The Potential of Electric Load Reductions Obtained in Hot Humid Climates from Office Buildings Using Efficient Electric Lighting, High Performance Glazings, and Daylighting

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A typical office building has been thermally modelled and numerous simulations with DOE2.1D were performed to quantify the energy efficiency performance of individual and combined strategies: efficient electric lighting, high performance glazings and controlled daylighting in perimeter spaces. Glazing area was left as a parametric input. Simulation runs were made for two extreme climatic areas in Florida, represented by Jacksonville and Miami. Results were analyzed according to four different criteria: electric lighting savings due to daylighting, total electricity consumption, peak electric demand and HVAC sizing. In the vast majority of cases, it was found that double glazings with low-E and spectrally reflective coatings performed significantly better than single glazings. Glazing characteristics have a considerable impact with respect to all criteria. Daylighting and high electric lighting efficiency both have beneficial effects on electricity consumption. Preliminary estimates of the first cost savings potential due to the HVAC system downsizing when high performance glazings are used are particularly encouraging, showing that energy efficiency strategies may be much more cost-effective than anticipated. Important electric peak demand reductions were also obtained, particularly from the use of high performance glazings, so that many utilities could be interested in supporting this strategy through incentives and demand side management (DSM) programs.

Introduction

In Florida, electricity demand is expected to increase by 54% between 1985 and 2005, while the summer and winter peaks are expected to rise by about 48% (Governor's Energy Office 1988). In order to meet this demand during the next twenty years, the Florida Public Service Commission foresees that new generation plants will be necessary soon. By 1995, the existing plants using fossil fuels (coal, oil and gas) will account for about 69% of the total needed generating capacity in Florida (Florida Public Service Commission 1988). As a shift towards coal-fired generation plants is likely, the aggravated release of pollutants and carbon dioxide (adding to the global warming threat) will become major issues. Therefore, electricity generation in Florida will more and more constitute a source of social and environmental problems. For this reason, it appears desirable to increase the energy efficiency of commercial buildings, in order to decrease their peak loads and the need for new generation plants.

In a hot/humid climate such as Florida, the heating load of commercial buildings is low or negligible compared to the cooling load. However, the peak heating demand during the warm-up period of cold winter days may be comparable to--and even significantly higher than--cooling peaks. Abundant daylight is available throughout the year, but is generally ignored as a valuable resource by architects and engineers. As this resource is combined with a liability of potentially excessive solar heat gains, inefficient building designs with large cooling loads and expensive electricity peaks are still encountered in most cases.

For this preliminary report, three different design improvements (efficient electric lighting, high performance glazings and controlled daylighting) were modeled and simulated in order to assess their impact in decreasing the electricity consumption and peak electric demands of a typical office building.

The glazing area was varied parametrically so that insights on possible area optimization could be gained. The way these different options interrelate will be described, as well as their possible contribution to decreasing the mechanical system first cost. The appearance of new regulatory policies incorporating Demand Side Management (DSM) programs suggests that the energy, demand and HVAC equipment sizing impacts of better building design be explored. Such an analysis could help the development of some specific DSM program oriented to the commercial sector.

We show here that utilizing daylight to turn off or dim electric lights and employing high performance glazing systems lead to significant first cost (chiller size) savings as well as energy cost savings for the model office building studied. The result of this can be short or zero payback times, depending upon the extra costs of the glazing, light dimming and glare control systems. Energy and economic results are strongly dependent, however, on a number of building and equipment design choices and operating and occupancy schedules. Further work is needed to better delineate the sensitivities of our results to a variety of important parameters.

Methodology

Computer Simulation

The building energy simulations were performed with DOE-2, a computer program that has daylighting simulation capabilities and makes detailed hour-by-hour calculations using the weighting-factor methodology (Simulation Research Group 1989). Version 2.1D, the latest available at this writing, was used throughout this work. Important improvements have been incorporated since the older versions B and C, that for example were used in the 80's by scientists at Lawrence Berkeley Laboratory (LBL) to predict the energy benefits of daylighting in office buildings (Choi et al. 1984; Johnson et al. 1984; Selkowitz et al. 1984; Johnson et al. 1985; Sweitzer et al. 1987). A recent study (Schliesing and Crowley 1990) suggests that results of DOE2.1B and D may differ substantially for certain types of buildings, though differences on the annual energy results should remain small for office buildings.

Building Configuration

The typical building selected here has a square shape with perimeter spaces where daylighting is a possible design strategy. The consequences of altering the building shape are investigated in a companion paper (Gueymard and McCluney 1992). The floor plan appears in Figure 1, showing the 16,000 ft^2 square core and the four perimeter spaces of 1500 ft^2 each facing the cardinal directions, for a total floor area of 16,000 ft^2 (1486.5 m^2). The simulation has been limited to a mid-floor in a high-rise building so as to neglect the heat transfer effects through the roof and underground surfaces. The floor plan is mostly identical to what was used at LBL for preliminary related work (see, for example, Johnson et al. 1985). An

