

Daylight Harvesting in Retail Stores

November 2009



Overview

Objective

This paper helps retail operators define strategies commonly used to implement daylight harvesting, which improves energy efficiency within the store. In addition to explaining types of daylighting available to retailers, this paper also presents lighting control strategies (dimming and on/off control) associated with daylight harvesting, which are implemented via facility management systems.

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Executive summary

Greening the future

This paper provides a comprehensive overview of daylighting systems, design essentials, and an assessment of its energy savings potential. The information presented here is intended to be used in the earliest stages of the building design process.

Daylight harvesting is the controlled admission of natural light into a space with the intent of limiting or eliminating electrical lighting. The entire process makes use of photo sensors to detect ambient daylight levels and automatically adjusts the artificial lighting output level to reach the desired illumination.

Building modeling and design of a cost-effective daylighting system is critical to the success of daylighting programs. Major findings indicate that, while most retailers are interested in implementing daylighting in stores, there is a need to gain more substantial knowledge regarding controlling lighting levels and other environmental elements. Whatever the initial intent for daylighting, the indisputable facts are:

- For the project to be successful, the daylighting and control systems must be designed in conjunction with the facility
- For retailers seeking Leadership in Energy and Environmental Design (LEED®) certification, daylight harvesting is a way to gain additional LEED points, while reducing energy usage
- A well designed lighting control system will provide years of sustainable energy savings through a reduction in energy usage
- Daylighting is most effective when controls exist to manage the electrical lighting system

With a properly designed daylighting system, most retailers will see a reduction in energy costs associated with lighting systems of between 35 and 60 percent. However, there are initial costs associated with the development and implementation of the system that must be considered:

- Daylight harvesting typically costs between \$75,000 and \$85,000 in a new 50,000 sq. ft. retail facility, including the cost of skylights
- A facility management system to manage indoor lighting and HVAC loads costs, on average, \$10,000 to \$15,000 and often offers additional operational cost saving opportunities not discussed in this paper
- Most retailers see a further four to nine percent energy savings from facility commissioning services, which are necessary to properly calibrate the building's systems
- The typical payback for daylighting and the facility management system to manage loads is between four and six years

Energy facts about the retail industry today

Profile of energy demand in retail stores

Most retail owners know that good energy management practices mean good business. However, good practices are more than just turning off lights when not in use. With more retailers than ever implementing energy management policies, retailers know that reducing energy consumption is critical to maintaining a profitable business.

In the United States, there are approximately 657,000 retail buildings — a number that represents about 13.5 percent of all U.S. commercial space. Retail facilities consume approximately \$21 billion worth of energy annually.¹ On average, a retailer's energy costs account for anywhere from three to eight percent of its total operating expense.

According to the Energy Information Administration (EIA),²

Retail buildings are the second highest consumer of energy among all building types. Across the country, the average annual energy intensity for retail properties is 81.5 kBtu per square foot and the average cost is \$.57 per square foot. Of the total energy consumption, 67% is for electricity and 33% is for natural gas and other fuels. This translates to 16.1 kWh per square foot of electricity and 0.27 therms per square foot of natural gas.

As shown in Figure 1, a supermarket's refrigeration, HVAC, and lighting represents the heaviest areas of demand in retail facility. Among these factors, lighting accounts for 23 percent of the total energy consumption, not including its effect on cooling loads. On the other hand, big box retail stores' operations are not usually energy intensive when it comes to lighting (based on a square foot basis), but due to their large size and longer hours of operation, they generate substantial energy bills. So, controlling lighting levels is a good starting point for energy reduction efforts with payback of all attractive costs related with the changes. Implemented correctly, energy efficiency can be considered as a more effective way of increasing quality and productivity in retail than almost any other potential investment.

Substantially reducing the electric lighting load will also reduce the cooling load of the building. Much of the energy utilized by the lighting system results in heat being added to the conditioned space, which causes the HVAC system to work harder and longer. Therefore, introducing daylighting into the building can significantly reduce cooling loads.

Skylighting then becomes an important contribution to daylighting the space. Because daylight introduces less heat into a building than the equivalent amount of electric light, turning off electric lights when sufficient daylight is available can save a significant amount of lighting energy and cooling costs.

