and single glazing with tints or reflective coatings. Further analysis examined how maximum savings under full sun conditions varied against more realistic assumptions of interior and exterior shading. Costs for each type of high-performance glazing system were collected relative to the cost of single-glazed windows available from local suppliers.

The simulation results were summarized both in terms of kilowatt hours saved (kWh) per ft^2 of glass as well as the effect of the high-performance glazings on peak heating and cooling loads. The savings from the windows were compared to costs to estimate the levelized cost of conserved electricity. Savings of peak load energy were estimated in $/kW saved during peak conditions and how the various options affected the building-specific coincidental peak load factor (CPLF).

The analysis results indicated that the energy-related performance of windows in the Florida climate is dominated by the solar heat transmission characteristics of the window unit. Generally, high R-value glazing units have less benefit for a hot, humid region, with available savings being concentrated during peak load heating and cooling periods when temperature differences are important. However, reduction of the glazing shading coefficient has a large overall impact in the Florida climate. In general, reflectively coated windows will yield superior performance both in terms of annual energy saved as well as reductions to summertime peak loads.

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DESCRIPTION OF HIGH-PERFORMANCE GLAZINGS

High-performance windows are advanced technology glazings usually with a high insulation value and varying solar transmittances, depending on the product type. This analysis seeks to determine their merits relative to conventional single-glass or double-glass products, both clear and reflectively coated.

"High-performance windows" refers to a number of methods of improving glazing thermal performance. These technologies generally can be grouped into the following categories:

1) Low-e glass: Double-glazed windows with a special low-emittance coating of 0.40 or less on one of the glazing surfaces are classified by their manufacturer as low-e windows. Generally, the lower the glazing emittance, the higher the window's R-value. R-value is the thermal resistance of the glazing system (h-ft^2-°F/Btu) including air film resistances. Low-e glazings are most beneficial in reducing wintertime heat loss, although they also help to reduce transmission of solar heat in summer as well. The low-e coatings are generally applied directly to one of the glass surfaces. The lower the emissivity of the material (generally 0.15 to 0.35, the better the relative performance. The R-value of double-glazed units with low-e coatings typically varies from 2.5 to 3.4 h-ft^2-°F/Btu. The shading coefficients vary for clear, low-e double-glazed units from 0.71 to 0.85. The extra cost of low-e glass over conventional double glazing is about \$2 to \$3 per ft^2 for a given manufacturer.

2) Low-emittance Polyester Film: Very thin low-emittance polyester films are suspended between the two panes of glass, giving greater thermal resistance as well as very low emissivity characteristics (0.05 to 0.15). The R-values of these windows vary from 4.0 to 4.8 h-ft^2-°F/Btu. The shading coefficient of the clear product is 0.71. The product generally adds \$4 per ft^2 of glazing to which it is incorporated.

3) Argon Filled: Both low-e windows and low-e polyester film products can be filled with argon gas rather than air. This inert gas has a higher thermal resistance than air. Solar transmittance is unaffected by the gas, so shading coefficients are identical to the air-filled product. The R-value of the low-e windows with argon fill is about 4.8 h-ft^2-°F/Btu; it has a value of 5.1 with the low-e polyester film product. The cost of argon-filled windows generally adds about \$7 per ft^2 to the type of window to which it is added (not including the extra costs for the low-e or polyester film). The argon-filled windows are designed for use in cold regions and are clearly non-cost-effective in warm climates. Accordingly, analysis of these units was excluded from the study.

4) Reflective coatings and tints: Both low-e windows and heat mirror products can be combined with reflective coatings and tints to reduce solar gain for hot climate such as that in Florida. Generally little additional cost is incurred above the cost of the standard low-e or heat mirror incremental costs. Shading coefficients for such glass vary from 0.64 to 0.25 depending on the level of the tint. Visible light transmittance is of concern with reflectively tinted glass since it reduces available daylighting and could increase the use of interior electrical lighting in some applications. Low-e products transmit 71% to 77% of visible light, whereas tinted window products only provide 22% to 57% transmittance.

