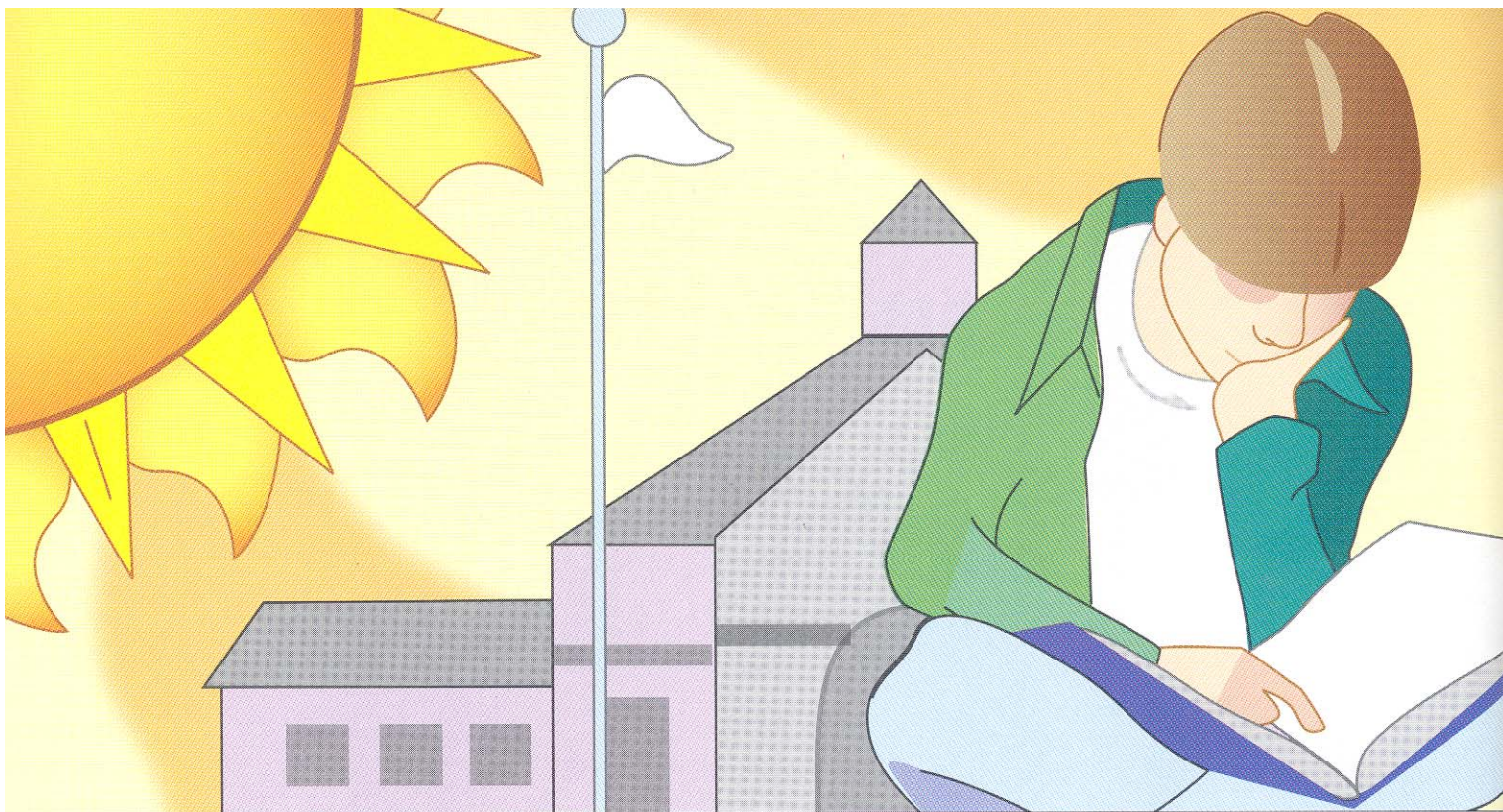




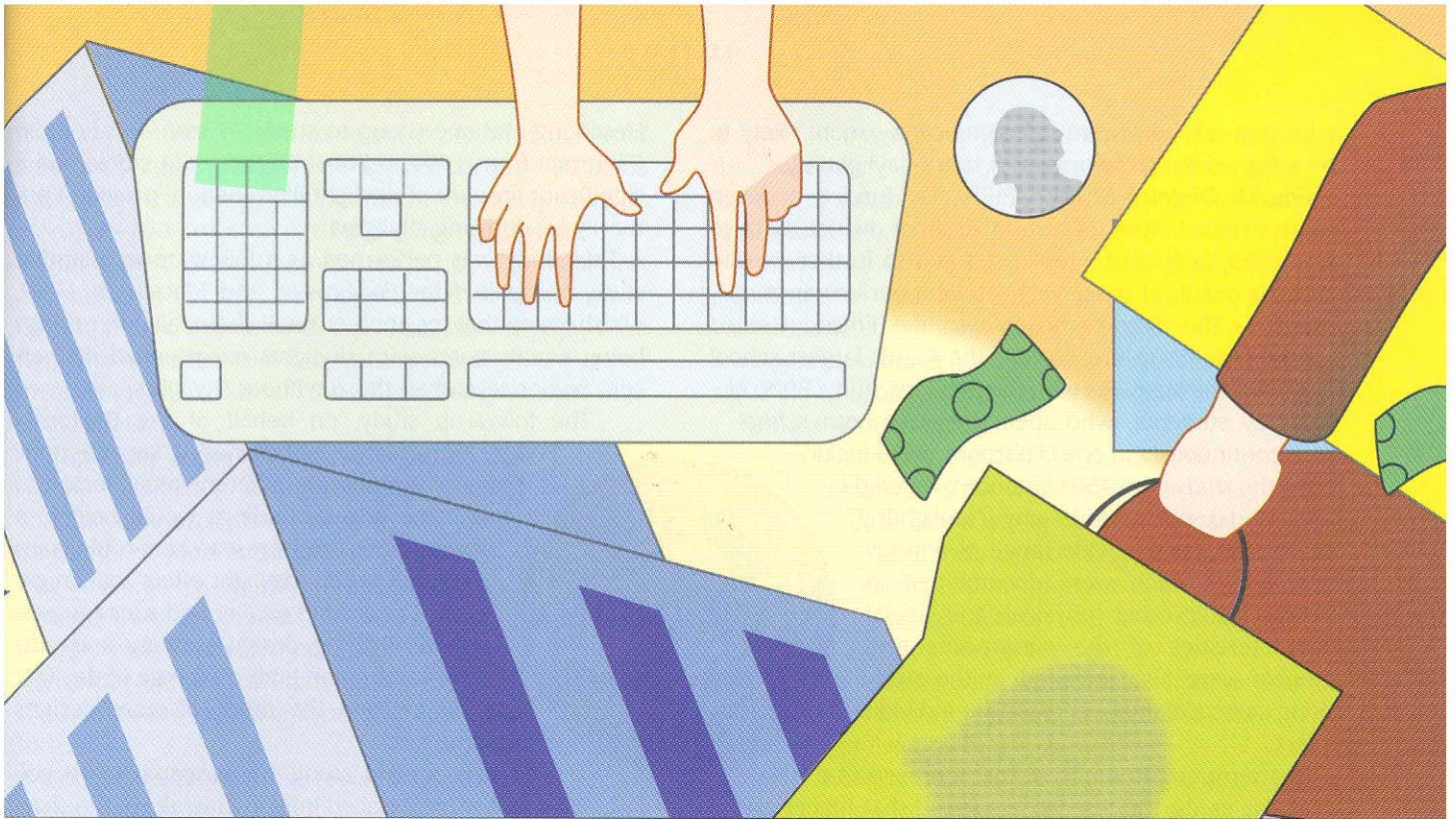
Daylight *by* Data

*INTUITIVELY, WE ALL
KNOW DAYLIGHTING
AND WINDOWS IN
BUILDINGS MUST BE A
GOOD IDEA, RIGHT?
NOW COMES HARD
DATA THAT ACTUALLY
QUANTIFIES THE
BENEFITS ACROSS THREE
TYPES OF FACILITIES*