Energy conservation through daylight harvesting

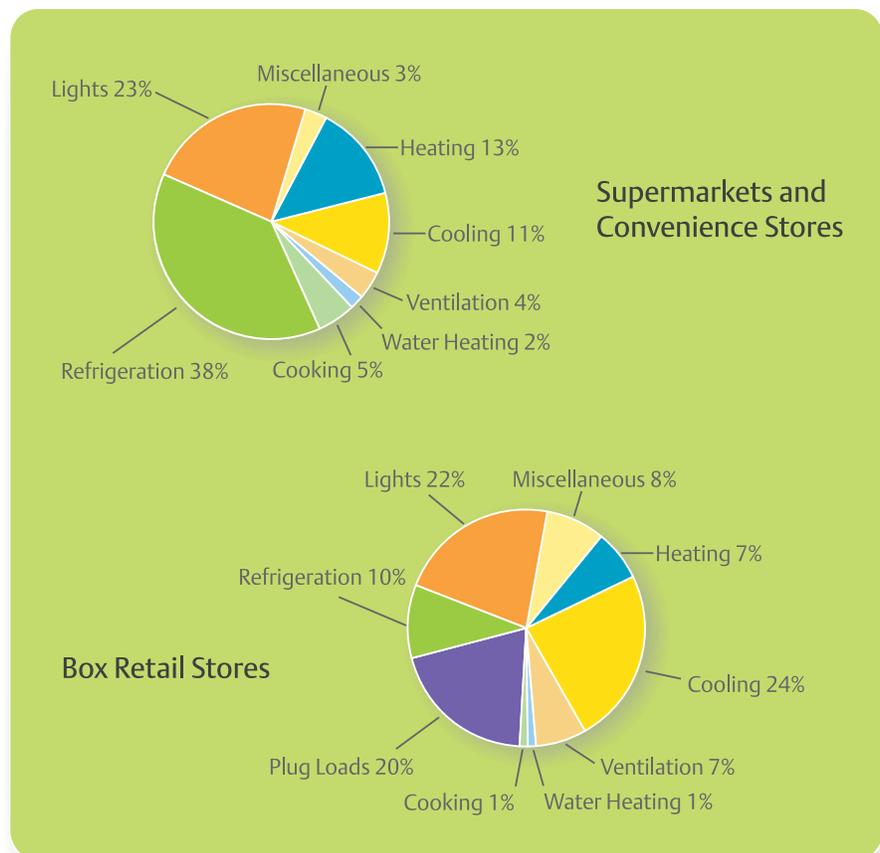
Lighting plays a major role in the identity, visual quality, and comfort of a retail store. In most cases, lighting design is an expression of a retailer's style and branding. It works in harmony with other design components to highlight the store's products, and exhibit an image that characterizes the store's selling strategy. In boutiques, for example, the image of sophistication is created through accent lighting, rather than general illumination.

Many conventional display lights generate high energy consumption. Imagine the cost associated with several incandescent reflector lamps, which typically add up to 750 to 1,500W each and remain on at least 15 hours a day.

To conserve energy in retail stores, lighting systems must be carefully designed to preserve high lighting quality. An efficient lighting strategy, including natural daylight, can provide proper levels of illumination and reduce energy costs. Achieving these benefits usually requires integration of natural and artificial lighting sources early in the building design process. Natural daylight is one of the most important elements in creating a low-energy building in many climates.

Figure 1

Typical energy consumption outlay for retail facilities³



Daylight harvesting and its impact on retail operational savings

What is daylight harvesting?

The concept of daylight harvesting is relatively straightforward. It pertains to a controlled admission of natural light into an environment, with the intent of limiting or eliminating electric lighting. This lighting control strategy utilizes one or several photosensors to detect ambient daylight levels and automatically adjust the artificial lighting output level to reach the desired illumination. This proven method of lighting improves the indoor environmental quality. The main reason daylight harvesting has become a buzz word in the retail industry today is because of the associated energy savings, which may range from 35 to 60 percent.⁴

When the concepts of sustainability and green building design took center stage in the retail industry, the idea of daylight harvesting appeared relatively new. Actually, daylight harvesting is an old concept. Using sunlight to provide ambient light is the most basic form of illumination, dating back thousands of years. Up until the 1960's, building designers and architects designed a building's reflective lighting plan around the use of natural light from glass windows, clerestories, skylights, and roof monitors. While there is a remarkable interest in using direct sunlight in buildings to reduce energy consumption, direct sunlight creates potential problems of overheating and visual discomfort resulting from glare conditions.

Contrary to popular belief, daylight harvesting is not simply using skylights, which allow the light to pass through and go where it wants. Although a lighting designer may utilize skylights, daylight harvesting uses a combination of reflective "lightwells", lenses, diffusers, and lighting controls to precisely introduce light into an area.

