An Analysis of Climate Rejecting and Climate Adapting Design Strategies for a Midsize Office Building

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Introduction

In 1984 and 1985 the Solar Energy Research Institute (SERI) in Boulder, Colorado reviewed a wide range of midsize building energy conserving design strategies to attempt to discover which of these strategies was most successful. Their conclusion was that energy conservation strategies for midsized buildings could be grouped in two general categories. The first of these was termed climate rejecting design strategies. Buildings placed in this category essentially attempted to close themselves off from ambient climatic conditions with minimally conductive envelopes, hence minimizing energy exchanges with their environment. Appropriate luminescent and climatic conditions were then achieved within this relatively undynamic energy context with efficient lighting and HVAC equipment. In the second category, climate adapting design strategies, building envelopes and equipment attempted to make maximum use of ambient environmental energies. Lighting and HVAC equipment in these buildings was selected and controlled in a manner that facilitated maximizing the use of ambient environmental energies. Neither strategy in SERI's review could be determined to be categorically more energy conserving than the other.

Study Issue

This SERI dichotomy of energy conserving design strategies offered an interesting hypothesis to test under field conditions because it suggests a strategic rather than a tactical approach to energy conserving design efforts. Most of the strategies that have recently been developed to improve this energy efficiency of midsize buildings are essentially a way of adding energy conserving tactics to an established strategic design solution to the building problem. The energy conscious design methodology espoused by the AIA (AIA Energy Conservation Design Methodology, 1985) created an elaborate system of nomographs which describe energy issues that could be solved by selecting energy conservation tactics from a prescribed list and assembling them to become a building. Burt, Hill, Kosar, and Rittelmann (1985) proposed a greatly simplified methodology to define building energy issues but, essentially helped designers to solve these problems with a similar set of tactics. What the SERI method appears to accomplish that differs from these two methodologies is that it does not prescribe solutions but focuses on developing broad definitions of solution boundaries for building energy conservation problems that have contextual, cost, and quality implications. By suggesting that either the use of efficient machinery in climate rejecting solutions or the creation of building envelopes that exchange dynamic energies with the ambient environment in climate adapting solutions may be equally effective in conserving energy, the design issue shifts to one of where such buildings are to be constructed, at what cost, and with what qualitative goals. The design of energy conserving buildings using the SERI methodology becomes less a matter of selecting appropriate building components (though such selections would be eventually necessary under any design methodology) than it would be a decision based on the specifics of a building's context, use, and the cost/quality values of its owner or inhabitants.

The critical test of the usefulness of this hypothesis lies less in its ability to act as a tool to categorize existing energy conscious design solutions in midsize buildings than it does in determining its impact in helping to generate such solutions. The ability of both climate rejecting and climate adapting design strategies to conserve equal amounts of energy raises an interesting design issue. Currently available energy conscious design methodologies for commercial buildings tend to stress procedures that result in single optimal energy solutions rather than in a range of technological options that achieve similar levels of performance. Both the AIA and the Burt, Hill, Kosar, and Rittelmann methodologies stress a linear, analytic design procedure that results in a single optimal energy efficient building design solution. The problem with these methodologies is that they treat energy conservation as the single most important design issue in these buildings. While this contention may be true for designers with strong attitudes toward energy conservation, it does not typify the values of marketplace designers, developers, or owners in general. This marketplace audience balances a much broader range of issues when making design choices in commercial buildings. If the SERI contention that there exists a range of ways to achieve similar energy performance in midsize buildings were to prove to be true, then designers interested in energy efficiency would be able to provide clients with designs that satisfied both energy and non-energy design objectives more easily than if they were limited to a narrower range of energy efficient design solutions. The issue for building designers then, is whether or not the SERI approach to energy efficient design of midsize buildings is capable of generating meaningfully different design options and, if so, if these options are purchased at an energy efficiency price.

Study Procedure

The Base Building

Two design teams from Minneapolis were given the site and building program of an existing 52,000 square-foot suburban office building as a common base and directions to design a climate adapting, a climate rejecting, and a hybrid redesign of this building. This base building was constructed in 1984, consumed 95 percent of the energy of average office buildings in the Minneapolis/St. Paul metropolitan area, and was typical in terms of occupancy, equipment, and design of contemporary office building construction in this region. The energy performance of the base building had been monitored over the course of each climatic season. The results of this monitoring were given to each design team as well as being used to calibrate an hourly computer energy simulation model of the base building.

Elimination Parametrics

An initial step in the SERI design methodology is to conduct what is termed "elimination parametrics." In this procedure, major energy impacting elements are eliminated from the computer energy simulation program one at a time to estimate their impact on the total energy use of the building. The goal of this analysis is to help building designers identify which building elements and/or systems have major impacts on total building energy use and, hence, which energy systems should receive the most design attention. In the case of the base building of this study, this analysis suggested that lights, internal gains, and the building envelope were worthy of major analytical investment.

Alternative Building Designs

Each design team consisted of an architectural design firm that was supported by a common technical core that consisted of a computer modeler, a mechanical engineer with special expertise in energy issues, and a lighting designer. Each team was instructed to create a climate rejecting redesign of the base building, a climate adapting version of the same, and a hybrid design which combined noteworthy elements of the first two solutions. The design process tock place over a period of six months and was reviewed three times by external national experts in computer modeling, energy efficient architectural design, energy efficient mechanical design, and lighting design.

The first design team approached this problem by isolating those elements that directly impacted energy issues highlighted by the elimination parametrics of the base building and manipulating a range of glazing type, glazing size, bay and window head height, and bay depth within fairly narrow market place constraints. The results of this study were three fairly conventional office building designs that had bay depths of 39'-0", 34'-0", and 29'-0" respectively, ceiling heights of 8'-8", 9'-0", and 9'-0" respectively, and glazing-to-exterior wall percentages of 29%, 40%, and 49% respectively. A broad range of glazing types were analyzed in each case and lighting and mechanical systems were selected on a cost/benefit base to be compatible with each envelope strategy. The benefit of this study was to evaluate, in depth, a broad range of building technologies within the confines of a fairly narrow range of strategic design alternatives.

