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The use and environmental impact of daylighting

Frank Sharp*, Doug Lindsey, Jeff Dols, Josh Coker

EPRI, United States

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ABSTRACT

With an expanding population and finite natural resources, it is critical to develop and implement energy-saving solutions that meet the needs of society without impacting future sustainability. LEED (Leadership in Energy and Environmental Design) certification is an effort to promote the selection and use of high-efficiency products. Within LEED, the use of energy-efficient lighting and daylighting (the use of natural sunlight for indoor lighting applications) is a focus.

Daylighting is an area of significant research within the lighting industry and one of the largest areas of interest for those pursuing LEED certification. If designed and implemented correctly, daylighting can deliver environmentally neutral lighting to interior spaces. Once a daylighting system is installed, there is no ongoing impact as there is no pollution, no sources to maintain, no energy drawn, and little fixture maintenance required over the life of the product.

There are a variety of daylighting designs in the marketplace, but limited information on how or where they are best utilized. If not properly utilized daylighting can result in ineffective lighting and unsatisfied consumers. Ineffective daylighting designs may cause users to revert back to more environmentally taxing lighting solutions. Additionally, ineffective implementation of daylighting can create a negative view of efficient lighting.

This paper evaluates the design and implementation of various daylighting systems. It discusses three primary designs: skylights, solar concentrators, and tubular daylighting devices. Each design has unique uses and limitations. This paper is a brief guide to assist in the understanding and selection of daylighting technologies.

1. Introduction

Daylighting, as defined by the Illuminating Engineering Society, "refers to the art and practice of admitting beam sunlight, diffuse skylight, and reflected light from exterior surfaces into a building to contribute to lighting requirements and energy savings through the use of electric lighting controls" (IESRP-5-13, 2013). Throughout history, the ability to deliver and utilize light within interior spaces has been critical for the advancement of humanity and the improvement of both the lifestyles and working conditions of people. It is difficult to imagine modern society without interior lighting. In fact, many of our daily tasks would be extremely inconvenient or difficult to complete in the varying environmental conditions of the outdoors. Properly utilized interior lighting allows for people to safely and effectively complete a range of tasks regardless of the time of day or exterior conditions.

Due to the importance of interior lighting within society, the proper use and application of light is an area that requires greater attention and study. Throughout history, there have been limited means of delivering light to interior spaces or of lighting tasks after sunset. Electric lighting products were first produced in the late 1800s, and the technology was the subject of rapid expansion. During the early 1900s, the use of electric lighting expanded rapidly, resulting in these products becoming more affordable, more reliable, and more prevalent. This allowed for the use of electric lighting in interior spaces, which offered a popular alternative to the gas lighting of the day. However, concern about proper utilization of electric lighting was sometimes ignored for the sake of convenience. This simplified approach often ignored key issues that exist in the application of electric lighting. Today, with more lighting technologies and choices than ever before, each application should be individually studied and appraised. Lighting is no longer an area where one solution can be applied universally for all ranges of applications. However, due to the complexity of modern

* Corresponding author. 942 Corridor Park Blvd., Knoxville, TN 37922, United States. Tel.: +1 865 218 8055.
E-mail address: fsharp@epri.com (F. Sharp).

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lighting, further investigation to find the correct technology for a given application comes with its own challenges.

As anyone who has studied lighting design and application will attest to, providing sufficient lighting in a space or for a particular task can be complicated. Although many applications have similarities, each environment has unique needs or challenges. Some challenges may include the size or height of the space, occupant needs, budget, maintenance considerations, using natural light, building wiring, and others. Handling these unique components of a space becomes even more complex when the personal preferences of humans get involved. Some people prefer more or less light, a specific color temperature (CCT), or color rendering index (CRI). These vary greatly between lamps, fixtures, and associated lighting technologies. These competing interests mean that any lighting project can become a battle between the involved entities (building owner, facilities management, employer/corporate agent, lighting designer, and lighting consumer/end user).

1.1. Concerns with electronic lighting

Today, all electrical loads are under scrutiny to verify the proper balance between the consumption and utilization of power. With the limitations of natural resources and the advancement of new technologies, reducing energy usage has become an immediate concern. In decades past, the power consumed by lighting was not of primary concern because lighting was seen as a necessity, and there were no other replacement options. While electric lighting continues to provide many advantages and benefits, the fact that lighting is a large consumer of electricity has become a major issue (Leslie et al.). The state of California has a lighting plan to reduce 60–80% in electrical lighting energy consumption by 2020 (Papamichael, 2013).