Benefits realized

Daylight harvesting can provide many benefits to retail store owners:

- **Energy Savings** – Daylight harvesting can reduce lighting related energy consumption by 35 to 60 percent.⁵ Daylight also produces less heat per unit of illumination than most artificial light sources, reducing the load on HVAC systems.⁶ Moreover, in a conference paper presented at the American Council for an Energy-Efficient Economy, experts said, “It is estimated that daylighting will reduce the artificial lighting load by 79 percent, compared to the base-case model.”⁷
- **Improved Color Rendition** – Daylighting is an ideal strategy to eliminate distortion of color perception in a production environment because it provides true full spectrum natural light using the Color Rendering Index (CRI). CRI is a quantitative measure of the ability of a light source to reproduce the colors of various objects faithfully in comparison with an ideal or natural light source.⁸ The color rendition of daylighting is 100, and because daylighting uses natural light, no artificial light source can match its CRI. Simply put, high quality light is provided without putting a strain on energy consumption and production.
- **Increased Sales** – The effect of daylighting on sales shows a significant correlation between variables. Studies show that daylight harvesting can dramatically enhance a store’s appearance, as well as its merchandise appeal, thus attracting and retaining shoppers. In 1998, a study was conducted on a chain retailer with skylights at two-thirds of its sites. The study showed that, over an 18-month period, “stores with skylighting were found to sell 40 percent more than the equivalent non-sky lit stores.”⁹ Through daylight harvesting, windows provide visual relief, a contact with nature, time orientation, and the possibility of ventilation.
- **Safety** – It is important to understand that safe, sustainable facilities don’t happen by accident. The level of safety and sustainability integrated in a retail store varies greatly on several factors. But achieving safety, while incorporating daylighting into the building, is more than just exposing occupants to natural light. Daylighting contributes to the safety of the occupants by shedding light on dark corners. This can also help retailers avoid workplace injuries.
- **Building Value and Marketability** – Higher building value is generated from lower operating costs. Value in a commercial building is determined by Net Operating Income (NOI), not by how much it cost to construct the building. The most common way to increase NOI is to reduce operating expenses such as maintenance, management, energy, vacancy, credit losses, and insurance. Use of daylighting in the store is a great way to lower operating expense, thus, boosting NOI.
- **LEED Certification** – Incorporating daylighting into a building’s design can earn LEED credits. Daylight harvesting can touch on several areas of LEED certification, such as energy and atmosphere, indoor environment quality, and innovation and design. Daylight harvesting can earn between eight and 22 points in these areas, which will be used to achieve a LEED certification level.

Types of daylight harvesting in retail facilities

There are three types of daylight harvesting: sidelighting, toplighting, and optical systems.

1. Sidelighting

The most common example of daylight harvesting is sidelighting (Figure 2). It is most often used in store fronts. The distribution of daylight tends to be uneven, with large amounts of daylight in areas close to windows and decreasing amounts further away. In this situation, it is desirable to control light fixtures adjacent to the windows (also called glazing) separately from those further back from the window area to obtain maximum energy savings while still providing the necessary illumination levels.

Figure 2

Vertical glazing



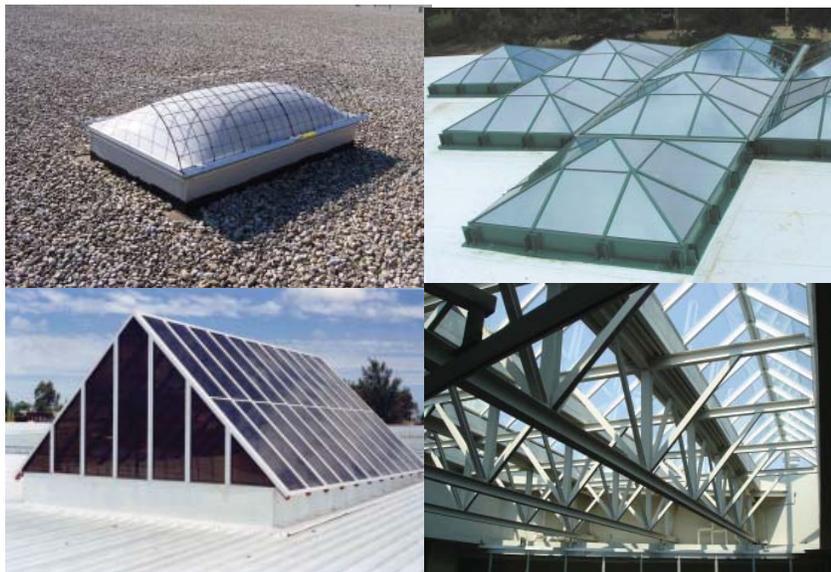
2. Toplighting

Toplighting, commonly used in warehouses, schools, and offices, utilizes rooftop apertures (typically skylights) to introduce daylight into a space (see Figure 3). Rooflights may be used for providing daylight to the top floor of multi-story buildings or to the core of single-story buildings. Compared to horizontal windows, they offer a number of advantages:

- Lighting from above is generally more natural and efficient.
- Complete lighting uniformity can be easily achieved.
- Reduced likelihood of obstructions, such as trees or other buildings.
- Maximum available lighting at all times, since roof lights face the brightest part of sky.
- Through programmed solar tracking or light sensors in the dome, the movement of the sun can be tracked, repositioning reflectors throughout the day to maximize efficiency.
- In courtyards and atriums, it helps occupants feel connected to the outdoors at all times of the day.
- Through light-wells, the character of the building can be completely changed.

