Field Demonstration of Lighting and HVAC Cost Savings from High Performance Design Summary

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PROJECT OVERVIEW

The Association of State Energy Research and Technology Transfer Institutions, Inc. (ASERTTI) and the National Association of State Energy Officials (NASEO) with the Department of Energy (DOE) and the EnergySmart Schools Program conducted a joint project that encompassed applied research, field testing and technology integration.

The following organizations worked collectively to conduct this research:

- Energy Center of Wisconsin
- Iowa Energy Center
- Lighting Research Center
- Lawrence Berkeley National Laboratory
- Dalhoff & Associates
- Fort Collins Utilities

As part of the overall project there were eight distinct tasks outlined, each with its own set of goals, activities and deliverables. This document was created as part of Task 4: Advanced Daylighting Research.
Energy Smart Schools – Field demonstration of lighting and HVAC cost savings from high performance design

CHALLENGE
Demonstrating actual lighting and HVAC impacts from high performance glazing and daylighting strategies is difficult. While many schools and other buildings have been designed and built using these strategies, attempts to compare energy consumption with standard designs must confront the myriad ways in which any particular building differs from other buildings. This leaves open the question of the extent to which measured differences in energy consumption are due to deliberate design strategies versus other uncontrolled factors such as operation schedules and building orientation.

SOLUTION
An experiment was conducted at the Iowa Resource Station near Des Moines, Iowa in two sets of identical rooms with independent lighting and HVAC delivery systems. One set of four rooms (“high performance”) was configured with high-performance glazing with reduced visible transmittance as well as direct/indirect electric lighting with photosensor dimming. The other set of four rooms (“standard”) was configured with standard clear-glass glazing and ceiling-mounted fluorescent fixtures with no dimming.

Each configuration comprised one east-facing, one south-facing, and one west-facing room—as well as an interior room with no fenestration. All rooms were the same size (276 ft²) and the two sets were oriented identically. Both configurations were operated as typical variable air-volume (VAV) systems with a central chilled-water coil and terminal hydronic re-heat coils. This set-up allowed for a direct comparison of lighting and HVAC energy consumption through the analysis of the more than 600 parameters that are recorded at one-minute intervals in this highly instrumented facility.

The experiment was conducted in three rounds during the summer, fall and winter of 2003, comprising a total of 70 days of operation. Within each round, three slightly different configurations of the high-performance rooms were tested: (1) base case, as noted above; (2) reduced fenestration, simulated by partially covering windows in the high-performance rooms with exterior panels with an insulating value comparable to the adjacent exterior walls; and, (3) addition of an interior light shelf to improve the distribution of natural light to the interior of the rooms.

RESULTS
The lighting and HVAC operating cost savings for the high-performance rooms are considerable, and represent a savings of about 22 percent on operating costs of about $1.13 per square foot.¹ The table below shows how these costs and savings break out:

<table>
<thead>
<tr>
<th></th>
<th>Standard configuration annual operating costs (cents/ft²)</th>
<th>Savings for High-Performance configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting energy</td>
<td>22</td>
<td>7</td>
</tr>
<tr>
<td>Cooling energy</td>
<td>19</td>
<td>5</td>
</tr>
<tr>
<td>Heating energy</td>
<td>6</td>
<td>-0.1</td>
</tr>
<tr>
<td>Fan energy</td>
<td>13</td>
<td>0.3</td>
</tr>
<tr>
<td>Demand charges</td>
<td>53</td>
<td>12</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>113</strong></td>
<td><strong>24</strong></td>
</tr>
</tbody>
</table>

¹ These are based on typical Midwestern utility time-of-day utility rates of: 6 cents/kWh for on-peak electricity, 3 cents/kWh for off-peak electricity, $6/kW monthly demand charge, and $1/kW rolling-demand charge. The analysis is also based on 250 days of annual week-day, non-holiday operation.
**Lighting Energy.** The dimmable fixtures in the high-performance rooms operated at reduced output much of the time. These fixtures used about half the electricity as the fixtures in the standard rooms on sunny days. The overall savings is somewhat less due occasional overcast conditions, shorter days during the winter, and the fact that daylighting was not possible for the interior room, which represents a quarter of the floor space.

**Cooling Energy and Chiller Sizing.** On a weather normalized basis, the high performance rooms require 25 percent less cooling than the standard rooms. These savings derive from three differences between the two configurations: (1) reduced need to remove heat from dimmed electric lighting; (2) reduced heat gain through the high-performance windows; and, (3) reduced cooling required to condition ventilation air, which increases as the other cooling loads increase. Under hot conditions, the last two factors dominate, as electric lighting represents only about 10 percent of the building’s cooling load.

Analysis of hourly cooling loads on the two systems show that the high-performance configuration results in 26 percent lower cooling load at the Des Moines summer design temperature of 93°F.

**Heating Energy.** Reduced solar gain and electric lighting loads should translate into higher wintertime heating costs for the high performance configuration, and the data do reflect this effect at temperatures below about 40°F. However, the data also reveal that the high performance rooms require less reheat energy at higher temperatures. This is presumably due to less time in which cooling is needed in only one or two rooms to deal with high solar and electric lighting loads. On balance, these two effects effectively cancel out, and the impact on heating energy is negligible.

**Fan Energy.** The high performance rooms require somewhat less fan energy during hot weather, due to reduced need for VAV-system airflow to meet the cooling load. At other times, the two systems used about same amount of fan energy.

**Demand Charges.** Analysis of 15-minute combined lighting and HVAC system demand shows a substantial reduction in monthly (and rolling annual) demand charges, representing more than half of the total operating cost savings. These savings are predicated on the assumption that a school using the high performance configuration tested here would be installed with a 25 percent smaller chiller, with a comparable reduction in chiller power draw when it is operating. Demand savings without chiller downsizing would be much smaller, since it only takes one 15-minute period of chiller operation in a given month to set the peak demand charge for the month (as well as the rolling demand charge for the year). These results reinforce the need to couple high performance glazing and lighting specifications with chiller sizing.

**Effect of Different High Performance Configurations.** The data did not show large differences in lighting or HVAC energy use across the three high-performance configurations tested. The configuration with reduced fenestration area had somewhat higher lighting energy use due to decreased daylight availability, and the configuration with the light shelf was between this level and the standard configuration. None of the configurations showed statistically significant differences in HVAC energy, though this is at least partly a consequence of less statistical precision when analyzing across varying weather conditions rather than being able to directly compare energy use across configurations under identical conditions.

**FUTURE**
The results of this experiment show that that there is significant potential for reduced lighting and HVAC operating costs—as well as upfront capital costs for chillers—through careful attention to glazing characteristics and lighting configuration.