COMPARATIVE CHARACTERISTICS OF CONVENTIONAL PRODUCTS

Conventional clear single glass has an R-value of 0.89, an infrared emittance of 0.84, and a shading coefficient of 1.00. However, existing windows, as installed, may have significantly different shading coefficients. Often insect screens cover the glazing and the placement of the windows in the wall width may result in substantial inset shadowing. Consequently, a base shading coefficient for a single-glazed window as installed may be on the order of 0.80. A double-glazed unit has an R-value of 2.00 h-ft^2-°F/Btu, and emittance of 0.84, and a shading coefficient of 0.89. The as-installed shading coefficient may only be on the order of 0.70. Double-glazed windows generally cost about $2.50 more per ft^2 than single-glazed units. Addition of reflective tints to conventional glazing units generally adds about $1.60 per ft^2 to the cost.

Tinted single-glazed windows are a popular residential retrofit item in Florida. The tint does not appreciably affect the thermal resistance of the glazing unit or its emittance, but the shading coefficient drops from 1.0 to 0.85 for a typical film. However, such windows transmit much-reduced levels of visible light and offer only limited solar control.

ANALYSIS METHODS

The various options and sensitivities were modeled using a detailed hourly simulation, the Thermal Analysis Research Program (TARP). A special version of the program was used which considers moisture-absorption-desorption within the building (MADTARP). The cases were simulated using Orlando typical cooling year (TCY) data and a prototype residential detached single-family house. The building is 30 ft by 50 ft with 1500 ft^2 of conditioned floor area with an attached garage. The building has 214 ft^2 of glazing (14.3% of gross floor area) with a 2 ft overhang on all sides of the house. The prototype is illustrated in Figure 1. The glazing distribution is oriented in the following cardinal directions:

North: 60 ft^2
South: 70 ft^2
East: 42 ft^2
West: 42 ft^2

Since the utility rebate programs apply to existing buildings, the modeled thermal characteristics of the building were designed to reflect typical existing housing stock in the state. Uninsulated block wall construction was assumed with R-11 ceiling insulation and uninsulated slab-on-grade construction. The building roof was assumed to have a surface solar absorptance of 0.8 with a medium-colored wall with an absorptance of 0.5.

Internal loads for a family of four were assumed: 50,807 Btu/day in sensible gains and 25,037 Btu/day in latent gains. A thermostat setpoint for heating conditions of 72°F was assumed; a cooling setpoint 78°F was used. The house was vented at 15 air changes per hour (ach) whenever the ambient dry-bulb temperature was between 72°F and 78°F and the ambient enthalpy was less than 34.7 Btu/lb. This is a reasonable approximation of typical natural ventilation behavior in Florida residences where occupants control house venting based both on temperature and humidity conditions. During sealed operation, natural air infiltration is assumed to average 0.42 ach (the simulation program alters the hourly infiltration and ventilation rates based on hourly temperature and winds speeds). This lower assumption is based on monitored data from the FSEC Rangewood project and other recent field studies of infiltration in Florida homes (Cromer and Cummings 1986; Cummings 1988).

A 2.5-ton central air-conditioning system with a seasonal energy efficiency ratio (SEER) of 8.0 was assumed. Duct losses in the attic were set to 10%. The cooling season was defined as the months of May through October for Orlando. The heating season was allowed to extend into any month that did not have mechanical cooling. Table 1 describes the individual window types used to determine the reduction in both annual energy consumption and peak energy demand.

Because the cost effectiveness of high-performance windows and reflective films is highly dependent on the presence of shading mechanisms that might affect their savings, we performed sensitivity analysis to examine these parameters. Draperies, curtains, and blinds are commonly used on windows in many homes. Exterior shading may be present from awnings and shutters or from trees, landscaping, or other buildings. Savings from window treatments are also strongly dependent on aperture orientation and overhang dimensions. Window treatments on east and west exposures will reduce heat gain the most. Accordingly, a sensitivity matrix was planned for each glazing type as depicted in Table 2.

The contribution of single-glazed windows to building thermal loads as estimated by TARP is graphically shown in Figure 2. The two pie charts show the contribution of individual building components to the overall air conditioner thermal load as estimated by TARP. The first pie chart shows the annual cooling load that is due to the glazed building surfaces; the second chart shows the fraction attributable on the peak load day. As can be seen, glazings are a larger part of the peak load day fraction of overall thermal load than of annual loads.

SPECIFIC DATA

The specific characteristics of the glazings modeled in the simulations are summarized in the three tables that follow. Table 3 describes the physical characteristics of the windows. The glazing efficacy is defined as the ratio of the fractional visible transmittance to the shading coefficient. Thus, higher efficacies suggest greater daylighting benefits while reducing overall cooling costs. Table 4 shows the estimated shading coefficients used for each case and Table 5 presents the cost data used in the analysis.