Normally, three to five percent of the roof area (also known as aperture area) devoted to skylights is enough to turn off all floor lighting during the daylight hours. This is an attractive option that many retailers may find hard to resist, especially if their main goal is to save energy and improve their bottom line.

Figure 3
Toplighting



3. Optical Systems

This type of daylight harvesting uses a tubular daylighting device or fiber optic system that provides optically-controlled daylight to modern buildings. As shown in Figure 4, the tubular daylighting device is a round tube lined with highly reflective material that leads the light rays through a building, starting from an entrance-point located on its roof to its terminus. Fiber optic technology brings light into spaces that cannot normally be reached by sunlight (see Figure 5). This particular system is an evolving technology that may offer feasible solutions for retailers. Fiber optic daylighting uses fiber optics, together with solar light collectors, to diffuse daylight to spaces commonly hard to daylight using either of the previously discussed strategies.

Unlike toplighting, which normally has three to five percent aperture area, retailers can apply optical systems to provide sufficient daylight with only one to one and a half percent aperture area.

Figure 4
Tubular daylighting device



Figure 5
Fiber bundle



Daylighting may increase sales

Studies have shown that there is a strong correlation between natural daylight and increased sales. In 2003, the California Energy Commission, in line with its Public Interest Energy Research (PIER) program, released a technical report titled *Daylighting and Retail Sales*. It outlines their findings of a study involving 73 chain stores, of which 24 stores had a significant amount of daylight. Statistical models were used to examine the relationship between average monthly sales levels and the presence of daylight in the stores, while simultaneously controlling for more traditionally explanatory variables, such as size and age of the store, amount of parking, local neighborhood demographics, number of competitors, and other store characteristics. Results showed the “average effect of daylighting on sales for all daylit stores in this chain was variously calculated from one to six percent, depending on the type of model and time period considered.”¹⁰ In fact, based on the group’s statistical analysis of the study’s variables, it was discovered that “daylight [has] 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.”¹¹

In addition to increased sales, these studies showed that the primary stimulus for retail operators to include daylight harvesting was the need to save also on energy costs. Photo-controls were used to turn off electric lights when sufficient daylight levels were detected. These tools significantly reduced operating costs. Daylighting produced substantial dollar savings for the participants.

Incorporating daylighting into a retail space

Considerations for daylighting

Lighting is an important element of any building. Appropriate lighting enhances the aesthetics of indoor spaces and provides illumination for tasks and activities. With an efficient lighting strategy like daylight harvesting, proper levels of illumination and reduced energy costs can be achieved. However, in order to achieve these benefits, it is important to integrate certain considerations for daylighting into the early part of the building design process.

Before designing a daylight harvesting system, it is important to consider the following elements first:

1. Electric Lighting Systems

A mixture of light sources can create a pleasing and comfortable environment that is energy efficient and suitable for a variety of tasks. Electric lighting should be coordinated with a daylighting strategy or adjusted in response to it. A typical electric lighting system includes lamps, ballasts, and luminaires or lighting fixtures.

For general illumination in retail establishments, fluorescent lighting provides an efficient option with moderate color quality. To achieve good performance characteristics while simultaneously reducing energy usage, it is important to consider the different types of lamps and ballasts since each type has different performance characteristics. The specific type of lights used depends on the type of tasks being performed in the space.

2. Lighting Controls

The main goal of lighting controls is to eliminate energy waste, while enabling lighting to support activities in the environment. Lighting controls are designed to turn on the right amount of light where and when it is needed, as well as turn lights off when they are not needed.

Lighting controls support this goal in two ways:

- Lighting controls provide flexibility in adapting the lighting system to different uses.
- Lighting controls provide the ability for users to adjust light levels based on changing needs or individual preference, either through dimming, or multi-level switching. Dimming provides the greatest amount of flexibility in light level adjustment.

An effective control system ensures that the lighting system operates—and consumes energy—only when it's needed, therefore saving the owner money. Determining when the lighting system should be operating depends on how the space is occupied. Generally, either a time schedule, a threshold event, or a combination of factors should be considered in turning lights on or off.

If occupancy is predictable, a time schedule should be considered. For example, the schedule might automatically shut off the lights by area, by floor or in an entire building.

If occupancy is not predictable, a threshold-event-based strategy should be considered. For example, occupancy sensors can be used to automatically turn lights on and off, depending on whether the sensor detects the presence of people in the monitored area. The lights could then be programmed to turn off after a set time when people are not detected.