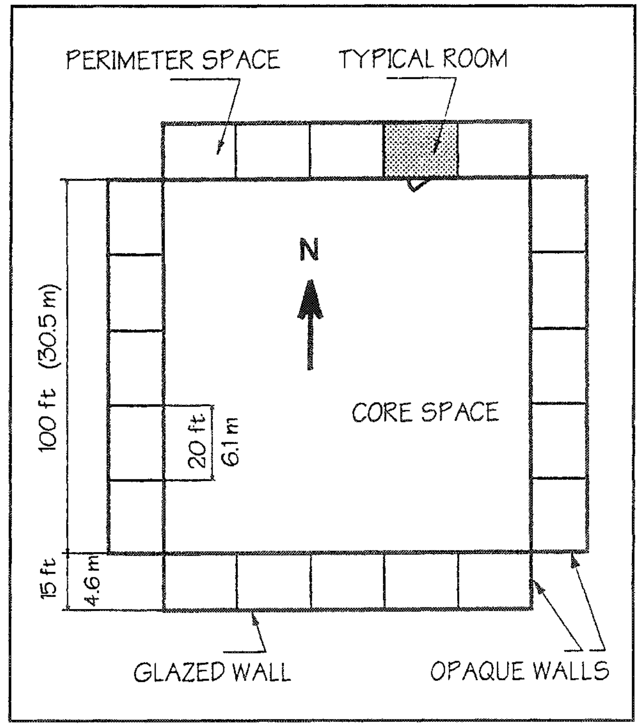

Figure 1. Plan of a Typical Floor of the Model Office Building

important difference is that the perimeter spaces are divided into 5 individual rooms (instead of 10), each one being separated from the core by an internal wall (U = 0.5 BTU/H ft^2°F or 2.84 W/M^2) and a door that is assumed tb remain open 50% of the time. The main other characteristics of the building are as follows:

- Room height: 9 ft (2.7 m)
- Plenum height: 3 ft (0.9 m)
- External opaque wall U-value: 0.185 BTU/H ft^2°F (1.05 W/m2 K)
- Floor U-value (with carpet): 0.188 BTU/H ft^2°F (1.07 W/M^2 K)
- Design minimum ventilation air per person: 20 cf:in (9.4 L/s)
- Number of occupants: 160 max.
- Power density for general office equipment: 0.5 W/ft^2 (5.4 W/M^2)
- Humidity set-points: 55 and 65%

- Heating and cooling setpoint temperatures (during occupied hours): 72 and 78°F (22.2 and 25.6°C) resp.
- HVAC system: one Variable Air Volume system for the whole floor, with electric resistance terminal reheat, open-centrifugal chiller and cooling tower.

By comparison with the earlier work from LBL, many differences had to be incorporated in the design of the building, its thermal characteristics and the mechanical system operation. This was motivated by the desire to simulate a typical Florida office building as closely as possible in order not only to obtain relative results, but also valid absolute performance indicators. This preoccupation with a more realistic building model resulted from a desire to comply with the Florida Energy Efficiency Code for Building Construction (State of Florida 1991), to which any new construction project must adhere prior to receiving a building permit. In the case of office buildings, two important constraints of this Code are relevant to the present analysis: a "maximum energy budget" that varies with climate, from 34 kBTU/ft^2 (107.3 kWh/m^2) in northern areas like Jacksonville to 37 kBTU/ft^2 (116.7 kWh/m^2) in the southern areas, like Miami; also the maximum lighting power budget is limited to 2 W/ft^2 (21.5 W/M^2) in any climatic area. DOE-2 runs were made for the model building defined above and located in Jacksonville and Miami, for which TMY weather data were available.

Glazing Characteristics

With the development of new coating technologies, the glazing industry now offers a large range of reflective, spectrally selective and low-E products that should help the building designer to meet different--and sometimes conflicting--needs: energy performance, occupant comfort, aesthetics, cost etc.

However, few studies have been made to help designers choose the right glazing type for a given type of building in a given climate. The tendency has been to promote and select low-E glazings in cold climates and low solar transmittance glazings in hot climates. (We believe this to be a gross over simplification of the optimum selection process.) It now becomes important to bring some hard scientific evidence into this difficult area, which is one of the goals of the present work.

Several different glazings were first selected from the manufacturers literature. After some preliminary simulations, eight glazings were retained for the final detailed parametric runs, the results of which are presented here. For easy reference, each glazing has been given a code name, which comprises a number and a few letters. Number 1 corresponds to a single pane (or "monolithic") glazing, while number 2 corresponds to a double-pane (or sealed "insulating") unit. The detailed descriptions of these glazings, as well as their thermal and optical characteristics, are given in Table 1.

The visible transmittances, T_v, range from 0.12 (for glazings coded 1PRL and 2PRL) to 0.89 (for 1PC), while the shading coefficient, SC, ranges from 0.20 (2PRL and 2PERG) to 0.96 (lPC). The visible transmittance is a measure of the beneficial visual effect of a window (its primary *raison d'etre),* while the shading coefficient is a measure of its ability to reject solar heat gains, that are undesirable most of the time in cooling dominated commercial buildings, especially in hot climates. It is interesting to characterize the conflicting characteristics of commercial glazings by the ratio T_v/SC. This parameter will be referred to here as CI', the *Modified Coolness Index.* (The coolness index CI, or luminous efficacy transmittance, is defined as the ratio T_v/F, where F is the solar heat gain coefficient. Glazing manufacturers have not yet begun publishing F values, so we here use the modified coolness index instead.) The maximum theoretical value of CI' for an ideally transmitting glazing (T_v = 1, no absorptance) would be 2.8 (Sweitzer et al. 1987). While the standard single clear pane unit is characterized by CI' = 0.93, some high performance glazings with a green spectrally-selective coating exhibit values of CI' nearly double this value (Table 1). Needless to say, such glazings with high CI' values are good potential candidates for energy efficient daylighting applications in hot climates. However, glazings with low or relatively low T_v and CI' are still frequently specified in new Florida office buildings, so that a representative sample has been included (LPRL, 2PRL and 1PRH).

The sample of eight glazings selected here also exhibits a large range of conductance (winter U-value), from 1.13 BTU/h ft^2°F (6.42 W/m^2 K) for 1PC to 0.22 BTU/h ft^2°F (1.25 W/m^2 K) for 2PERG. The latter is 5 times more resistant to heat flow than the standard glazing. (Note that these are center-of-glass values; no edge effect has been considered here).

The four main exterior walls (100 ft long) were equipped with a continuous glazed ribbon of varying height, from 0 (no glazing) to 9 ft (fully glazed). The same type of glazing was present on each facade, and no external shade was considered.