What do school kids, shoppers and office workers have in common? It seems they all have an affinity for daylight. Research recently conducted by the Heschong Mahone Group, Inc., Sacramento, CA, offers compelling evidence of daylight's benefits in three distinct building types—class rooms, retail space and offices. Carried out as part of the California Energy Commission's Public Interest Energy Research (PIER) program, the studies appear to demonstrate a connection between daylighting and student and worker performance in schools and offices, as well as higher sales in a retail environment. What follows are excerpts from four of the recent PIER technical reports.

Daylighting In Schools

The study entitled "Daylighting in Schools: Reanalysis Report" expands upon and validates previous research by the Heschong Mahone Group that found a statistical cor-



relation between the amount of daylight in elementary school classrooms and the performance of students on standardized math and reading tests.

Original Research. Conducted in 1997-98, the original research focused on three large school districts that had a range of daylighting conditions in their classrooms. The research team collected test scores and demographic information for 8000-to-9000 second through fifth graders in each district, and classified 2000 classrooms for the amount and quality of daylight available. Elementary schools were selected since the children in these schools typically spend all year in one classroom. Thus, researchers could directly isolate the effects of that one classroom. For this study, the research team also specifically selected districts that had a number of classrooms lit from above with skylights or roof monitors ("toplighting"). "We reasoned that daylight provided through windows might have a number of complicating factors, such as the quality of view, whereas daylight provided from above typically had fewer other qualities that might influence results, thus we would be more likely to isolate a pure 'daylighting' effect," says Lisa Heschong, project director.

The three districts were located in San Juan Capistrano, (Southern) CA; Seattle, WA; and Fort Collins, CO. These districts have very different climates, school building types, curriculums and testing protocols. The Capistrano Unified School District proved to be the most useful study site, because each student took standardized tests at both the beginning and end of the school year, which gave a clear measure of their academic progress per year. In Capistrano, students with the most daylighting in their classrooms progressed 20 percent faster on math

tests and 26 percent faster on reading tests in one year than those with the least. Similarly, students in classrooms with the largest window areas were found to progress 15 percent faster in math and 23 percent faster in reading than those with no windows.

Meanwhile, the Seattle and Fort Collins school districts administer only one standardized test at the end of the school year, providing a somewhat cruder measure of student progress. In these districts, the study used the just final scores on math and reading tests at the end of the school year and compared the results to the group average test score. In both of these districts the study also found positive effects for daylighting. Students in classrooms with the most daylighting were found to have seven percent to 18 percent higher scores than those with the least.

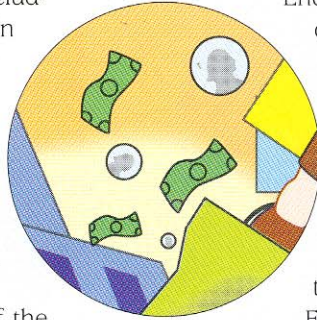
Data Reanalysis. Reviewers of the original research, however, asked if the difference in test scores could be explained by other factors such as teacher quality, home life, nutrition, individual talents and motivation. Reviewers asked if "better" teachers were more likely to be assigned to the more daylit classrooms, thus influencing the results. As a result, a PIER funded follow-up study was conducted to re-examine data from two of the districts, and add additional information about teacher qualifications and classroom preferences. The reanalysis confirmed the original results, finding that:

- Elementary school students in classrooms with the most daylight showed a central tendency for a 21 percent improvement in learning rates compared to students in classrooms with the least daylight.
- There was no teacher assignment bias that might have skewed the original results; more experienced or more

educated teachers were not significantly more likely to be assigned to classrooms with more daylighting.