By ensuring the lighting system provides light only when it's needed, the control system can significantly reduce wasted energy, and improve the building's profitability for the owner.

3. Control Methods

Since daylight is generally available during hours when most commercial buildings are occupied, daylighting is often a feasible primary source of illumination. However, if all lights are on when there is ample daylight available, then no energy is being saved and the owner is wasting money. If the building is heated or cooled, daylighting may even result in a net increase in energy consumption if the proper controls are not present due to the added heat delivered by the electrical lighting that is providing unnecessary light.

The first step in designing a daylight harvesting control system is to select the control method. Two control methods are available — dimming and switching.

The advantages of switching include a lower initial cost, simpler design, and faster commissioning. Its disadvantages include typically lower energy savings and less flexibility than continuous dimming. Abrupt changes in light levels are also possible, and can be considered irritating by occupants — even if they understand the benefits associated with the changes.

Dimming is continuous over the dimmable ballast's range, allowing a wide range of light output. Although the cost of dimmable ballasts is falling, dimming can cost about twice as much as switching. However, dimming is preferable for many applications because the lighting changes are not as noticeable, and are therefore more acceptable to occupants.

Due to their advantages and disadvantages, switching is often recommended for spaces with a transient population. Continuous dimming is often recommended for spaces where users are more stationary or occupy the space for longer periods of time.

Photosensors automatically adjust the light output of a lighting system, based upon detected ambient luminance. The technology behind photosensors is the photocell — a light-responding silicon chip that converts incident radiant energy into electrical current.

While some photosensors only turn lights on and off with a discrete signal, others provide an analog signal to a controller capable of dimming lights. Automatic dimming can help with lumen maintenance, which involves dimming luminaires when they are new. The power supplied to the luminaires is gradually increased to compensate for minor light loss as the lamp ages.

Nearly all photosensors are used to decrease the electric power demand for lighting. In addition to lowering the electric power demand, dimming lights also reduces the thermal load on a building's cooling system. Any solar heat gain that occurs in a building during the day must be accounted for during a complete analysis of a building's energy usage.

4. Establishing Control Zones

Lighting controls support the lighting system, introducing light when it is needed. However ensuring the light is provided where it is needed often requires establishing control zones. A lighting control zone is simply a light fixture or group of fixtures, controlled simultaneously as a single entity by a controller. Zones are typically established based on types of tasks to be lighted, lighting schedules, types of lighting systems, architectural finishes/furnishings, and daylight availability. In daylight harvesting applications, zones are established based on a combination of factors.

Perhaps the most important factors in determining control zones are ensuring that the light fixtures in each zone receive a consistent amount of daylight at any given time, and all parts of the illuminated area have a consistent light level requirement. Since each control zone adds cost to the building, the challenge is to minimize the number of control zones while ensuring maximum response of the control system to daylight availability.

Zoning can be accomplished in a number of ways. One effective way to facilitate logical control zones in new construction is to plan light fixtures' circuit wiring around daylight sources, such as windows and skylights. Daylight control zones should be switched separately from other zones, such as HVAC or security zones.

It is important to note that the greater the desired response range of the control zones, the smaller they must generally be. For example, a control system can turn the lights on automatically when a person enters a building during non-operating hours. Only the areas in use by this person should be lighted, not the entire floor. A zone can also be as small as a single ballast or light fixture, which enables the greatest amount of control flexibility. To enable, this, each user could be provided access to the lighting control system via PC or handheld remote to dim his or her own lighting to their personal preference. However, most operators would probably consider the cost associated with such a system prohibitive.

Generally, the smaller the control zone, the greater the potential range of lighting output. This typically corresponds to larger utility cost savings, and a greater capability for the lighting system to support users' visual needs.

5. Window Designs

According to the U.S. Department of Energy, the daylight that arrives at a work surface comes from three sources: the exterior reflected component, which includes ground surfaces, pavement, adjacent buildings, wide windowsills, and objects; the direct sun/sky component; and the internally reflected component. Once daylight enters a room, the surrounding wall, ceiling, and floor surfaces are important light reflectors. Highly reflective

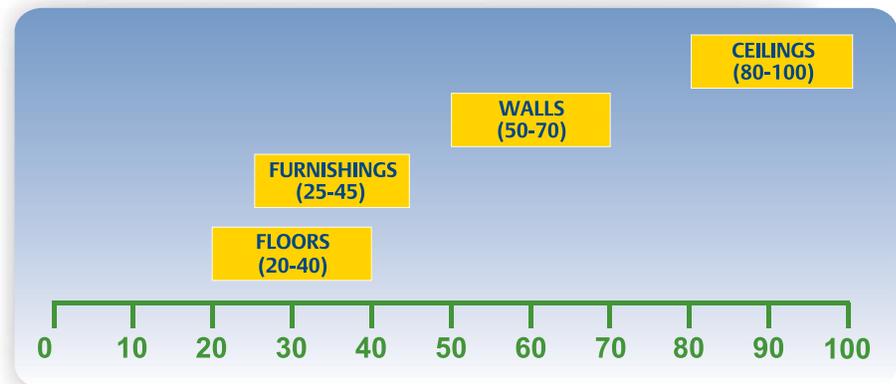
surfaces will better spread the daylight around the room, and will reduce extreme brightness contrasts.