In order to compare the building energy performance when equipped with different glazings, two non-dimensional parameters were introduced. First the

Table 1. Optical and Thermal Characteristics of the Selected Glazings (Manufacturers' Data). T_v: visible transmittance; T_s: solar transmittance; SC: shading coefficient; CI' = T_v/SC; winter U-value. Glass thickness: 1/4" (6 mm); glass color is in italic.

Code	Description	T_v	T_s	SC	CI'	U-Value (Btu/h ft² F)	U-Value (W/m² K)
1PC	1 pane *clear*	0.89	0.81	0.96	0.927	1.13	6.42
1PRL	1 pane refl. *bronze*	0.12	0.11	0.35	0.343	0.92	5.22
1PRH	1 pane refl. *blue-green*	0.33	0.28	0.44	0.750	1.09	6.19
2PE	2 panes low-E *clear*	0.50	0.30	0.44	1.136	0.30	1.70
2PRL	2 panes refl. *pewter*	0.12	0.09	0.20	0.600	0.41	2.33
2PRH	2 panes refl. *evergreen*	0.59	0.26	0.44	1.341	0.48	2.73
2PER	2 panes low-E refl. *evergreen*	0.56	0.20	0.33	1.697	0.31	1.76
2PERG	2 panes low-E refl. gas-filled *rose*	0.29	0.13	0.20	1.450	0.22	1.25

Glazing to Floor area Ratio (GFR) is used when the glazing area is fixed because of design considerations (for a new building) or by the building itself (in case of a retrofit). For the square building shape under investigation, the maximum possible GFR is 0.225.

The second parameter is the *Effective Aperture* (EA), as introduced in the LBL work on daylighting referenced above. This parameter is defined as the product of T_v and of the *Window to Wall area Ratio* (WWR). The rationale behind the use of the effective aperture is that different glazed wall areas and types of glazing, but with the same EA, will provide the same amount of visible light in first approximation. If the natural light level in the perimeter rooms is a key factor, the glazing selection process should be based on this parameter.

Electric Liqhting and Daylighting

A design illumination level of 60 fc (646 lux) at a standard 30" (0.76 m) work plane has been chosen for the core as well as the perimeter rooms. In the base case, this illumination level is provided by a rather standard lighting system, with a power density of 2 W/ft² (21.5 W/m²), corresponding to the maximum allowance from the Florida Energy Code. More efficient lighting systems are already available and their energy conservation potential is certainly high. The current U.S. practice calls for anaverage lighting power density of 2.2 W/ft² (23.7 W/m²) in offices (Goldstein and Watson 1988). These authors recommended a targeted optimum budget of 0.6 W/ft² (6.5 W/m²). Warren et al. (1986) describe a 5-story daylit office that has been built near San Francisco with an installed lighting power density of 0.92 W/ft² (10 W/m²). An energy-efficient lighting system with a power density of 0.88 W/ft⁴ (9.5 W/m²) was finally retained by us as an example of an advanced design that can be available and cost-effective now or in the near future. This represents a 56% installed power reduction from the base case. If daylighting were perfectly effective at avoiding electric lighting during its normal operating period, the electricity saved would be in the proportion of the *Daylit Ratio,* i.e. the ratio of the daylit area (6000 ft²) to the total floor area, in our case 37.5%.

In the daylighting case, the four perimeter zones are equipped with a continuous fluorescent dimming system with a threshold of zero light output at 10% of maximum power input The light sensors needed to control the dimmer were installed in each room 10 ft (3 m) from the window. Light draperies (visible transmittance: 0.35, shading coefficient: 0.4) were assumed to close automatically when either the glare index exceeded a limit of 20, or when the solar heat gain exceeded 20 BTU/h ft² (63 W/m²).

Results

Electric Lighting Savings Due to Daylighting

Figure 2 presents the results of the parametric runs made for different Effective Apertures and all the selected glazings in Miami. Daylighting appears effective at reducing the total annual electric lighting load of the modeled whole floor, but saturates at about 25% reduction at an EA=0.5. Because these results are presented against EA, all types of glazing perform identically at first approximation (where the differences in the variation of transmittance with the incidence angle are neglected). The saturation turning point (23% reduction) is reached at an EA of about 0.28.

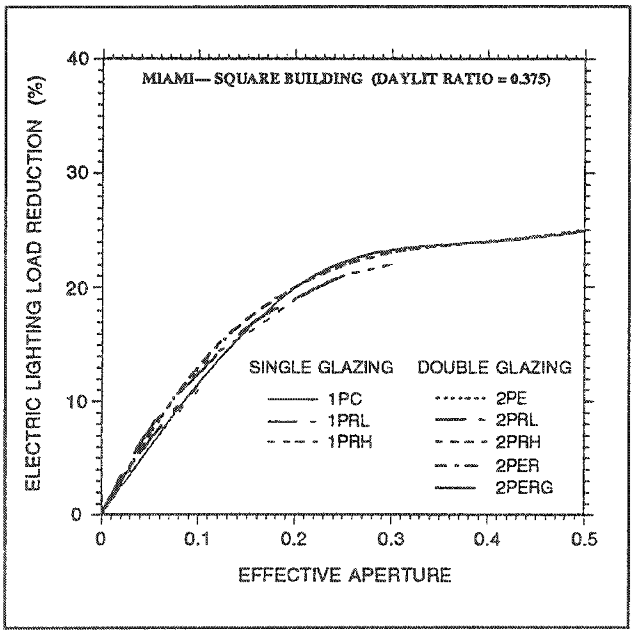

Figure 2. Percent Electric Lighting Energy Reduction in Miami for Different Glazings, as a Function of the Effective Aperture

If the same load reduction results are now plotted against GFR (Figure 3), a dramatic discrimination appears between glazings, the relative performance of which being directly driven by their visible transmittance. As could be expected, low transmittance glazings (IPRL and 2PRL) are not very effective for a given glazing area because the design illuminance level is generally higher than the illumination they successfully transmit, so that some electric light back-up is needed with these glazings.