Fourth District Study. PIER also funded an even more detailed study of a fourth school district, both to see if results could be replicated and to further investigate the details of the daylight-student performance relationship. The district chosen was the Fresno Unified School District, in Fresno, CA, the fourth largest school district in the state. As with the previous study, 8000 elementary students, who spent the 10-month school year continuously in one classroom, were included in the study. The 450 classrooms studied in Fresno did not include any "toplighting" designs, but had a wide range of window conditions, which were documented in detail. Many other physical and social characteristics of the classrooms and schools were also included in the study, using statistical analysis to isolate individual effects.

In attempting to replicate the approach of the previous study, the researchers found that higher and more uniform levels of daylight illumination, per se, as measured on the horizontal task plane, were not associated with better student performance. However, when more detailed characteristics of each classroom were considered, students were found to be performing best



Heschong Mahone Group to study 73 store locations in California from 1999 to 2001. Of these, 24 stores had a significant amount of daylight illumination, provided primarily by diffusing skylights.

This study was performed as a follow-up to a similar study completed for Pacific Gas and Electric in 1999, which found that for another retail chain, all other things being equal, stores with skylights experienced 40 percent higher sales than those without skylights.

The follow-up study, on behalf of the California Energy Commission, examined a second retail chain, in an entirely different retail sector, to see if the original findings would hold in a new situation, and if researchers could learn more about any daylight effect that might exist. The second retailer had a less aggressive daylighting design strategy and also more variation in both the range of daylight conditions and the range of store designs than the first.

For the second study, the research team collected much more detailed information about the characteristics of each store; the demographics of each neighborhood; and the nearby retail competition. Finally, store managers were interviewed and employees were surveyed about their observations and preferences. Researchers, however, were not permitted to interview

Students with the most daylighting improved 20 percent faster on math tests

in the classrooms with the best window views.

- On reading tests, students improved 14 percent more for each 100 sq ft increase in view window area. In addition, if they also had a view of human activity, such as the playground or a sidewalk, their progress improved another 6 percent.
- On math tests, students improved seven percent for each 100 sq ft increase in window area above the door, along with an addition 10 percent improvement if they also had a view of vegetation, such as trees or bushes.
- On both tests, window characteristics that indicated a potential for glare or lack of control had a consistently negative association, such as a five percent decrease in performance if the classroom windows had no blinds or curtains. East-facing windows, difficult to shade from the low morning sun, were found to have a consistent negative association with both math and reading scores. Moreover, many of the older daylit classrooms, with large glass surface areas and poor ventilation except via open windows, had poor acoustic conditions which were likely to have a negative effect on learning.

Daylighting In Retail

The study entitled "Daylight and Retail Sales" presents evidence that a major retailer is experiencing higher sales in daylit stores than in similar non-daylit stores. The retailer, who requested anonymity, allowed the

customers.

Ultimately, this study of 73 stores found that increased hours of daylight per store were strongly associated with increased sales, but at a smaller magnitude than reported in the previous study.

Specifically, the study found that:

- The average effect of daylighting on sales for all daylit stores in this chain ranged from 0 percent to 6 percent, depending on the type of model and time period considered. The effect for individual stores ranged up to a 40 percent increase for those stores with the most parking and most aggressive daylighting.
- A dose/response relationship was found, whereby more hours of useful daylight per year in a store are associated with a greater daylight effect on sales.
- Daylight was found to have as much explanatory power in predicting sales as other more traditional measures of retail potential, such as parking area, number of local competitors and neighborhood demographics.
- Along with an increase in average monthly sales, the daylit stores were also found to have a one-to-two percent increase in the number of transactions per month.
- The value of the energy savings from the daylighting (ranging from \$0.24 per sq ft per year for the current design, with a potential of \$0.66 per sq ft per year with a state-of-the art design) is far overshadowed by the value of the predicted increase in sales due to daylighting. By

the most conservative estimate, the profit from increased sales associated with daylight is worth at least 20 times more than the energy savings, and more likely, may be worth 50-200 times more than the energy savings.