When considering window design, it is important to note that the window frame materials should be light-colored to reduce contrast with the view, and have an anti-glare finish. The window jambs and sills can be beneficial light reflectors as well. Deep jambs should be splayed or angled toward the interior to reduce the contrast around the perimeter of the window.

Retailers should also remember that the most essential interior light-reflecting surface is the ceiling. Highly reflective paints and ceiling tiles are now available with .90 or higher reflectance values. Tilting the ceiling plane toward the daylight source increases the daylight that is reflected from this surface. In small rooms the rear wall is the second most important surface, because it is directly facing the window. This surface should also be a reflective matte finish. The sidewalls and floor have less impact on the reflected daylight in the space.

Store furnishings, such as display cases, can have a significant impact on reflected light, so retailers may prefer to select light-colored materials.

Figure 6
Suggested reflectance levels for various room surfaces



Since light essentially has no scale for architectural purposes, the proportions of the room are more important than the dimensions. A room that has a higher ceiling, compared to the room depth, will have deeper penetration of daylight whether from side lighting (windows) or top lighting (skylights and clerestories). Raising the window head height will also result in deeper penetration and more even illumination in the room. Punched window openings, such as small, square windows separated by wall area, result in uneven illumination and harsh contrast between the window and adjacent wall surfaces. A more even distribution is achieved with horizontal strip windows.

Figure 7
Punched window openings



Figure 8
Horizontal strip windows



6. Effective Aperture

Retailers must also consider the relationship between visible light and the size of the window. One way to do so is through the Effective Aperture method. The Effective Aperture (EA) is defined as the product of the visible transmittance and the window-to-wall ratio (WWR). The window-to-wall ratio is the proportion of window area, compared to the total wall area where the window is located. For example, if a window covers 25 square feet of a 100 square-foot wall, then the WWR is 25/100 or 0.25. A good starting target for EA is in the range of 0.20 to 0.30. For a given EA number, a higher WWR (larger window) results in a lower visible transmittance.

7. Design Coordination

When using daylighting, the electrical lighting and interior design require special consideration. When considering artificial lighting, it is important to note that the coordination of the artificial lighting system with the daylighting design is critical for the success of the overall building. The layout and circuiting of the artificial lighting should correspond to the daylight aperture. In a typical sidelighting design with windows along one wall, it is best to place the luminaires in rows parallel to the window wall and circuiting so that the row nearest the windows will be the first to dim, or switch off, followed by successive rows.

For interior design, it is important that those responsible for interior finishes and furnishing must be aware of the desired reflectance values in order to maintain the intended performance of the daylighting system. Dark interior finishes can unintentionally compromise an otherwise great daylighting design.

Role of federal government, states and organizations in daylight harvesting

Code compliance

With increasing energy costs and innovative, enhanced products, building engineers and architects are developing buildings that allow more natural daylight than ever before. Generally, more than 20% of the total power consumption in a retail store, particularly in supermarkets and convenience stores (see Figure 1), goes to lighting. By engaging their engineer and architect in advanced building design, retailers can significantly cut their operational costs – particularly in energy consumption. This is the main reason why many state’s provisions on energy code mandate effective lighting controls.

In order to promote energy conservation and encourage retailers to comply with building codes, the federal government has created incentives for green buildings and their associated components (i.e. daylight harvesting). Through Leadership in Energy and Environmental Design (LEED®) and the EPA’s Commercial Building Tax Deduction Act of 2005, architects and retailers are recognizing mandated energy efficiency as a business opportunity as well.

Daylight harvesting is mandatory for certain spaces under many energy codes (Table 1).

Table 1

Energy Codes						
Lighting Controls	California Title 24 (2005)	New York State Energy Code	IECC (2003)	Oregon State Energy Code	Washington State Energy Code	ASHRAE 90.1 (2001/2004)
Automated Shut-off	•	•	•	•	•	•
Space Control	•	•	•	•	•	•
Exterior Lighting Control	•	•	•	•	•	•
Light Level Reduction Control	•	•	•			
Daylight Harvesting	•			•	•	

Tax incentives for daylight harvesting

Daylight harvesting systems offer multiple tax savings opportunities. A recent tax law change, as mandated in the Energy Policy Act (EPA) of 2005, provides a tax credit to improve the energy efficiency in buildings. Code Sec 179D provides up to \$1.80 per square foot in immediate tax deductions for building investments that achieve specified energy cost reductions above ASHRAE 2001 building energy code standards.¹² The EPA's act provides two paths to obtain tax savings for lighting controls: free riding path and modeling.