The cost data in Table 5 show substantially greater costs for the double-glazed low-e and low-e polyester film products. These high prices are somewhat artificial in the sense that they reflect the disproportionate cost of non-local high-quality products. For instance, the double-glazed low-e window used in the analysis is manufactured by a nationally known firm and has a cost of about \$13 per ft^2. However, the plain double-glazed window from the same company without the low-e coating is about \$10 per ft^2 as opposed to \$2.50 for a locally manufactured window. Thus, we can expect that local manufacturers could manufacture a low-e double-glazed product with a reflective coating for about \$7 per ft^2.

SIMULATION RESULTS

The results of two simulated cases are presented below for each type of window glazing: 1) a totally unshaded building where all windows are in full sun, and 2) a building with 20% shading on the exterior and light-colored draperies over half of the window area. The former case represents the optimum savings potential for window treatments; the latter case represents a realistic assessment of what might typically be saved in an average residential setting. Results are presented both for peak and annual savings for each orientation in Tables 6 - 9. Peak savings are given in watts saved per ft^2 foot of glazing, annual savings are provided in kWh saved per ft^2 of glass. Electric resistance heat with a COP of 1.0 and a cooling system with an SEER of 8.0 is assumed to be used to met the loads. This will generally increase the importance of high R-value products relative to analysis, which assumes a heat pump is used to meet heating loads.

A fundamental conclusion to be drawn from the simulation results is that savings from changes to window shading coefficients are nearly uniform in terms of directional effects for an annual analysis of energy consumption. However, savings differ dramatically in terms of savings of peak load.

The analysis of peak day performance suggests that west windows in Florida houses are most aggravating to building comfort conditions and utility load shape. In the analysis west windows were shown to have more than seven times the impact of other windows in increasing peak summertime loads. East windows assist in reducing wintertime peak loads (which typically occur from 6 a.m. to 9 a.m.), while north and south windows are more neutral. The effect of shading of windows serves to reduce both annual and peak cooling demand savings from high-performance windows On the other hand, the assumption of increased shading of windows will increase estimates of heating loads savings from high-performance windows. This results because less solar heat is available to the building, increasing the exterior temperature at which auxiliary space heat will be required to meet interior comfort conditions. Such an increase in the cumulative temperature differences will show lower heating loads as the thermal resistance of the glazing is increased.

A final type of analysis was performed to see how the coincidental peak load factor (CPLF) of the simulated house was affected by the various window treatments. The CPLF is commonly used by utilities to determine the load characteristics of various options. It is defined as:

$$\text{CPLF} = \frac{\text{Average demand over a 24-hour period}}{\text{Hourly demand during utility system peak}}$$

Due to the economies possible through the use of maximum capacity from baseline generation facilities and the dis-economies resulting from generation of peak loads with combustion turbines, a desirable load from a utility standpoint is one which is constant (CPLF=1.0). Since few end-uses are not dominated by natural cycles (time of day, seasonality), CPLFs exceeding 1.0 are desirable to increase overall capacity utilization of cheaper base-load generation facilities. Thus, desirable loads would demand power out of phase with the typical summer day demand load curve. Such an objective is very difficult with respect to residential loads. Indeed, residential load shape generally determines the utility load shape in Florida, since about half the overall load comes from the residential sector.

Given the difficulty of obtaining high CPLFs for residential loads, strategies which increase the existing values for the residential sector are desirable. Thus we calculated how the CPLFs varied for cooling peak demand for all the identified window options. They are listed in Table 10 using the more realistic shaded cases as our basis for estimating changes to the residential sector. The results reveal three vital aspects of this analysis for cooling season load characteristics:

1) Addition of energy-efficient windows to the north or sough exposures of residences will not generally alter the CPLF of the building since load is both depressed during the peak load period as well as during other hours of the day.

2) Use of window treatments on the east windows will actually **degrade** the CPLF since these cooling loads are concentrated before the peak hours. They will also tend to reduce the CPLF during the winter peak periods as well.

3) Window treatments on the west face provide the greatest improvements to the building CPLF since alteration of the solar transmission properties of these windows provides substantial impacts on the load during the peak hours. This change is graphically depicted in Figure 3, which shows how the air-conditioning demand for the modeled house is altered by the addition of a reflective film to single-glazed windows or a double-glazed low-e window with reflective film.