The second team took a slightly different approach to this problem. This team began by stipulating that daylighting was the central issue of this building type in terms of energy efficiency and that introduction of an atria was a logical way of increasing the daylighting contribution to the building's lighting needs. This study formulated a three, two, and a single story atria based solution to the base building redesign problem and then, as in the first team study, selected lighting and HVAC strategies that were compatible with each. The benefit of this study was its ability to extend the vision of how fundamental

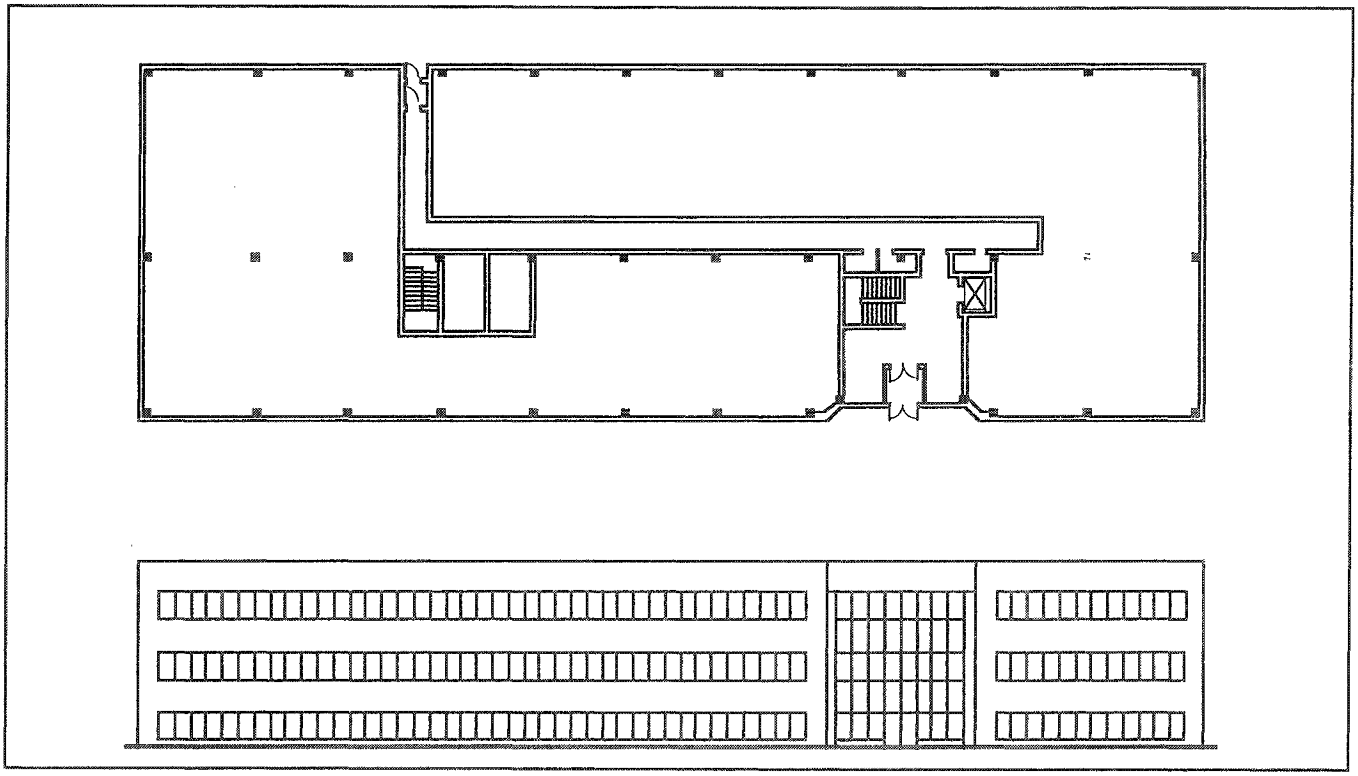