- Free Riding Path¹³

Those facilities that already have energy efficient lighting at the EPA's qualifying level can obtain an immediate tax deduction of up to 60 cents per square foot using the free riding path, provided they meet all of the normal lighting project requirements set forth by the EPA.

With free riding, the energy performance of the existing lighting platform are taken into account. The EPA permits a tax deduction, provided there is a new lighting investment. Many companies that already have energy efficient lighting are using free riding to obtain tax deductions for investments in further energy reducing lighting, daylight harvesting, or energy management technologies.

- Modeling¹⁴

With the EPA's computer simulated energy modeling option, the amount of the tax deduction is a direct function of the energy reduction accomplished by the daylighting system. In general, the greater the window to wall ratio, the greater the amount of energy and tax savings. Simply stated, with more windows, retailers can get more daylight, save more electrical costs related to artificial lighting, and get a larger tax deduction. To document compliance with the modeling requirements, taxpayers must use approved modeling software. Computer modeling software can determine the optimal number, usually quantified as Effective Aperture. This varies according to climate, latitude, and the characteristics of the skylight, but it is usually four to eight percent of floor area.¹⁵

Unique concerns of retail operators

Daylight harvesting projects – succeed or fail?

Several studies on daylight harvesting projects were able to determine whether these projects are actually living up to their potentials. In Craig DiLouie's white paper,¹⁶ he described the results generated from these studies. In a particular study, he cited that:

- Savings from automatic daylighting control systems are often not fully realized when a building is turned over to users. This is because users change original setpoints to non-optimal parameters, reducing energy savings.
- Daylighting performance needs attention and evaluation from multiple design disciplines during the design development and construction process.
- Users are not educated about installed control systems; when something does not work, users often disable the system instead of fixing the problem.

Based on these premises, he concluded that daylight harvesting projects often fail because there is a lack of coordination or understanding between the design disciplines and end users. He also explained that the improper location of daylighting controls, as well as inadequate specification of control systems, component parameters and sequences of operation, can also bring about failure. In some instances, DiLouie said that daylight harvesting projects may also fail because of inaccurate or incomplete shop drawings made by contractors, or the fact that systems are not checked or commissioned thoroughly. Also, field changes made when commissioning a system are not documented and taken back to the designer to complete the feedback loop.

With these problems, the most common failure modes identified in the study are:

- Under-dimming, which results in less than expected energy savings.
- Lights left on at night, which results in less than expected energy savings.
- Frequent cycling of dimming or switching, which results in occupants irritation.
- Over-dimming, which results in occupants irritation.

Given all the facts generated in the study, the researchers concluded that for daylight harvesting projects to succeed, they must do the following:

- Conduct a daylight simulation, and use these plans when designing the lighting system and its controls.
 - Prepare plans that document daylight zones and establish independent control zones that work optimally with these daylight zones.
 - Locate the photosensor on the reflected ceiling plans and interior elevations.
 - Identify light fixtures that are controlled by individual sensors or controllers.
 - Write daylighting controls instructions for building operators/contractors.
 - Require the contractor to submit shop drawings based on design documents, and review with the retailer.
 - Include the requirement for calibration and commissioning of controls in the specifications, and require calibration logs to be submitted by the contractor for approval by the design engineer.
 - Provide the building operator with training by the controls manufacturer.
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Getting ahead of basic energy controls – practical control strategies for retail

Daylight design essentials

Designing a daylight harvesting system begins with development of an initial concept. Decisions made in the early stages about control methods and the type of daylighting strategy employed can have a significant impact on reducing energy consumption.

The ultimate objective of daylighting is to achieve multiple benefits and high performance at a lower cost than the combined components. To determine some design essentials, here are the five key questions:

- How is daylighting operating in the store?
- Is the daylighting strategy selected operating within the design parameters?
- How much lighting energy is currently being used, where and why?
- Where are the biggest opportunities, and what are their key factors?
- How many hours of useful daylight are needed?

Emerson Climate Technologies Retail Solutions begins with the concept design and floor plan. Working with Clive Samuels & Associates, they develop energy-efficient facility designs that are customized to a building's environment and help sustain long-term building efficiency. The team's design capabilities cover several key areas that impact the long-term operational efficiency of buildings:

- HVAC
- Refrigeration
- Electrical Power & Lighting
- Model-based Building Analysis
- Energy Management Systems
- LEED® Certification
- Project Ideation/Conceptualization
- Engineering & Oversight
- Turnkey Implementation

Retail Solutions starts with a floor plan and develops a customized, scientific, itemized breakdown of energy usage, delving into all the relevant components.