CONCLUSIONS

The results indicate that the energy-related performance of windows in the Florida climate is dominated by the solar heat transmission characteristics of the window unit. Many high-performance glazings are designed for colder climates that are thermally dominated by conductive losses. Such windows often have high R-values resulting from the use of low-emittance coatings, multiple glazings, and argon fill. Generally the R-value of glass has less benefit for a hot, humid climate, with available savings being concentrated during peak load heating and cooling periods when temperature differences are important.

Reduction of the glazing shading coefficient has a large overall impact in the Florida climate. In general, reflectively coated windows will yield superior performance, particularly when combined with double glazing, because the reflective coating will not result in a performance liability during the brief heating season, as will reflectively coated single-glazed units. A tinted coating on single glazing is not very effective; clear double-glazed units readily exceed these coatings in overall energy-related performance.

Tinted windows are popular retrofit items in Florida utility programs. A typical single-glazed unit with a reflective film has a shading coefficient of 0.51 (transmits about half the solar again of an uncoated unit). Based on simulation results, such a coating would save a maximum of 3.0 kWh/ft^2 of glazing per year for east and west windows and 2.4 kWh/ft^2 for north and south windows. The analysis assumes seasonal heating and cooling COPs of 1.00 and 2.34, respectively, in Orlando. The same coating would save 7.0 W/ft^2 of glazing during the peak consumption period for west windows during summer conditions. Summertime peak load savings for the other orientations are: 1.1 W/ft^2 for north, 1.2 for south, and 1.0 for east. Overall savings are much higher for east and west windows. All things being equal, west window shading will save more than seven times the peak cooling energy consumption than treatments to other windows. The overall effect on a peak load day in Orlando of using differing west window treatments is graphically illustrated in Figure 3. The base case represents the use of standard single glazing (Base). The two cases showing reductions to peak loads are single glazing with a reflective film (SGR) and double glazed with a low-e film (DGL). Although the improvements appear modest, they reflect a significant improvement to the overall residential electricity demand load shape.

Reflective and tinted coatings on single glazing actually result in negative savings during the winter peak load period from reduced solar heat transmission. This drawback is greatest for the south orientation, representing an addition of 1.5 W/ft^2 during winter peak in Orlando. This disadvantage does not apply to any of the other high-performance window types, which all show superior performance in beneficial changes to the wintertime peak load shape.

The above analysis assumes that the base case windows are in full sun with no shading. Thus, actual realized savings are likely to be significantly less since some window shading is almost always present such as draperies, screens, trees and so forth. Use of the more realistic assumption of shading will reduce the savings somewhat -- typically by about 40%. Overall, however, the annual savings is most strongly affected by the solar transmittance characteristic of the glazing.

In terms of offsetting peak generation capacity, a reflective coating for a west window saves peak electricity more cheaply than new capacity can be added. Based on the cost data in Table 5, the cost of such a coating is about \$1.60/ft^2. Given this expense and the performance data in Table 9 for the more realistic shaded cases, the deferred generation capacity from adding a reflective coating to such a window is about \$400/kW. Based on analysis of options by the Florida Electric Power Coordinating Group the cost of new peak power generation using combustion turbine factilities is approximately \$550/kW, not including indirect costs such as transmission facilities (FEPG, 1986). The average cost of electricity in Florida is approximately \$0.085/kWh. Adding reflective film to the west windows is cost competitive from the basis of energy consumption as well. If we assume the glazing unit will last 20 years at a 5% real (no inflation) after-tax cost of capital, the levelized cost of the energy saved (1.72 kWh/ft^2) is about \$.075/kWh.

On the other hand, the savings from non-reflective, high-R-value windows are generally lower and have the greatest effect on heating loads. Installation of double-glazed low-e window units in the prototype house would result in no more than 3.3 kWh/ft^2 savings. However, a high-performance window combined with a reflective coating performs very well and gives generally better performance than an reflective coat on a single-glazed window because of the overall lower shading coefficient coupled with the savings realized during the heating season.

Application of reflective coatings to windows generally does not alter the coincidental peak load factor (CPLF) for residential dwellings when applied on north or south exposures. Such application generally lowers the CPLF when applied to east windows, although use on west windows shows a significant increase in CPLF and associated reductions in peak loads.