Figure 1. Base Building Plan and Elevation

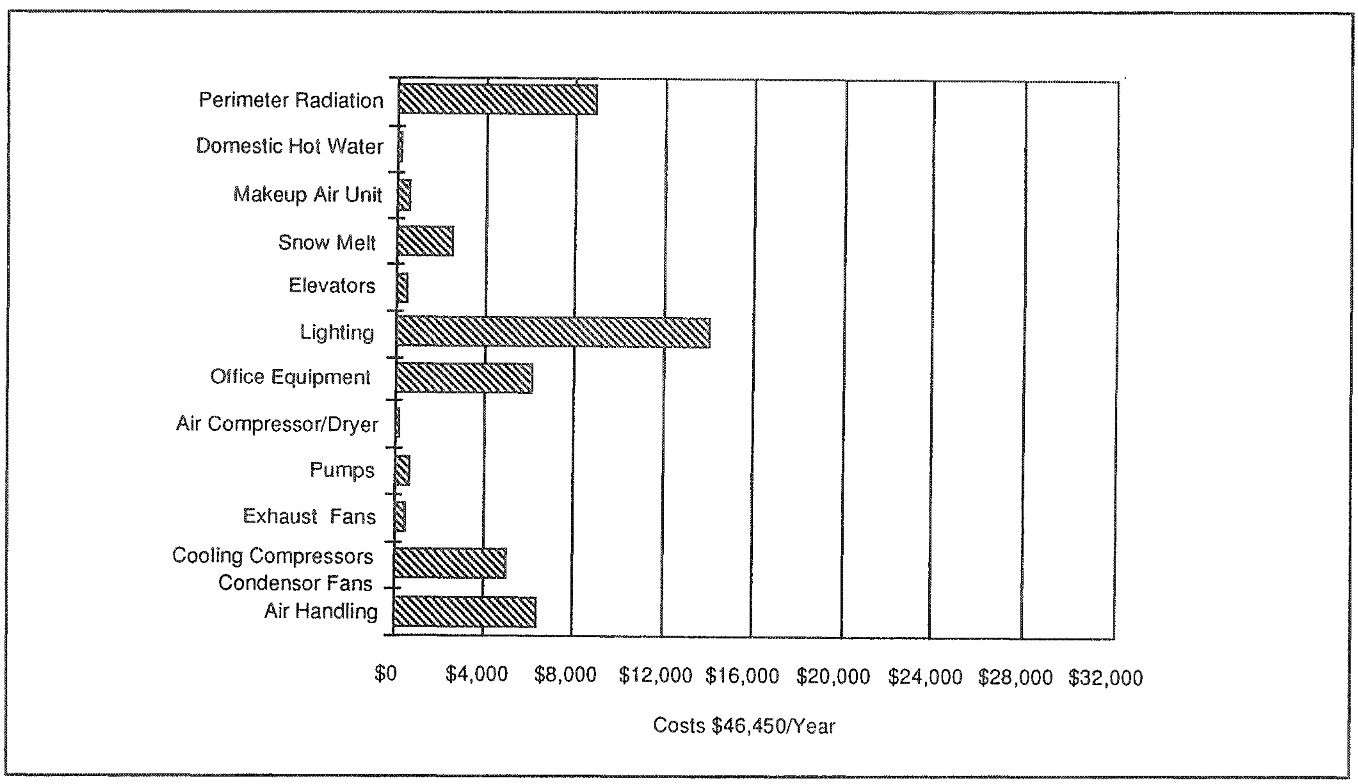

Figure 2. Base Building Utility End Use Energy

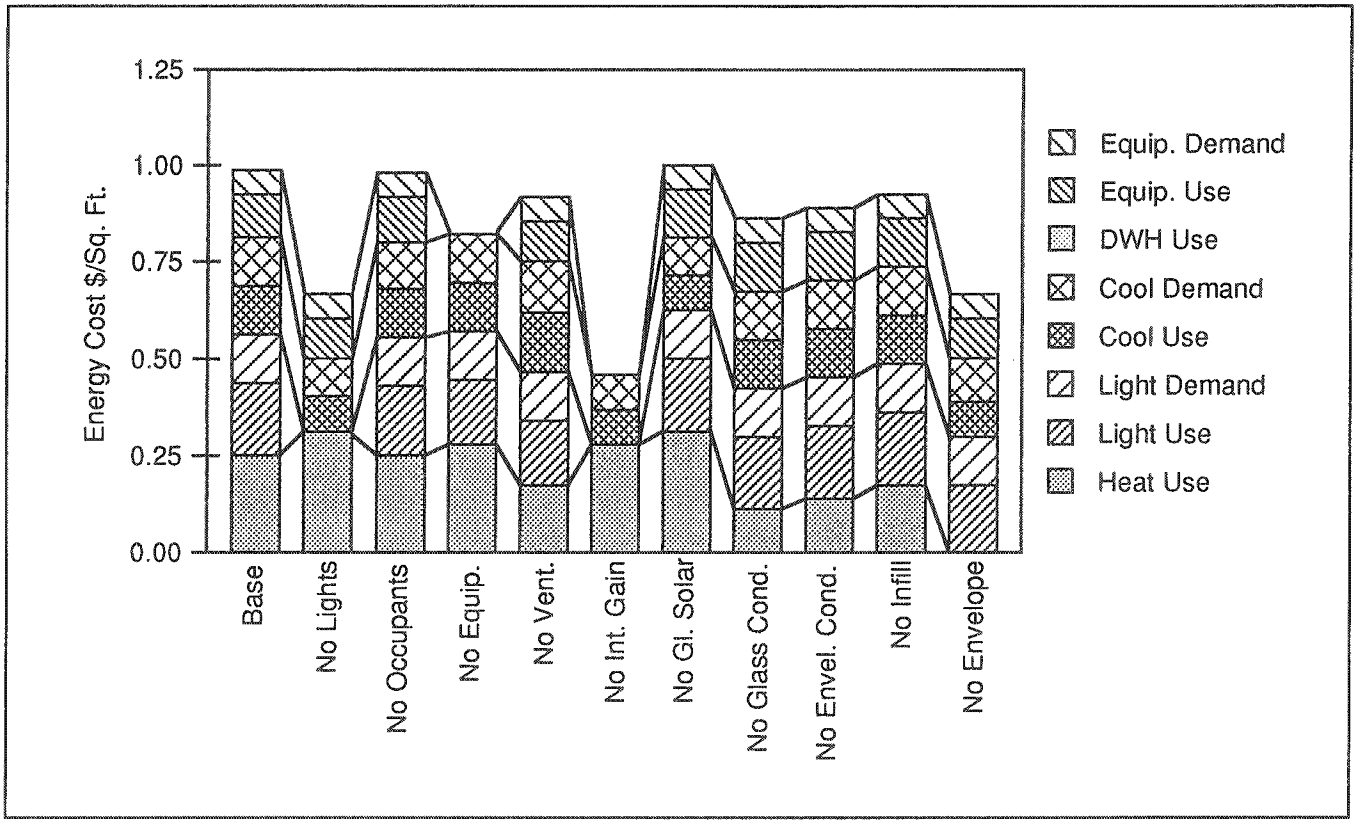

Figure 3. Monitored Model Elimination Parametric

decisions of spatial allocation and arrangement might impact energy consumption patterns in buildings.

These six buildings were then analyzed in terms of energy performance using uniform computer simulation assumptions and procedures. The construction costs for all six were developed by a single, highly regarded, local development firm to assure consistent cost assumptions and calculation procedures.