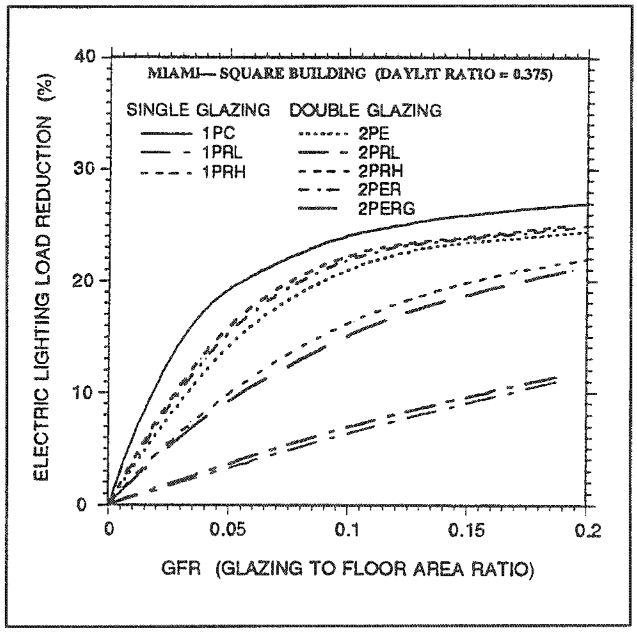

Figure 3. Percent Electric Lighting Energy Reduction in Miami for Different Glazings, as a Function of the Glazing to Floor Area Ratio

Building Energy Performance Index

The *Building Energy Performance Index* (BEPI) is defined here as the annual total energy consumption due to electric lighting, electric equipment, heating, cooling and air handling of the building, per unit floor area. This is equivalent to a "specific consumption" or to the "energy budget" defined in the Florida Energy Code.

When the daylighting option is not used, BEPI increases monotonically with glazing area, but more or less rapidly depending on glazing type. As an example, Figures 4 and 5 display the results for Jacksonville and Miami, respectively, with the maximum electric lighting power density ($2W/ft^2$). Similar results are obtained with the lower power density ($0.88\ W/ft^2$), except for a downshift of 20-35% of BEPI for the range of the different glazing types and areas.

With this conventional non-daylit design, the ideal building would be windowless from the energy efficiency point of view, which of course does not correspond to a good design for many other reasons. Double glazings perform significantly better than single glazings, particularly in Jacksonville. The best glazing for a non daylit building is generally 2PERG for both cities. It successfully limits the BEPI increase over the windowless base case to a small fraction (6% in Jacksonville and 4% in Miami) for a GFR of 0.2, compared to a large increase

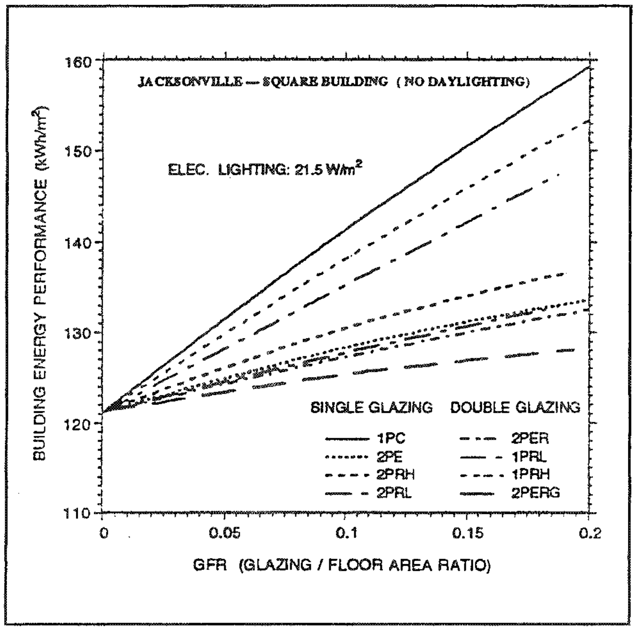

Figure 4. Building Energy Performance Index as a Function of GFR in Jacksonville

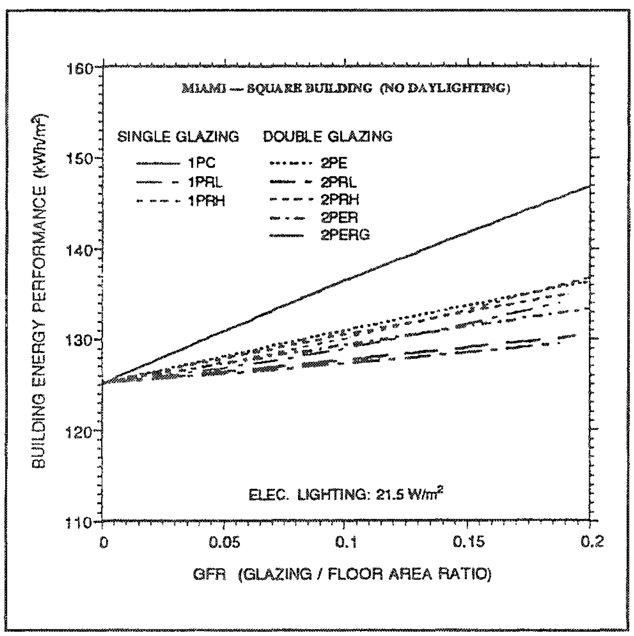

Figure 5. Building Energy Performance Index as a Function of GFR in Miami

(31% in Jacksonville and 18% in Miami) for 1 PC, the worst performer. However 2PRL performs marginally better--or almost as well in the case of the reduced power density--than 2PERG in Miami.

When daylighting is added to the perimeter areas, it results in significant energy savings, generally with a rather flat optimal glazing size giving a BEPI better than the base case's one. Figure 6 presents the results for Jacksonville as a function of EA at the lowest power density (0.88 W/ft²). With the best performing glazings (2PER and 2PERG), the optimal EA is about 0.25. The same tendency is observed for the higher power density and for Miami, except that in this latter climate, the optimal EA is around 0.32, with no significant variation in BEPI when EA increases (at least up to EA=0.5).