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TABLE 1
Simulated Cases for Window Types

Window Type	Code
Single-glazed standard	SGS
Single-glazed tinted, bronze	SGT
Double-glazed standard	DGS
Single-glazed reflective	SGR
Double-glazed reflective	DGR
Double-glazed low-e	DGLE
Double-glazed low-e film-66	DGHM-66
Double-glazed low-e film-88	DGHM-88
Double-glazed low-e, reflective	DGLER
Double-glazed low-e film reflect-4	DGHMR-44

TABLE 2
Sensitivity to Orientation and Shading

Orientation	Shading		
North	None	Interior	Int. + Exterior
South	None	Interior	Int. + Exterior
East	None	Interior	Int. + Exterior
West	None	Interior	Int. + Exterior
All	None	Interior	Int. + Exterior

TABLE 3
Window Physical Characteristics

Window Type	R-Value $h\text{-}ft^2\cdot{}^\circ F/Btu$	Shading Coeff.	% Visible Transmit	Efficacy (VT/SC)
SGS	0.89	1.00	90%	0.90
DG	2.00	0.89	82%	0.92
SGR	0.89	0.51	27%	0.53
SGT	0.89	0.85	69%	0.81
DGR	2.00	0.42	26%	0.61
DGLE	3.10	0.72	57%	0.79
DGHM-66	4.50	0.50	55%	1.10
DGHM-88	4.30	0.70	71%	1.01
DGLER	3.10	0.38	44%	1.16
DGHMR-44	4.80	0.25	22%	0.08

TABLE 4
Shading Coefficients of Various Cases

Case	No Shade	Interior[1]	Interior+Exterior[2]
SGS	1.00	0.79	0.63
DG	0.89	0.71	0.57
SGT	0.85	0.68	0.54
SGR	0.51	0.44	0.35
DGR	0.42	0.36	0.29
DGLE	0.72	0.57	0.46
DGHM-66	0.50	0.39	0.31
DGHM-88	0.70	0.56	0.45
DGLER	0.38	0.35	0.28
DGHMR-44	0.25	0.23	0.18

[1] Interior shading = 50% coverage of glazing surface on interior by semi-open-weave, light-colored draperies from Table 39 of ASHRAE, (1985), chapter 27. Shading coefficient (<u>SC</u>) = [<u>SCw</u>/drapery+ <u>SCglass</u>]/2).

[2] Exterior shading is assumed to have stand-alone shading coefficient of 0.80 so that the combined interior and exterior coefficient is Interior * 0.80. This could model the effect of screens, window inset shading, or the presence of some exterior shading from trees or other buildings.

TABLE 5
Cost of Glazing Treatments Relative to Single Glazing

Window Type	$/ ft^2
Single-glazed standard	$ 0.00
Double-glazed standard	$ 2.50
Single-glazed tinted	$ 1.20
Single-glazed reflective	$ 1.60
Double-glazed reflective	$ 5.00
Double-glazed low-e	$13.00
Double-glazed low-e Poly film-66 or 88	$15.40
Double-glazed low-e, reflective	$14.00

Source: Wemhoff (1987); Cummings (1988a). Includes 70% contractor discount and 20% builder overhead and profit.

TABLE 6
North Orientation: Orlando, FL
W/ft^2 of glazing*

	UNSHADED			SHADED		
Window Type	Cooling/Heating Peak Load Reduction		Ann. Savings	Cooling/Heating Peak Load Reduction		Ann. Savings
SGS	0.00	0.00	0.00	0.00	0.00	0.00
DG	0.34	2.02	1.73	0.26	2.06	1.48
SGT	0.26	-0.12	0.73	0.09	-0.04	0.24
SGR	0.84	-0.40	2.39	0.48	-0.23	1.37
DGR	1.15	1.63	4.02	0.74	1.83	2.85
DGLE	0.68	2.48	2.90	0.49	2.57	2.36
DGHM-66	1.08	2.64	4.16	0.77	2.79	3.28
DGHM-88	0.74	2.77	3.17	0.53	2.87	2.58
DGLER	1.26	2.20	4.56	0.80	2.42	3.24
DGHMR-44	1.51	2.48	5.41	1.00	2.73	3.94

TABLE 7
South Orientation: Orlando, FL
W/ft^2 of glazing*

	UNSHADED			SHADED		
Window Type	Cooling/Heating Peak Load Reduction		Ann. Savings	Cooling/Heating Peak Load Reduction		Ann. Savings
SGS	0.00	0.00	0.00	0.00	0.00	0.00
DG	0.35	1.78	1.50	0.26	1.93	1.36
SGT	0.27	-0.45	0.42	0.09	-0.15	0.14
SGR	0.88	-1.48	1.38	0.50	-0.85	1.38
DGR	1.19	0.36	2.82	0.76	1.08	2.15
DGLE	0.70	1.86	2.32	0.50	2.20	2.01
DGHM-66	1.12	1.54	3.13	0.80	2.08	3.13
DGHM-88	0.76	2.11	2.54	0.54	2.47	2.54
DGLER	1.31	0.84	3.72	0.82	1.65	2.51
DGHMR-44	1.57	0.83	3.86	1.03	1.74	3.01

* Annual savings given in kWh per ft^2 of glazing.