Study Outcomes

These two pairs of three buildings each were then placed on a common scale. The following are the major conclusions drawn from a comparison of these redesigns:

(1) Though each redesign team approached the problem in a different way, both determined that daylighting was the fundamental issue of the redesign strategies. Climate rejecting strategies in this case were defined as solutions that made minimal use of daylighting and maximum use of energy efficient bulbs, fixtures, ballasts, and lighting controls. Climate adapting strategies increased glazing areas, used high transmittance glazing types, raised ceiling and window head heights, and decreased bay depths as a function of core space distance from a natural light source. It is interesting to note in this regard that the glazing area as a percent of exterior wall surface grew progressively greater with the exception of Building 5, the two-story atria scheme which developed very deep building bays, 70'-0", without raising the ceiling height of the bay. The daylighting contribution does not, however, correlate with this increase. Building 3 contributes the second highest daylighting contribution to the office space, 47 percent, by creating the shallowest bay depth, 29'-0", and only slightly increasing glazing area over the two hybrid alternative designs. This comparison clearly points out that daylighting is not a simple design issue in office building design but a fairly complex problem that is more dependent on the intelligent integration of glazing type, ceiling and window head height, and bay depth decisions than it is on a matter of the absolute amount of glazing utilized in a building.

(2) The effectiveness of the design's daylighting strategy became the foundation for the selection of electric lighting systems in each building. Where daylighting played a small role in illuminating the interior spaces of the building, more efficient and more expensive

	Ceiling Height	Bay Depth	Glazing % of Wall	Glazing Type	Fixtures Lamps Ballasts	Lighting Controls	HVAC Type
Base	8'-8"	33'-0"	45%	Double Tinted	2 x 4 lens Standard lamps Stand. Ballasts	none	VAV Perimeter Radiation
Building 1	9'-0"	39'-0"	29%	Low emissivity Reflective	2 x 4 Parabolic T8 Lamps Elect. Ballasts	Occupancy	Heat Pumps
Building 2	9'-0"	34'-0"	40%	Low emissivity Tinted	2 x 4 Parabolic Standard Lamps Energy Saving	Occupancy 2 step daylighting	VAV Perimeter Reheat
Building 3	8'-0" Interior 11'-0" Perimeter	29'-0"	49%	Low emissivity Clear	2 x 4 Parabolic Standard Lamps Energy Saving	Occupancy 2 step daylighting	VAV Perimeter Reheat
Building 4	8'-0"	45'-0" 20'-0" Atrium	37%	Low emissivity Tinted	2 x 4 Parabolic T8 Lamps Elect. Ballasts	Occupancy continuous dimming	VAV Perimeter Reheat
Building 5	8'-8"	70'-0" 30'-0" Atrium	35%	Low emissivity Tinted	2 x 4 Parabolic Standard Lamps Energy Saving	Occupancy continuous dimming	VAV Perimeter Reheat
Building 6	17'-0"	48'-0" 16'-0" Atrium	29%	Low emissivity Tinted	HID	Occupancy stepped daylighting	Fan Coils Dx Cooling

Figure 4. Redesigned Base Building Characteristics

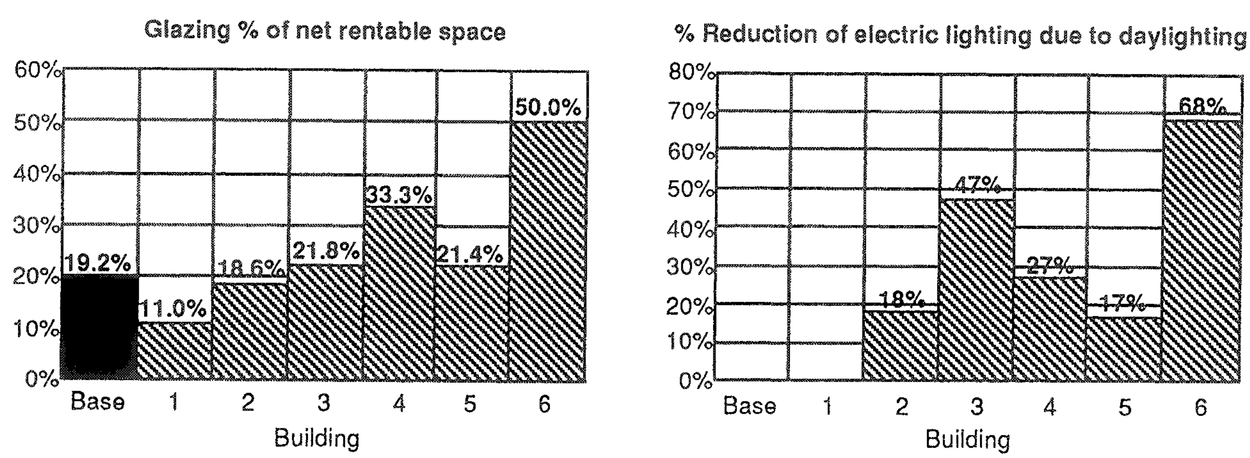

Figure 5. Daylighting Characteristics

electric lighting systems were selected. Where daylighting provided significant levels of illumination in these spaces, more sophisticated lighting controls and less expensive and less efficient fixtures were employed. A 20 footcandle credit, from 70 footcandles to the recommended IES standard of 50 foot candles, was taken in each redesigned building. The rationale for this reduction was that quality lighting design would provide comparable or better luminescent environments at this level. The result was that electric lighting energy in the redesigned buildings ranged from 12,380 Btu/square foot annually to a low of 6,240 Btu/square foot in the most daylight building. The average of the six redesigned buildings for electric lighting as compared with this 23,240 Btu/square foot of the base building was 10,280 Btu/square foot or approximately a 60 percent reduction in the use of electric lighting energy in the base building.