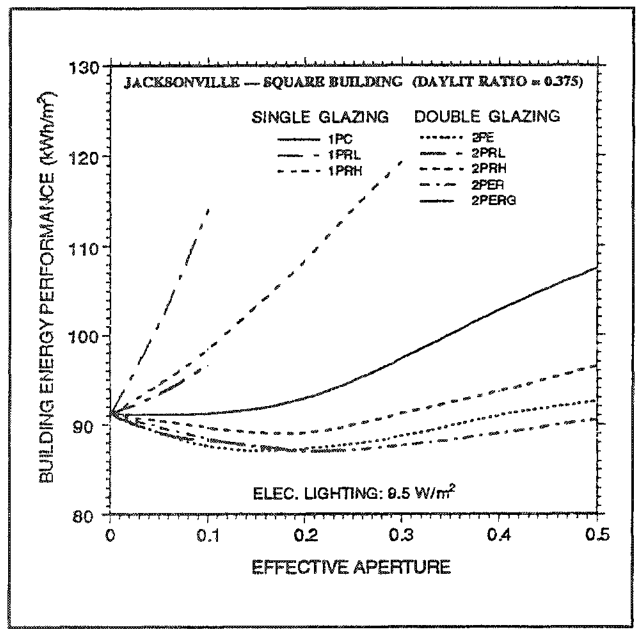

Figure 6. Building Energy Performance Index as a Function of the Effective Aperture in a Daylit Building with Efficient Electric Lighting (9.5 W/m²) in Jacksonville

Figure 7 is the equivalent of Figure 6, but showing BEPI as a function of GFR. Three best performers appear now: 2PE for GFR<0.075, 2PER for 0.075<GFR<0.12 and 2PERG for GFR>0.12. At their optimal areas, these three glazings succeed in lowering BEPI by 9.5% compared to the windowless baseline. It appears also that all the single glazing and the low transmittance double glazing (2PRL) do not offer any energy advantage over the base case (i.e., they are all above the horizontal line through BEPI=91.2 W/m², corresponding to the windowless base case). In Miami, this behavior is somewhat different (Figure 8). 1PC becomes the best performer up to GFR=0.05, and all glazings offer an energy dividend over the base case for GFR<0.2.

The use of a 56% more efficient lighting system (with a power density of 0.88 W/ft²) has a very beneficial effect on BEPI, reducing it by 20-35%, depending on location,

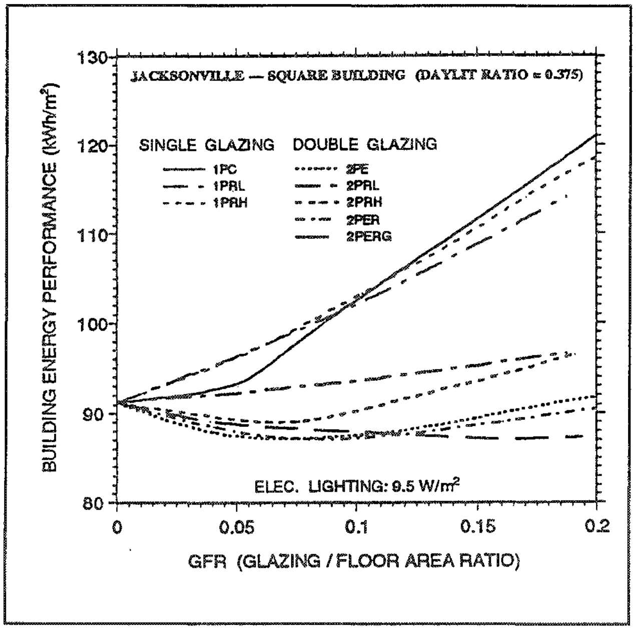

Figure 7. Building Energy Performance Index as a Function of GFR

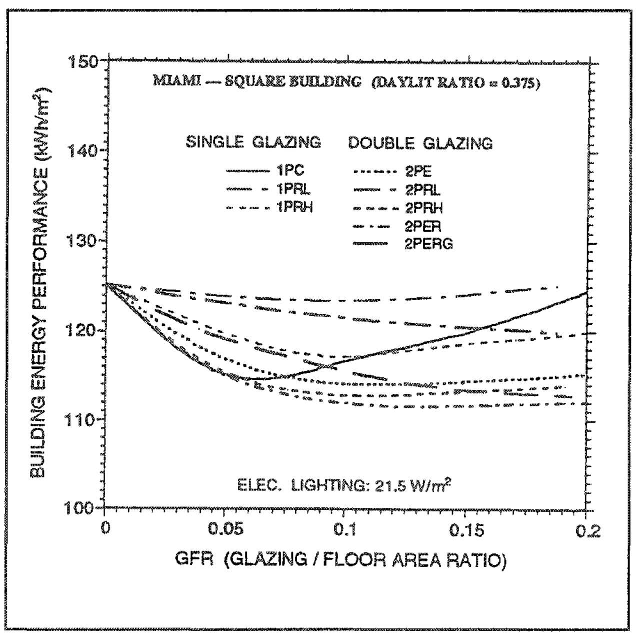

Figure 8. Building Energy Performance Index as a Function of GFR for Miami and a Lighting Power Density of 2 W/ft² (21.5 W/m²)

glazing type and glazing area. Although the general trends observed with daylighting are conserved (i.e., a distinct curvature in the variation of BEPI against EA or GFR for most glazings and a clear discrimination resulting from their characteristics), the reduction of BEPI at the optimal GFR (compared to the windowless base case) is not so pronounced as with the high power density. This is certainly a consequence of the law of diminishing returns.