- During the California power crisis of 2001, when almost all retailers in the state were operating their stores at half lighting power, the stores in this chain with daylight were found to benefit the most, with an average 6 percent increase in sales relative to the other non-daylit stores within the chain.

- Employees of the daylit stores reported slightly higher satisfaction with the lighting quality conditions overall than those in the non-daylit stores. Most strikingly, they *perceived* the daylit stores to have more uniform lighting than the non-daylit stores, even though direct measurements showed both horizontal and vertical illuminance levels in the daylit stores to be substantially less uniform.

- Store managers did not report any increase in maintenance attributable to the skylights.



Daylighting In Offices

The study entitled "Windows and Offices: A Study of Office Worker Performance and the Indoor Environment" reports on how factors such as daylight and view (and sec-

workers in the desktop study with the best views were the least likely to report negative health symptoms. Reports of increased fatigue were most strongly associated with a lack of view.

- Other variables related to view were also found to be significant. In the call center, higher cubicle partitions were associated with slower performance. In the desktop study, glare potential from windows was found to have a significant negative effect on performance in the cognitive assessment tests.

The study discusses a number of competing hypotheses for why better views might influence office worker or student performance.

These include providing mental relaxation, mental stimulation, or interestingly, circadian stimulation via higher daylight illumination levels received by the eye when looking out a window. Whether any, or all, of these factors are important will have to be resolved by future studies.

However, in the meantime, it appears that a view window can potentially have a major value for office managers. "The seven percent increase in call center worker speed attributable to a better view was valued by SMUD at \$118 per sq ft *per year*, essentially equal to the complete cost of construction of a low rise office building!," says Heschong. "Since the most recent SMUD

and 26 percent faster on reading tests in one year than those with the least

ondarily, ventilation and thermal comfort) influence worker performance. Two studies were conducted at the Sacramento Municipal Utility District (SMUD). The first looked at 100 workers in an incoming call center, whose performance was continuously tracked by a computer system and measured in terms of time to handle each call. The second "desktop" study examined the performance of 200 other office workers on a series of short cognitive assessment tests, taken at each individual's desktop computer. The desktop study also included a questionnaire about workers' comfort conditions and health symptoms.

Higher levels of daylight illumination were found to be associated with better performance on only one of the cognitive tests, for short term memory. However, both studies concluded that better access to window views consistently predicted better performance across all measures of office worker performance considered. Specifically, the studies found that:

- Workers in the call center were able to process calls 6 percent to 12 percent faster when they had the best possible view versus those with no view, all other things being equal. Office workers were found to perform 10 percent to 25 percent better on tests of mental function and memory recall when they had the best possible view versus those with no view.
- Office workers' "self reports" of better health conditions were strongly associated with better views. Those

building was originally built for about twice normal construction cost, the value of the excellent views provided to workers were repaid in about one year."

Not surprisingly, one of the key recommendations of the study is "to encourage the design of office buildings with views provided for all workers. Both the school and the office studies found consistent correlations between better views and better performance. There is a clear suggestion from this work that views to the outdoors are important for sustained human performance..."

A room with a view and ample daylight—sounds like a good thing, and the data tells the tale.

—Paul Tarricone

Full technical reports for the studies excerpted in this article were issued in October 2003. For more information on these studies or the California Energy Commission's PIER program, go to www.energy.ca.gov/reports.



About the Researcher: Lisa Heschong, LC, Member IESNA (1993), is an architect and principal of the Heschong Mahone Group, Sacramento, CA. She is the author of numerous books, guidelines, manuals, and journal articles on human comfort and energy efficiency, and has done work for the U.S. Department of Energy and California utilities. Ms. Heschong has a Masters of Architecture from the Massachusetts Institute of Technology.