(3) The six building redesigns reduced energy consumption by 22 percent to 33 percent from that of the base building with an average reduction of 27 percent. What is more important, the utility costs for each building were reduced from 25 percent to 30 percent with an average reduction of 27 percent. Building 1 had the lowest energy use, 57,820 Btu/square foot annually, but the highest energy costs, $0.76/square foot annually, because it employed a heat pump rather than a variable air volume HVAC system. The unit cost of electricity versus that of natural gas creates this disparity. Heating energy increases in Building 2 through Building 6 as the surface area of these alternative increases but has little impact on the utility costs of the buildings due to the low unit cost of natural gas in this region. Lighting energy varies inversely with daylighting contribution and cooling directly reflects electric lighting requirements. The utility costs of both are reflected in both the normal and the demand electricity expenses of the alternative designs. The significance of the utility cost analysis of these buildings is how essentially even it is over the six alternatives. If the heat pumps were replaced by a variable air volume system in Building 1, all six of the buildings would have utility costs that were within pennies of each other on a square foot basis. Though each design represents very different energy conservation strategies and design characteristics, they all perform about equally in economic terms. This finding suggests that a broad range of energy conserving strategies might be used to attain the same

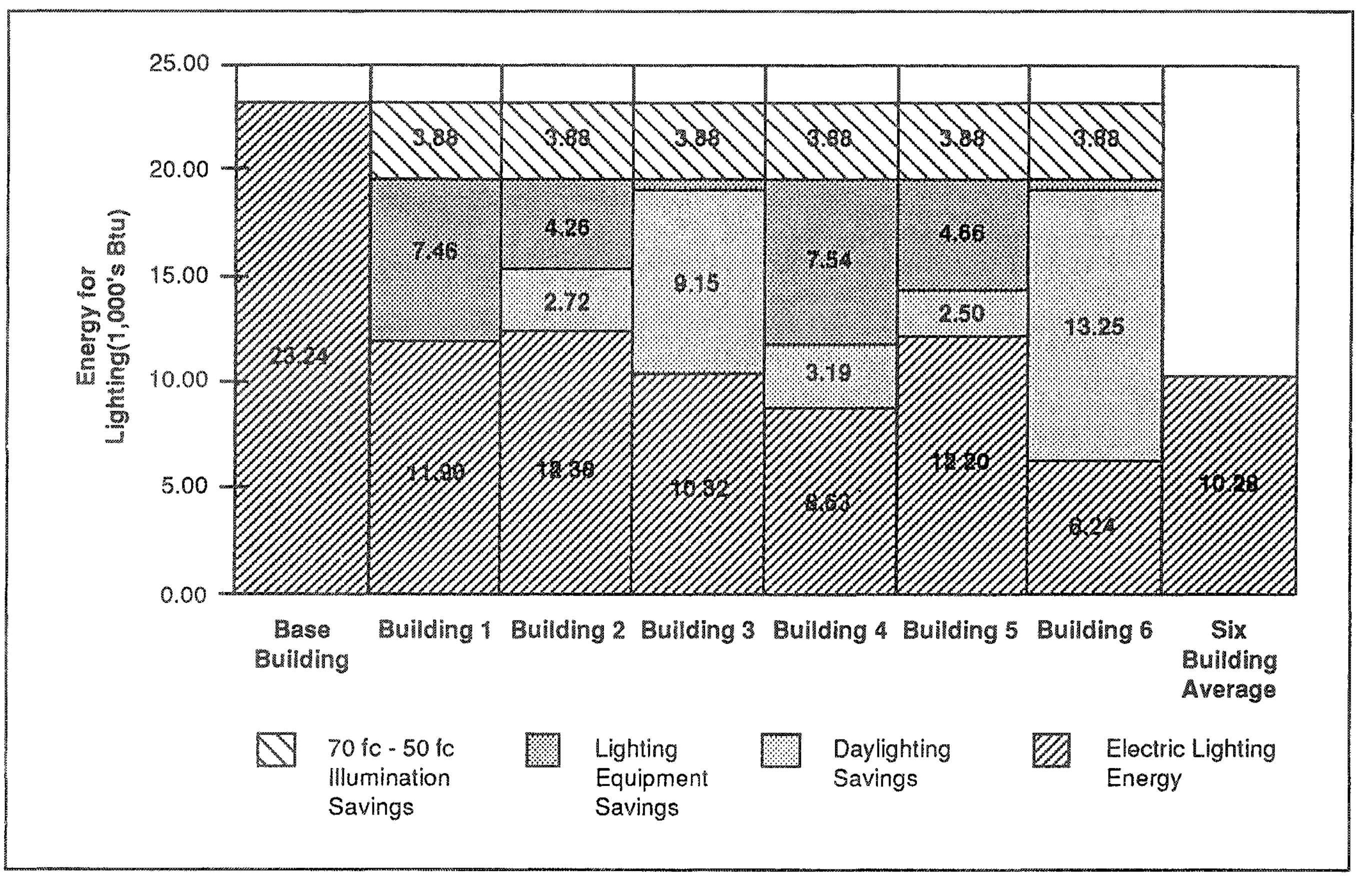

Figure 6. Lighting Energy Use and Savings

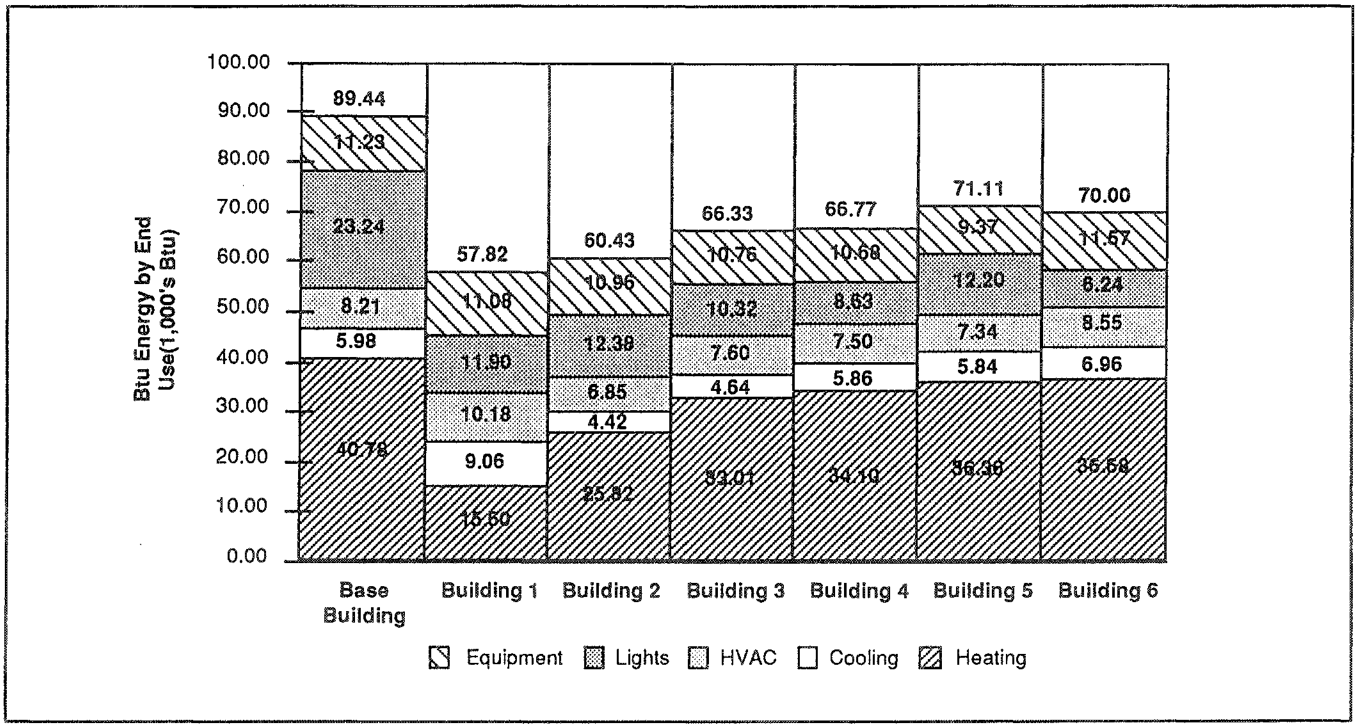

Figure 7. Total Energy Use by End Use

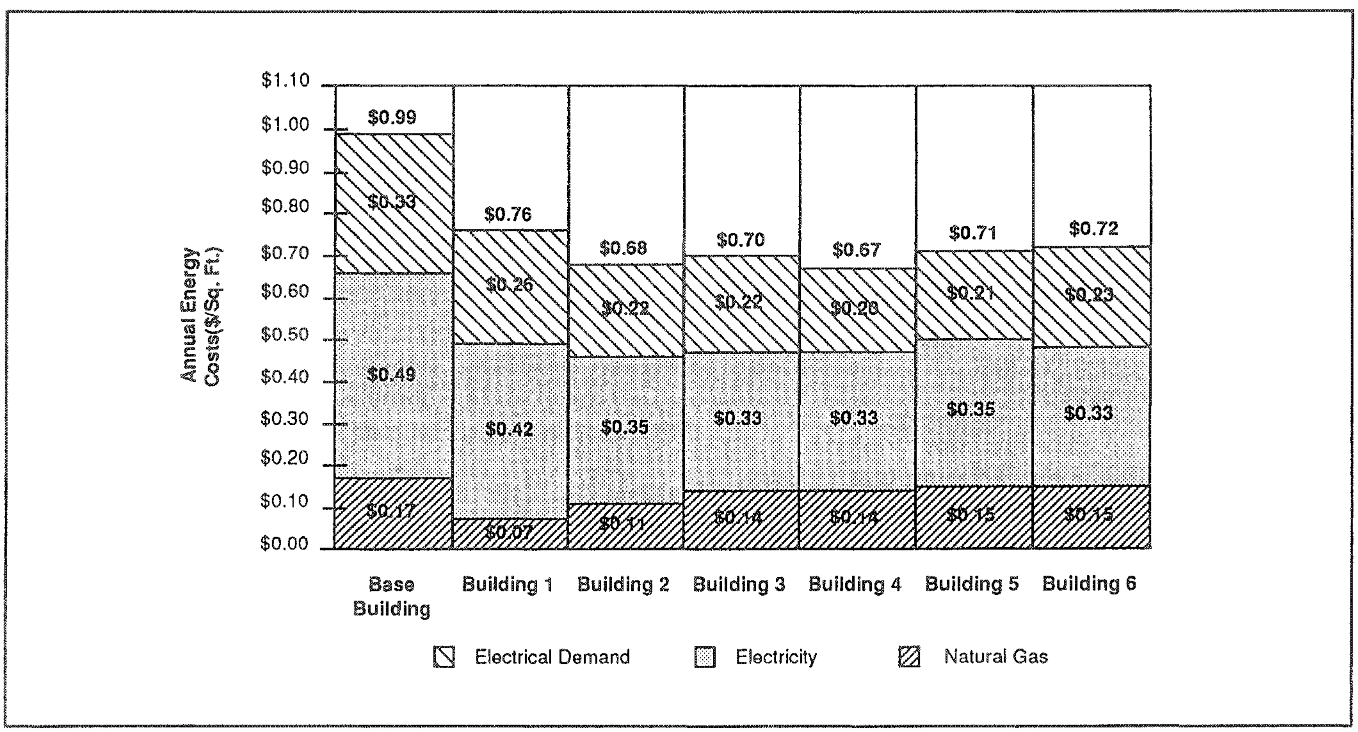

Figure 8. Annual Energy Costs

end. In a market place that demands a range of design characteristics to fulfill a range of needs, this is very good news for conservation enthusiasts. It essentially suggests that SERI was correct in its assertion that either climate rejecting design strategies or climate adapting design strategies could prove to be equally effective in conserving energy.

(4) This parity is reinforced by the analysis of each building's use of peak demand electricity on a typical summer day. All six strategies are tightly bunched together along a summer-day profile that consumes approximately 40 percent less demand electricity than did the base building. Building 6 with its major daylighting contribution paid the lowest demand penalty of the six buildings while Building 1, again primarily because of the us of heat pumps, paid the highest penalty. Again, the great similarity in the demand curves of the six office redesigns suggests that demand reduction as well as overall utility cost reduction might be effectively achieved by both climate rejecting and climate accepting design strategies.