TABLE 8
East Orientation: Orlando, FL
W/ft^2 of glazing*

Window Type	UNSHADED Cooling/Heating Peak Load Reduction		UNSHADED Ann. Savings	SHADED Cooling/Heating Peak Load Reduction		SHADED Ann. Savings
SGS	0.00	0.00	0.00	0.00	0.00	0.00
DG	0.31	1.66	1.82	0.24	1.86	1.53
SGT	0.21	-0.62	0.85	0.07	-0.21	0.28
SGR	0.68	-2.01	2.79	0.39	-1.15	1.59
DGR	0.96	0.27	4.49	0.63	0.71	3.13
DGLE	0.59	1.56	3.12	0.44	2.01	2.50
DGHM-66	0.92	1.00	4.57	0.67	1.74	3.54
DGHM-88	0.64	1.78	3.41	0.47	2.27	2.73
DGLER	1.06	0.17	5.06	0.68	1.72	3.52
DGHMR-44	1.27	0.02	6.62	0.85	1.25	4.31

TABLE 9
West Orientation: Orlando, FL
W/ft^2 of glazing*

Window Type	UNSHADED Cooling/Heating Peak Load Reduction		UNSHADED Ann. Savings	SHADED Cooling/Heating Peak Load Reduction		SHADED Ann. Savings
SGS	0.00	0.00	0.00	0.00	0.00	0.00
DG	1.72	1.98	1.87	1.01	2.04	1.56
SGT	2.14	-0.18	0.92	0.17	-0.06	0.31
SGR	6.98	-0.57	3.01	3.99	-0.33	1.72
DGR	8.42	1.43	4.76	5.00	1.71	3.28
DGLE	4.19	2.38	3.25	2.62	2.51	2.57
DGHM-66	7.35	2.46	4.80	4.78	2.67	3.69
DGHM-88	4.50	2.66	3.55	2.79	2.80	2.81
DGLER	9.03	1.98	5.34	5.19	2.30	3.68
DGHMR-44	10.92	2.22	6.36	6.64	2.57	4.51

* Annual savings given in kWh per ft^2 of glazing.

TABLE 10
Coincidental Peak Load Factors: Orlando

Case	All	North	South	East	West
SGS	0.47	0.47	0.47	0.47	0.47
DG	0.47	0.47	0.47	0.46	0.49
SGT	0.47	0.47	0.47	0.46	0.49
SGR	0.48	0.47	0.47	0.45	0.51
DGR	0.48	0.47	0.47	0.45	0.51
DGLE	0.48	0.47	0.47	0.45	0.50
DGHM-66	0.48	0.47	0.47	0.45	0.51
DGHM-88	0.48	0.47	0.47	0.45	0.50
DGLER	0.49	0.47	0.47	0.45	0.51
DGHMR-44	0.49	0.47	0.47	0.45	0.52