Peak Electric Demand

The peak electric demand is of major concern to utilities and is also related to the demand charge that represents an important fraction of the electricity bill. The monthly peak electric demands are calculated by DOE-2 and will be expressed here in Watts per unit floor area in order to facilitate the comparisons with other building types or climates.

For both cities, the maximum electricity demand occurs in January (as could be expected from an all-electric HVAC system), so that adding an optimal area of high performance glazing can generally reduce this demand below the windowless base case by a substantial amount, particularly in Jacksonville (Figure 9) because solar gains become effective. This beneficial effect does not occur with a non-daylit building in Miami where occurrences of cold morning temperatures are rare. In a non-daylit building, the electric lighting and heat storage effects may be sufficient to prevent a costly morning warm-up due to heat loss in the perimeter zone. In any case, the potential for decreasing the peak load just by specifying the right glazing type is considerable. However, this potential is

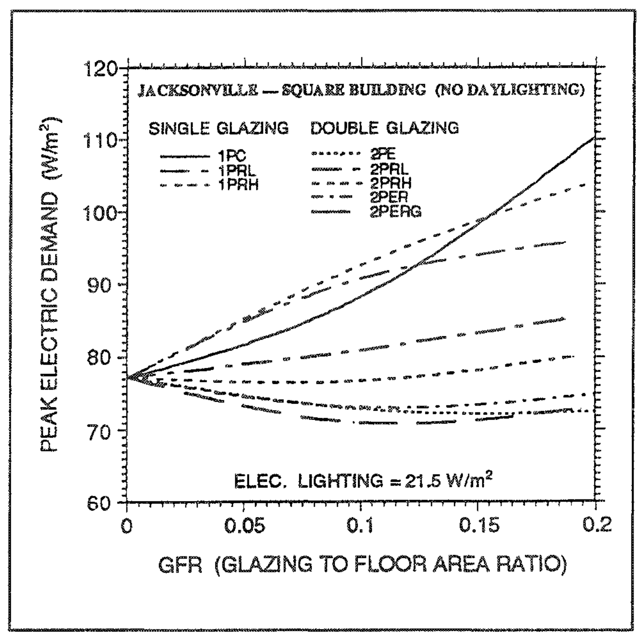

Figure 9. January Peak Electric Demand in Jacksonville vs GFR

also highly dependent on climate. Even within the relatively homogeneous Floridian climate, significant differences occur between the results corresponding to Jacksonville and Miami (most of them not shown because of space limitations). More work will be necessary to generalize this type of analysis to other climatic areas and to predict the best glazing characteristic/area combinations from a reasonable number of climatic parameters.

Figure 10 displays the percent reduction of peak electricity demand (that always occurs in winter because of the assumed electric heating system) for each type of glazing and for two values of GFR, relative to a common base case, defined here as 1PC without daylighting. The results for the daylit building are also obtained with reference to this base case, so that the effect of daylighting alone can be isolated. Unexpectedly, daylighting sometimes induces detrimental effects, particularly in Jacksonville. Different heat storage and release processes associated with the two design approaches could possibly explain this counter-productivity of daylighting for a given glazing type and area.

Clearly, the glazing optical and thermal characteristics can help reduce the peak demand by a significant amount (up to 20% in Jacksonville and 29% in Miami for GFR=0.1; 36 and 42% resp. for GFR=0.2). Single glazings give the lowest reductions and sometimes are even counter-productive (in Jacksonville). The consistently best performers are 2PE, 2PER and 2PERG, showing that the low-E coating has an important role in Florida's climate. This finding seems to invalidate the general belief in the building profession that single reflective glazings are more beneficial than low-E insulating units in the southern United States. It is also noticeable that the lighting power density has no clear effect on the peak demand. This may be attributed to the fact that the maximum demand occurs in January so that the more electric lighting is present, the lesser the load on the HVAC system during warm-up periods (especially in Jacksonville). In some cases moreover, the morning peak may occur before the lighting system is turned on and has a chance to make a difference.

The seasonal variation of the peak demand is displayed in Figure 11 for 1PC (without daylighting) and 2PER (with and without daylighting) in Miami, with GFR=0.2. It is apparent that the better thermal characteristics of 2PER are extremely beneficial to the winter peak (as already described), but that it also decreases the summer peak by a non negligible amount (5-6% at the higher power density and 10% at the lower). Adding daylighting decreases a little further the peak loads, particularly during summer time. A noticeable effect of the lower power density is to increase the U-shape of the seasonal peak demand variation: the winter peaks are not modified much for the reason explained above, while summer peaks decrease significantly (up to 25-30% between March and November) because the cooling load created by the lighting system is less. The use of a high performance glazing such as 2PER almost completely flattens the seasonal peak demand variations.

HVAC Sizing

Former daylighting studies performed at LBL (Choi et al. 1984; Johnson et al. 1985) suggested that lowering the power density and adding daylighting could help significantly in reducing the chiller size and the associated first cost. The findings of this study tend to confirm this conclusion and give more substance to it.

Figure 12 shows the savings potential *per unit glazing area* for a building with daylighting, compared to a common base case defined here as 1PC without daylighting. It is clear that important downsizings are attainable, especially for low to moderate glazed areas (GFR=0.1). In this case, the downsizing potential reaches 55-60 BTU/h ft^2 (174-189 W/m^2) with 2PER and 2PERG. For a highly glazed building (GFR=0.2), the downsizing potential is still around 35-40 BTU/h ft^2 (110-126 W/m^2).

If it is assumed that these savings of chiller size result in identical savings on the whole HVAC system (i.e., including the cooling tower, pumps and various equipment), it is possible to perform some simple economic calculations. It is difficult to obtain accurate cost saving data of general validity for reduced cooling equipment capacity. The LBL studies used an estimate of \$2000 per ton (1 ton is 12,000 BTU/h or 3.5 kW) of incremental HVAC system downsizing. This appears now to be somewhat exaggerated. If more recent cost data (Carroll et al. 1989; EPRI 1989) are used, the estimated first cost of a ton drops to about \$500-\$1000 depending on chiller size. For an average cost of \$800 a ton, the savings potential would be 3.7-4.0 \$/ft^2 for GFR=0.1 and 2.3-2.7 \$/ft^2 for GFR--0.2. Specifying a highly efficient lighting system would decrease the chiller downsizing potential offered by daylighting at GFR=0.1 in Miami, but not in the other cases (Figure 12).