Though construction costs for the six alternatives redesigns ranged from \$53.59/square foot to \$63.05/square foot as compared with an estimated cost of the base building at \$54.40/square foot, all of the solutions fell well within the limits of normal office building construction costs for structures located in Minnesota. Comparisons of the costs and benefits of alternate strategies is difficult if not impossible because each strategy provides a different level of quality of environment commensurate with its increased cost. The building that would be most comparable to the base building, Building 2, cost \$55.35/square foot to construct or \$0.95/square foot more per square foot than the base building. Thus, each of the six design strategies proved to be economically competitive in the office building development market.

Conclusions

When this study began, it was very unclear to participants what broad abstractions like climate adapting and climate rejecting design strategies meant in practice. As the study progressed, elimination parametrics clearly indicated that lighting, though not the building's only major energy use, was a potentially productive area for design exploration.

The conceptual dichotomy of climate rejecting and climate adapting energy conservation strategies did prove to be a powerful distinction in terms of propelling design explorations of daylighting in these buildings. In the case of both design teams, this distinction allowed designers to view their explorations as strategic rather than as tactical interventions. Approaching this problem as one of maximizing the use of or minimizing the impact of ambient climatic conditions on the creation of appropriate thermal and luminescent conditions within the building posed a energy conservation problem rather than stating conservation solutions. The latitude allowed by this shift from assigned solutions to understanding the basic nature of the problem to be solved created a period of design thoughtfulness in both design teams that tended to open up ranges of solution options rather than immediately narrowing these choices to a few well know possibilities. This procedure was not as much a matter of inducing radically new solutions to energy conservation as it was a matter of being able to suggest solutions that stemmed from problem understanding rather than from convention or habit. Thus, solutions tended to have a sense of internal coherence that is often lacking in the assembly of relatively habitual responses to energy conservation issues. The SERI approach to seeking energy conserving design strategies in midsize buildings thus suggests a procedure that requires a deeper understanding of this issue but repays this understanding with solutions that treat buildings as interdependent systems rather than as independent technologies.

The SERI model did not, however, prove to be a powerful design tool for the mechanical engineers or lighting designers on the two teams. When mechanical engineers or lighting designers were asked to conceptually drive the design process by suggesting mechanical systems that would help shape building designs as climate adapting or climate rejecting solutions to this problem, they were unable to do so. When they were presented with the kinds of problems associated with progressively larger areas of glazing, alternative glazing types, and the introduction of atria in some solutions, both were quickly able to suggest lighting and HVAC systems that would work well with these initial design decisions. Thus, the definition of climate rejecting and climate adapting office buildings in this study that propelled architectural explorations that either minimized or maximized use of daylight to illuminate study office buildings was not an effective conceptual distinction in terms of either mechanical or lighting designs in this case.

This distinction probably represents a broad commentary on the roles that have been assumed by architects and engineers in the design process rather than a definitive statement of what climate rejecting and climate adapting