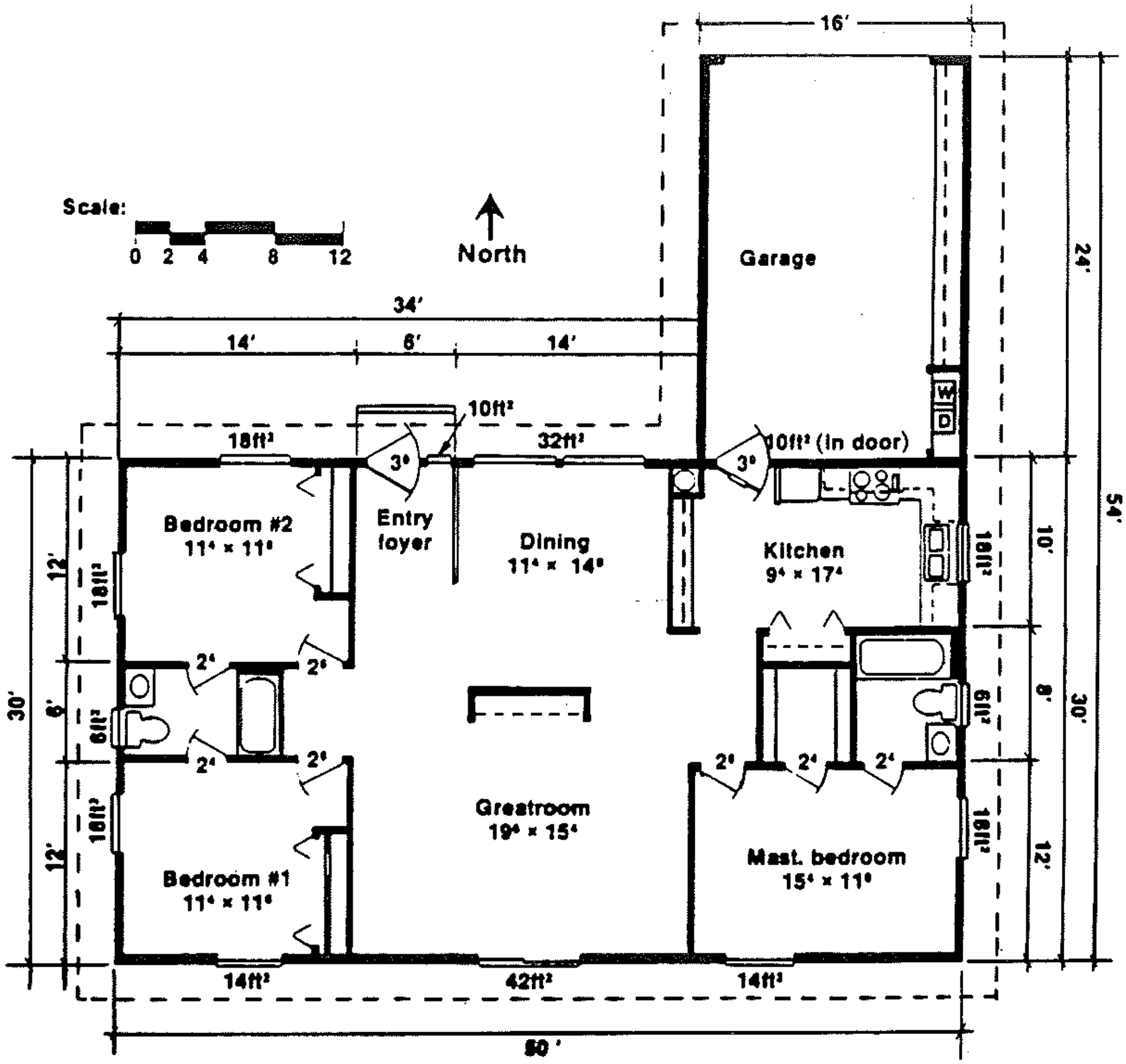

Figure 1. Floor plan for prototype Florida house used for computer simulations (concrete block construction, slab on grade foundation with 1,500 square feet of living area plus two-car garage).

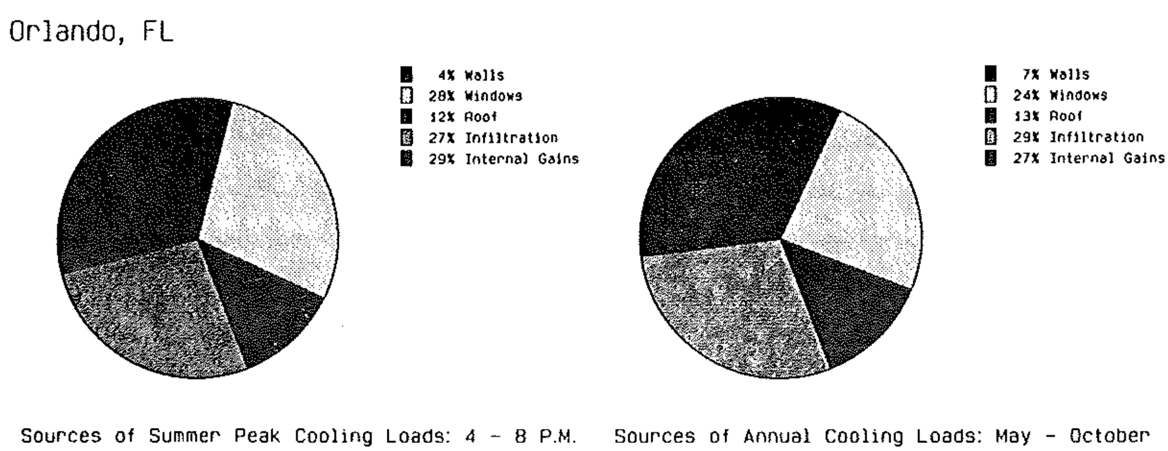

Figure 2. Annual and peak load sources for cooling load for the simulated Florida house