Retail Solutions provides the following services:

- Develop drawings for optimized facility selection and placement.
- Calculate tonnage and wattage for HVAC, refrigeration, lighting and other items.
- Recommend equipment choices.
- Manage the engineering project from start to finish, partnering with architectural contractor companies.
- Monitor, measure and manage energy after project completion.

Enabling all aspects of facility control, Emerson's E2 series of facility management systems delivers integrated control of all HVAC and refrigeration equipment, lighting systems, and more. Integrated into the E2, Retail Solutions' power management equipment minimizes power consumption throughout the day by integrating smart power monitoring equipment with the store's facility management system. At the same time, automatic transfer switches monitor, control and distribute backup power to everything from security and HVACR systems, to cash registers and lighting equipment — all to ensure uptime and maximum reliability.

Clive Samuels & Associates is ready to help retailers develop their daylight harvesting concepts, analyze existing facilities, and provide innovative new solutions. The firm includes a network of highly experienced senior engineers, working in state-of-the-art facilities to provide comprehensive heating, cooling and refrigeration engineering, design and testing services for retailers and other commercial facilities. Backed by the resources and strengths of Emerson Climate Technologies, the company provides affordable, forward-looking customized solutions that take advantage of industry-transforming technologies. They can easily manage an entire project from start to finish, or manage individual segments within a more comprehensive project.

With extensive expertise in 2D and 3D solid modeling, Clive Samuels & Associates helps customers explore their facility's performance prior to construction. This reduces construction time and initial cost, while reducing the number of change orders and problems on the job site.

Conclusion

Daylight harvesting is a very efficient operational strategy when implemented correctly. Keep in mind that an effective lighting strategy, such as daylight harvesting is not a commodity, nor is it a cost. The lighting control system should take advantage of the control strategies outlined in this paper, and should be well understood by the system's end users.

Although statistical data shows significant correlation between variables, resulting in significant increases in sales, learning and understanding scientific studies may not be as important as obtaining the design characteristics of a high performing daylighting design from a knowledgeable designer who has extensive daylighting experience. Increased sales can be achieved by a well engineered and maintained lighting control system in a store that can provide a short return on investment, as well as profitability for years to come.

With the growing demand for energy efficiency around the world, integrating the principles of daylighting enables designers to create a more comfortable and convenient retail store operation. Emerson's Retail Solutions group works with retailers on the following:

1. Conducting a daylight simulation.
 2. Preparing plans.
 3. Installation and Commissioning of controls.
 4. Monitoring settings and system conditions.
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Footnotes

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 - ² EIA, “National Action Plan for Energy Efficiency Sector Collaborative on Energy Efficiency – Retail Store Energy Use Profile.” 18 Dec. 2008 <epa.gov/cleanenergy/documents/sector-meeting/4biv_retail.pdf>
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 - ⁹ Northeast Energy Efficiency Partnerships, Inc. “Retail Skylighting Know How.” 12 Jan. 2009 <www.pge.com/includes/docs/pdfs/shared/edusafety/training/pec/daylight/>
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About Emerson

Emerson (NYSE:EMR), based in St. Louis, Missouri (USA), is a global leader in bringing technology and engineering together to provide innovative solutions to customers through its network power, process management, industrial automation, climate technologies, and appliance and tools businesses. Emerson's sales in fiscal 2009 were \$20.9 billion. The company is ranked 94th on the Fortune 500 list of America's largest companies. For more information, visit www.Emerson.com.

About Emerson Climate Technologies

Emerson Climate Technologies, a business of Emerson, is the world's leading provider of heating, ventilation, air conditioning and refrigeration solutions for residential, industrial and commercial applications. The group combines best-in-class technology with proven engineering, design, distribution, educational and monitoring services to provide customized, integrated climate-control solutions for customers worldwide. The innovative solutions of Emerson Climate Technologies, which include industry-leading brands such as Copeland Scroll and White-Rodgers, improve human comfort, safeguard food and protect the environment. For more information, visit EmersonClimate.com.

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Retail Solutions, a part of Emerson Climate Technologies, is a leading provider of facility management systems and facility services. For more than 20 years, the company has been at the forefront of developing new technology and trends in refrigeration systems, building HVAC, lighting controllers, refrigerant leak detection and more. Retail Solutions provides such valuable programs as turnkey project management, energy reduction and monitoring services as well as E-Commissioning™. Retail Solutions customers include some of the top supermarket, convenience and drugstore chains in the United States, Australia, South America, Europe and Asia. Retail Solutions headquarter is located in Atlanta, Georgia. For more information, visit www.EmersonRetailSolutions.com.

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