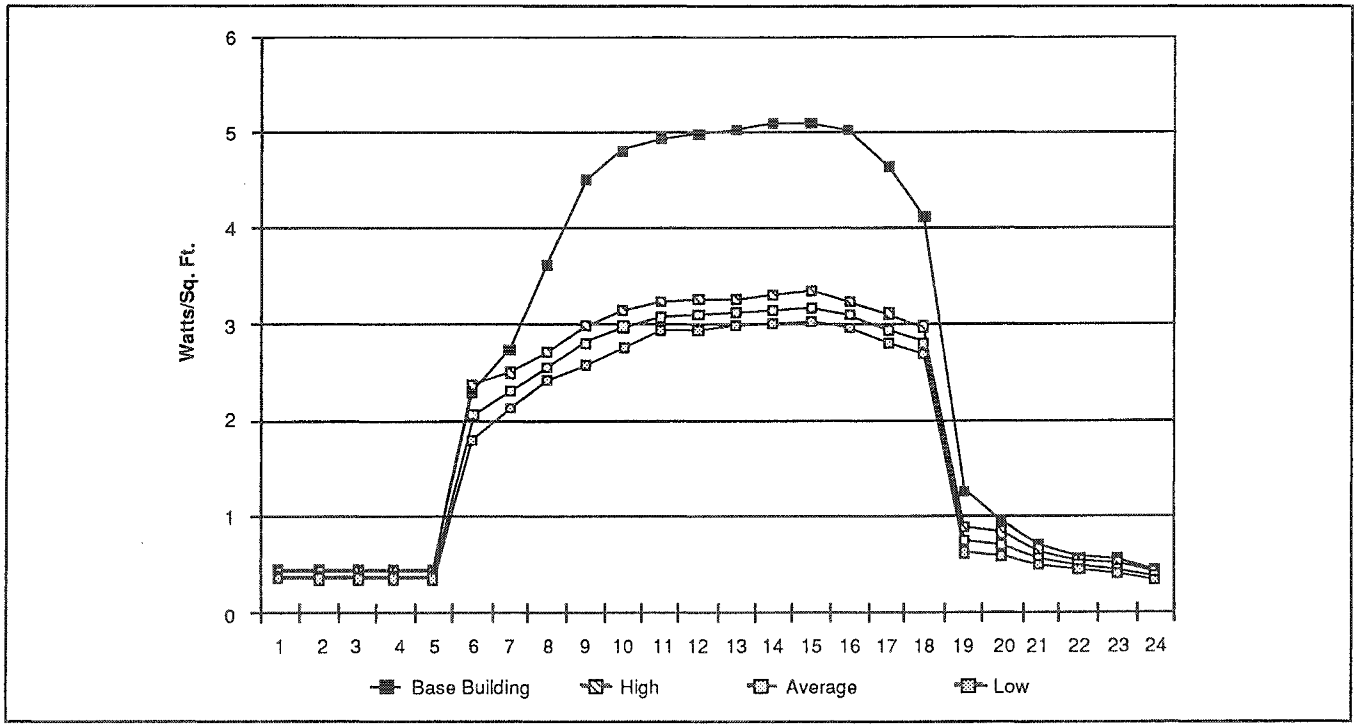

Figure 9. Comparison of Summer Day Peak Demand

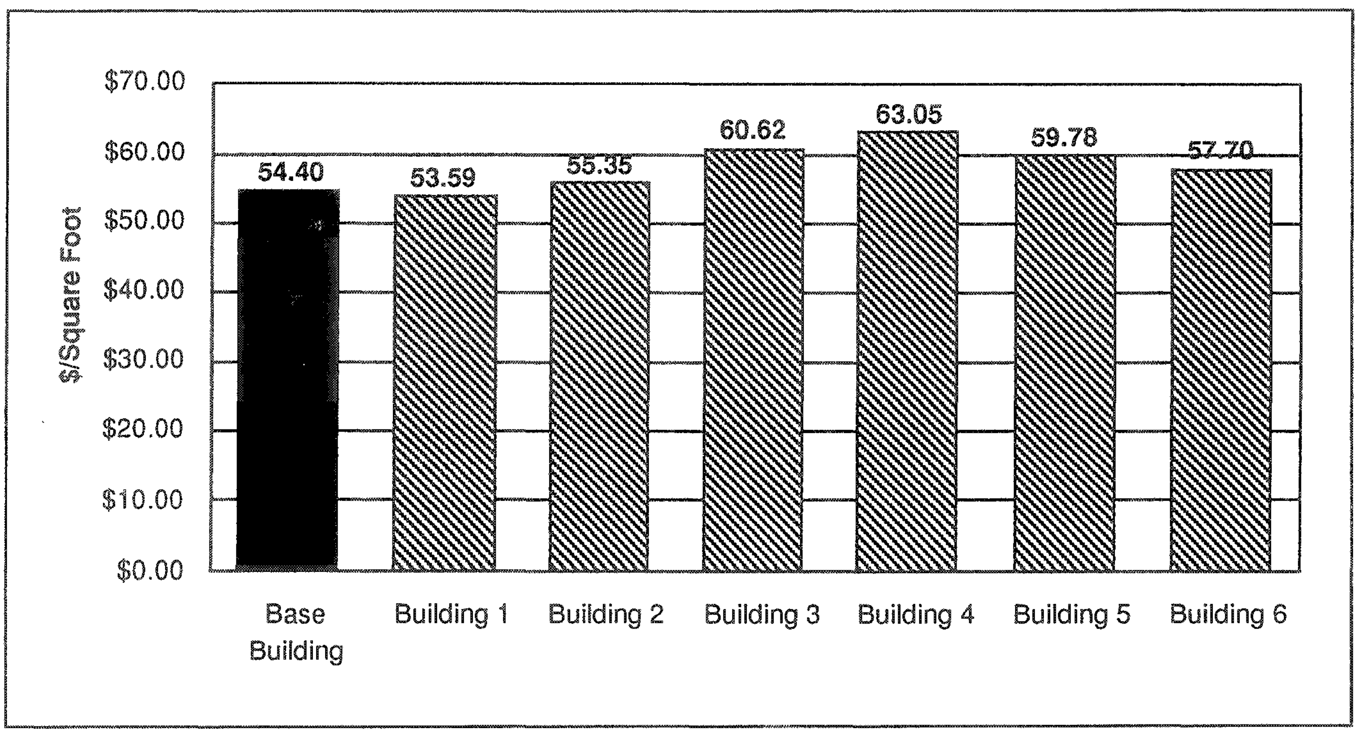

Figure 10. Building Construction Cost Estimates

solutions in office buildings might become. It is not difficult to imagine that such solutions might be driven by HVAC systems or lighting strategies. What is difficult to imagine, given the current status of design procedures, is that engineers who are more comfortable responding to problems formulated by other design team members could develop a way of thinking that would allow them to initiate conceptual solutions to design problems.

Finally, though climate adapting design strategies did tend to cost more in this study to achieve similar results than climate rejecting strategies, the cost/benefit outcome of this difference remains uncertain. The issue put forth by this portion of the analysis makes clear the difference between quantitative and qualitative measures of design success. Because climate adapting solutions in this study were defined as a function of amount of daylighting used to illuminate building space, buildings that made maximum use of sunlight as an ambient natural energy created a quality of interior environments that are often more valued in the marketplace than those that are typically created by climate rejecting solutions. The ceiling of climate adapting strategies tended to be higher and bay depths shallower than those of climate rejecting solutions reducing the confined and sometimes somewhat oppressive sense of office space that is associated with low ceilings and deep bays. Atria provide an additional sense of quality space in these buildings that is considered by most office building developers to be an amenity. While the environmental value of these qualitative measures is difficult to measure, it nonetheless exists as reflected in marketplace rental rates. Evaluation of differences in the quality of environments that these strategies created, remains, however, primarily a matter of interpretation and judgement rather than of calculation.

In summary, this study perhaps narrowly interpreted climate adaption to be a function of daylighting in office buildings. Though this interpretation is somewhat limited, the electrical and mechanical engineers who helped to develop these designs were unable to compete with the architects on the design teams in terms of propelling initial energy conserving design strategies in this procedure. The results of this process, however, remain important to those interested in energy conservation in midsize buildings in general or to people with specific interest in utility sponsored design assistance programs. The ability to generate very similar energy performance in office buildings using a wide range of conservation strategies suggests that significant design latitude exists in making conservation choices. This latitude requires thoughtful rather than rote responses to energy conservation design problems. The SERI conceptual model of understanding buildings as buildings as fundamentally climate rejecting or climate adapting responses to their surrounds would appear to aid in generating such thoughtfulness.

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