In addition to reducing the power consumption of lighting, there are other components of electrical lighting that need to be addressed and studied. These include light levels, light spectrum, and impacts of artificial lighting on humans. In many applications, occupants may accept an inefficient, or unproductive, lighting environment because they do not realize it can be improved, or they do not know how to improve it. The following sections will provide further information on each of these issues.

1.1.1. Power consumption

In commercial applications, lighting can be 30% or more of the monthly power consumption (U.S. DOE, 2012). Within residences, lighting is typically 8–10% of the monthly load. This residential percentage may not seem significant, but when one considers the number of homes within the United States, the residential lighting load is a substantial part of national electricity consumption. When looked at as a whole, lighting accounts for approximately 18–23% of all electricity within the United States (U.S. DOE, 2012). Due to this large load, lighting is an area where significant energy savings can be found.

Electric lighting technologies have greatly advanced in recent years to provide high-efficiency replacements to traditional lighting technologies. Compact fluorescent lamps (CFLs) (EPRI, 2003a, 2003b, 2007), light-emitting diode (LED) lamps (EPRI, 2011, 2012a, 2013), reduced-consumption halogen (RCH) lamps (EPRI, 2012b), and 2x incandescents (EPRI, 2012c) have provided consumers with the means to reduce power usage for lighting. These technologies are far more efficient than the standard incandescent technology, but they still consume some power. Daylighting, the use of natural sunlight for indoor applications, provides an even greater opportunity to deliver power savings and reduce loads during peak hours by redirecting the already existing outdoor light to indoor applications. After purchase and installation, many daylighting designs are off the power grid completely, so any light delivered saves money. In order to further reduce the amount of energy consumed by lighting, daylighting options should be seriously considered as primary light sources or at least light-assisting devices.

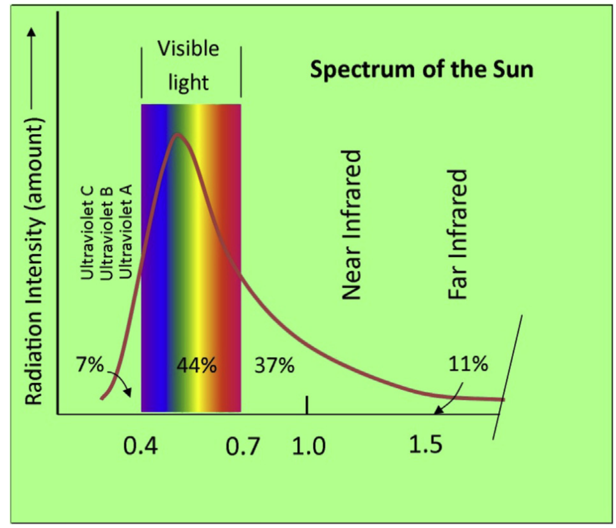

Fig. 1. Wave length of natural sunlight.

1.1.2. Light levels

Over-lighting can be as large of an issue as under-lighting. OSHA 1926.56 (OSHA 2008) calls for a minimum of 30 foot-candles for offices, a minimum of 10 foot-candles in mechanical and electrical equipment rooms, and a minimum of only 5 foot-candles in warehouses, corridors, and hallways. Although these minimum levels are well known and established, it is not uncommon to find offices with double to triple the mandated minimum. This can also be true in equipment rooms, hallways, corridors, and warehouses.

These over-lit spaces can result in a source of moderate power savings when light levels are reduced to appropriate levels. Numerous tests have shown that most employees do not notice reduced light levels within their office if the change is made without their knowledge, or whether dimming of their lights occurs slowly over a period of time – such as one percent every few minutes. Of course, as light levels are reduced, it is critical to maintain a light level that is safe and appropriate for the work in the space. It is also necessary that some consideration be given to the age of people that will occupy a space. For example, older workers may require greater amounts of light due to their aging eyes (DiLaura et al., 2011). In some cases, one lost hour of productivity or production due to improper lighting could more than offset a year's worth of power savings from reduced lighting consumption.

1.1.3. Light spectrum

The spectrum of artificial lighting is something many are beginning to consider when lighting a space. Although typically overlooked, this is a key characteristic for establishing and maintaining appropriate lighting within a space. The sun produces a broad spectrum of light, providing sufficient wavelengths for most people to perceive most colors. For this reason, light from the sun is defined as having a color rendering index (CRI) of 100, which is the maximum value a light source can achieve, and a CCT of approximately 5000 K (DiLaura et al., 2011). As the CRI of a source is reduced, it becomes more difficult for the human eye to accurately