The magnitude of these savings makes the chiller downsizing a critical issue in selecting the energy efficiency strategy in commercial buildings. More work is needed to better assess the magnitudes of dollar savings attributed to energy, demand and equipment first cost savings.

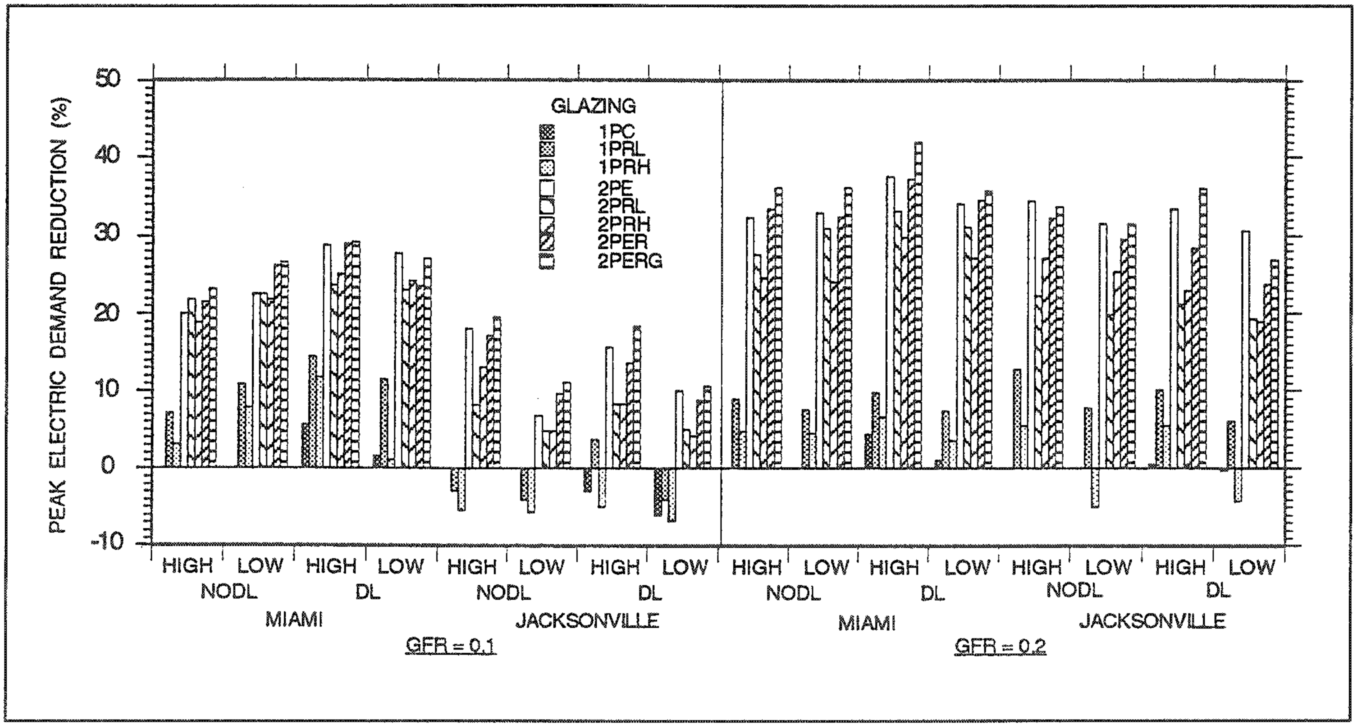

Figure 10. January Peak Electric Demand Reduction (Relative to Base Case, See Text) for Different Glazings. NODL: No Daylighting, DL: Daylit; HIGH: High Lighting Load (21.5 W/m²); LOW: Low Lighting Load (9.5 W/m²)