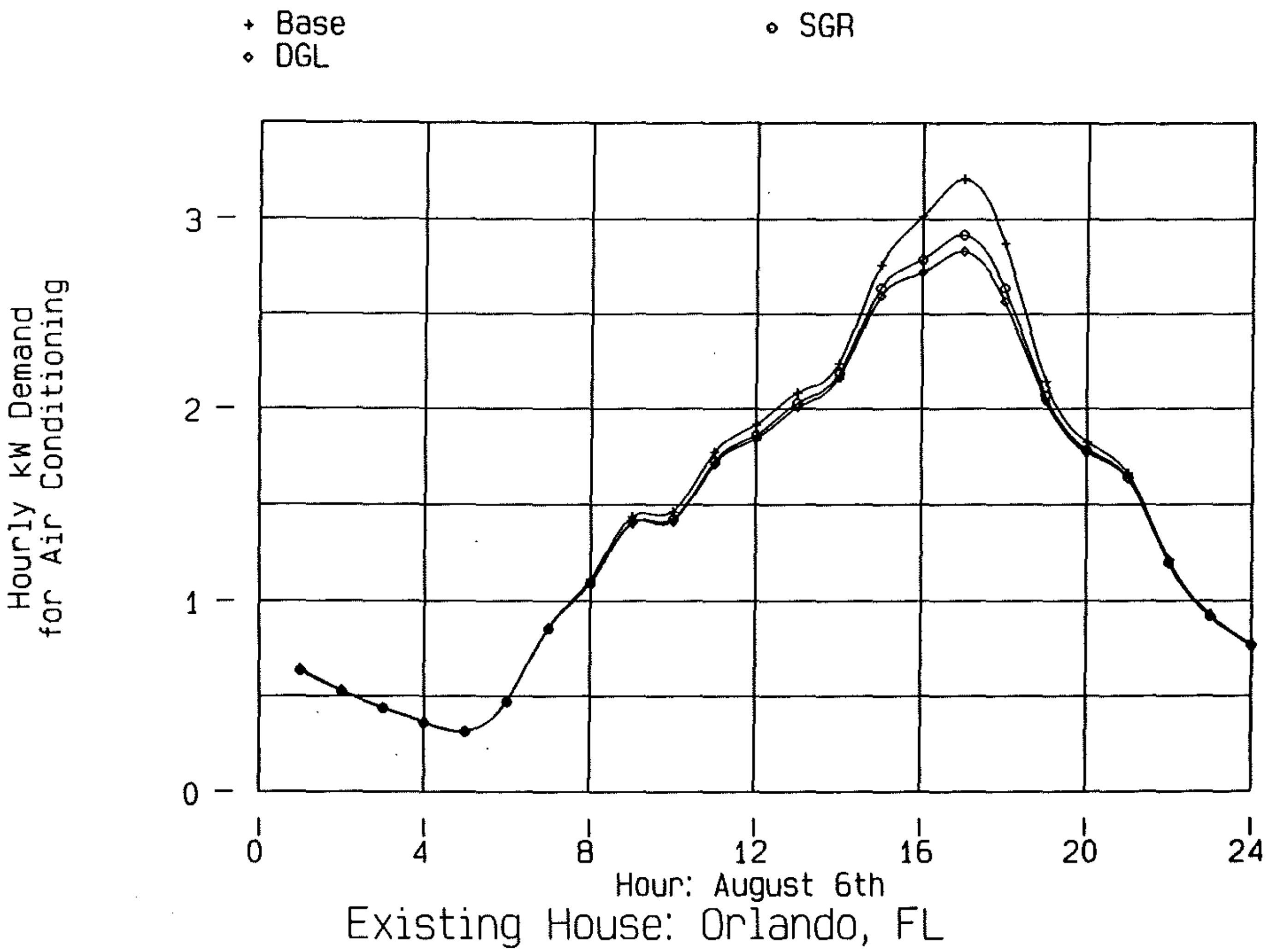

Figure 3. *Effect of west window improvements on peak air conditioning electricity demand for simulated Florida house*