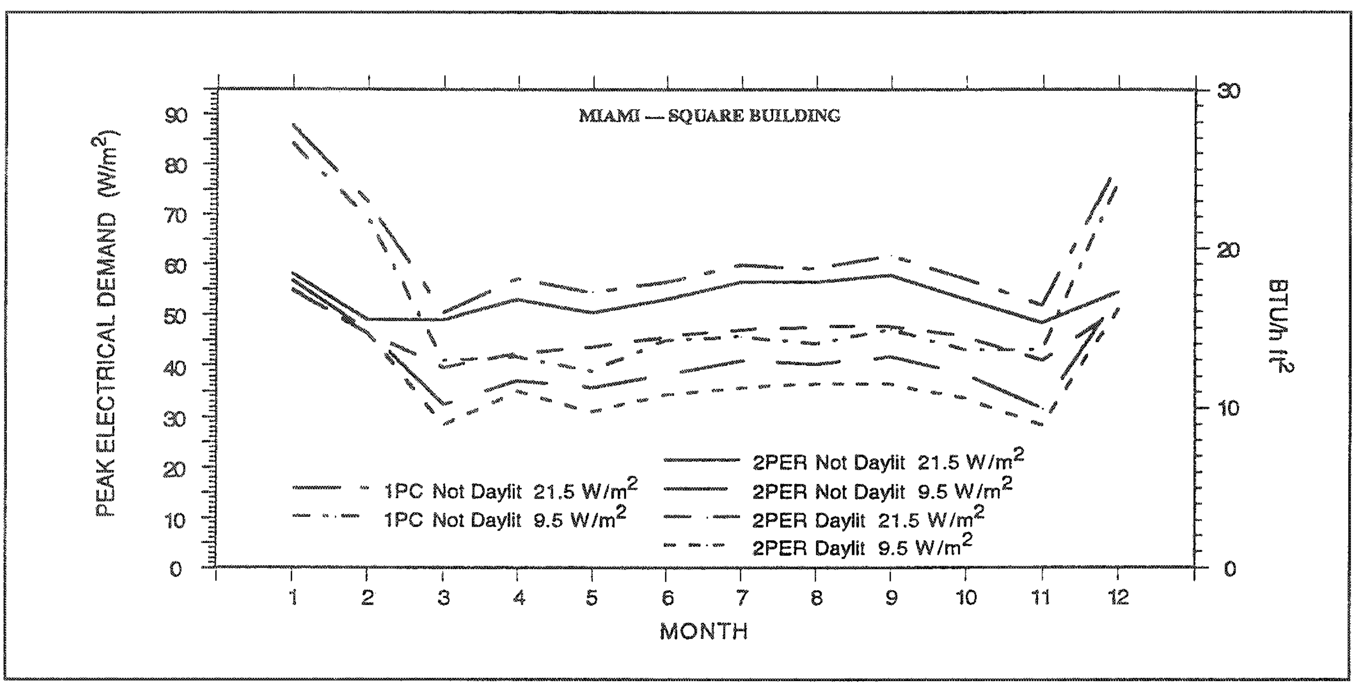

Figure 11. Monthly Peak Electrical Demand for Daylit and Non Daylit Buildings in Miami

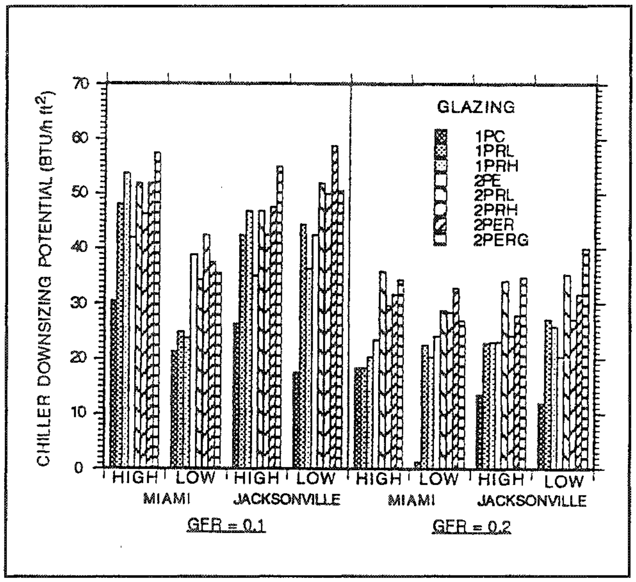

Figure 12. Chiller Downsizing Potential Relative to Base Case (See Text) for a Daylit Building. HIGH: High Lighting Load (21.5 W/m²); LOW: Low Lighting Load (9.5 W/m²)

Conclusion

Daylighting and improved glazing characteristics do lead to both first cost and operational cost savings for the commercial buildings studied. With still better glazings, these savings might be very cost effective.

In order to synthesize some of the results of the present study, Table 2 provides a breakdown of the best performing glazings, according to different criteria: climatic location, daylighting availability, lighting power density, glazed area, BEPI, peak demand and chiller size. In most cases, double glazings with low-E and spectrally selective characteristics perform most favorably and by a very significant difference over any type of single glazing. For the climate of Florida and with present technology, the best glazing characteristics seem to be as follows: U-value below 0.35 BTU/h ft^2°F (2 W/m^2 K), shading coefficient below 0.3 and CI' above 1.5. Of course, glass manufacturers should be encouraged to develop new coatings in order to further improve this combination. It is evident from Table 2 that selecting the best glazing system is dependent upon a variety of parameters. For this study, the impact of some of them could not be addressed completely, if at all (e.g., building design and operating schedules, climate characteristics, energy type and costs).

Though the use of a highly efficient lighting system may reduce BEPI by a significant amount, its impact on the chiller size and on the winter peak electric demand appeared limited or even negligible in most cases. However, its beneficial impact on the summer peak demand is significant. From the electric utility point of view, the consideration of high performance glazings with or without daylighting would represent a good strategy, from the standpoint of their peak load curves. This potential should be studied in depth in order to recommend the incentives to include in DSM programs for commercial buildings (new construction or retrofit). Accordingly, it would be very helpful to repeat such a study for different climatic areas, building orientations, HVAC systems (including gas heating) and a larger range of glazing characteristics.

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Table 2. Best Performing Glazings for a Low-Glazed Building (0<GFR<0.1) and a Highly Glazed Building (0.1<GFR<0.2), According to Different Criteria. More than one glazing are indicated if they are close enough to each other or if there are different best performers inside one GFR range.

City	Jacksonville				Miami			
Daylighting	Yes		No		Yes		No	
Light Power (W/m²)	21.5	9.5	21.5	9.5	21.5	9.5	21.5	9.5
0 < GFR < 0.1								
BEPI	2PER	2PE 2PER	2PERG	2PERG	2PER 2PRH 1PC	2PER 2PRH	2PRL 2PERG	2PERG 2PRL 2PER
Peak Demand	2PE 2PERG	2PE 2PERG	2PERG	2PE	2PE 2PER	2PE	2PERG 2PRL	2PERG 2PER
Chiller Size	2PERG	2PE 2PER	2PRL	2PERG	2PERG 2PER	2PERG 2PRH	2PRL 1PRL	2PER
0.1 < GFR < 0.2								
BEPI	2PER 2PERG	2PERG	2PERG	2PERG	2PER	2PER 2PERG	2PRL	2PERG
Peak demand	2PE 2PERG	2PE 2PERG	2PERG	2PE	2PERG	2PERG	2PERG	2PERG
Chiller size	2PERG	2PERG	2PRL	2PERG	2PERG 2PRL	2PER	2PRL	2PER 2PERG

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