Appendix B. Lighting

OVERVIEW

According to the U.S. Department of Energy, artificial lighting can account for 10% to 20% of the energy consumed by industries. This estimation increases a few percentage points if the associated cost for HVAC is included. The Rocky Mountain Institute estimates that business can effectively save 70% to 90% of this energy cost by utilizing modern lighting technology.

In recent years, lighting technology has improved dramatically. The most used industrial lamp technologies can be divided into three main categories:

- incandescent
- fluorescent
- high-intensity discharge (HID)

Incandescent

Incandescent lights use a tungsten filament encapsulated by glass. The filament creates a resistance to the electricity that generates a high temperature creating visible light. Halogen lamps can also be considered in the same group. Incandescent and halogen lamps can also contain an inert gas in the glass capsule that increases lamp life. Incandescent lamps are not very energy efficient, since most energy is spent producing heat.

Fluorescent

In fluorescent lamps, only a gas (normally mercury) fills the glass capsule. Electrodes placed at the ends of the tube form an arc through the gas. However, the lighting generated by fluorescent lights is not the direct product of the arc. Most light is generated by phosphors coating the inside of the tube, which react to the radiation emitted by the arc generating light. In order to control the amount of current flowing through the lamps, fluorescent lights require the use of ballasts. Fluorescent lights are much more efficient than incandescent lights. However, not all energy used is transformed into light; some energy is used by the ballast and some is lost (mostly into heat).

HID

High-intensity discharge lights, different from incandescent and fluorescent, are not often used in offices. HID lamps are great for large, open areas like outdoor lighting and large facility illumination. HID lamps consist of three different varieties: mercury vapor, high-pressure sodium, and metal halide. HID lighting is produced by passing an electric arc inside a capsule (glass, quartz, or ceramic) containing a gas or vapor. The current flows between two electrodes located at opposite ends of the lamp. Unlike fluorescent lamps, the arc in HID is the main source of light. Phosphors can be added to the outer capsule to change the color of the light. The same capsule also blocks harmful ultraviolet radiation emitted by mercury vapor and metal halide lamps. It is important to note that the lamps can work approximately 100 hours without the outer protective capsule. Therefore, for safety purposes, these lamps should be well guarded and maintained. Whenever possible, high-pressure sodium lamps should be used outdoors as they do not emit harmful radiation.

HID lamps also require ballasts to control the current flow through the lamps. Mercury vapor lights are normally characterized by the blue color they emit. Mercury lamps are available up to 1,000 watts. High-pressure sodium lamps can be identified by their orange light; their power ranges between 35 and 1,000 watts. Metal halide lamps emit a whiter color and are available up to 1,000 watts. Metal halide lamps tend to have a shorter lifespan, approximately 20,000 hours, compared to high-pressure sodium and mercury vapor lamps, whose lifespan is about 4,000 hours longer.

When constructing or retrofitting a facility, all lighting types should be considered. The lighting selection should not be based only on visual effects or energy efficiency. The best lighting design will take both criteria into account for the selection. Most utility companies provide rebates for using energy-efficient technology. These rebates can significantly reduce the payback period.

ENERGY SAVINGS OPPORTUNITIES AND RELATED BEST PRACTICES

In 1,285 energy audits of food processors conducted by the national network of IACs, the following were the most significant energy-related topics with regard to lighting (significance is based on the combination of frequency of occurrence and dollars being lost):

- fluorescent lighting
- HID lighting
- occupancy sensors
- daylighting
- minimal illumination levels

<u>Fluorescent Lighting</u>

A best practice related to fluorescent lighting is to change conventional ballasts and T-12 lamps to T-8 lamps with electronic ballasts. A conventional T-12 lamp is easily identified by its larger diameter (1.5”). Because of new technology, electronic ballasts and T-8 lamps (1” diameter) provide more light per surface area. New electronic ballasts generate less flickering due to a higher operating frequency. If retrofitted, a system may reduce total power usage by 25-30%.

Energy savings will vary depending on the size of the facility. The following estimated savings are calculated for a facility with 500 four-foot-long conventional T-12 lamps and 250 ballasts, operational for 8,760 hours per year, having marginal energy cost at $0.03/kWh and marginal cost of demand at $75/kW-yr. For this example, typical cost savings in energy usage and demand are about $2,500 and $400 per year, respectively. There are also additional maintenance savings, since T-8 lamps are more durable.

High-efficiency HID Lighting

HID lighting can be very efficient in production areas. Using it will instantly decrease power usage with a negligible corresponding decrease in illumination level. Technology has both improved the lifespan of the lamp and increased system efficiency. High-efficiency HID lights use less power (wattage) and are designed as a replacement to conventional HID lamps, which eliminates the need to replace ballasts.

Reductions of approximately 10% of lamp wattage are very common. The most common lamp wattage in the industry is 400. 360-watt lamps can replace these lamps as they burn out. Note that low wattage replacements are available for nearly all lamp wattages using conventional HID ballasts.

Also available are pulse-starting HID systems, which consume even less electricity than high-efficiency HID but with virtually no reduction in illumination levels. However, in order to have a pulse-start system, the ballasts must also be retrofitted, thus making the change expensive. Pulse-starting technology should be considered when constructing an addition to an existing facility. Pulse-start lights with 320 watts can replace existing 400-watt HID fixtures with minimal reduction in lighting level.

Energy usage cost savings associated with changing 100 existing 400-watt lamps to 360-watt, high-efficiency lamps are approximately $1,250, having marginal energy cost as $0.03/kWh. Demand cost savings also associated are about $360, having marginal cost of demand as $75/kW-yr.

Occupancy Sensors

Numerous types of occupancy sensors are available for all lighting systems. The technologies most used to sense presence in a room are infrared and ultrasonic. Infrared sensors detect body heat from occupants and ultrasonic sensors detect movement. Infrared sensors are good for enclosed office areas and should not be used in areas with obstructed views. Therefore, infrared sensors should be avoided in restrooms. Ultrasonic sensors are recommended for areas where movement can be detected. Thus, they should be avoided in rooms with large air movement or open offices. Dual technology is available to activate lights only when both sensors detect occupancy. Detection sensitivity and time delay can be adjusted in most sensors. It is estimated that restrooms, offices, and meeting rooms could have the lights turned off 65%, 45%, and 50% of the time, respectively, due to regular occupancy.

Occupancy sensors may also be used with HID lights. Unlike fluorescent or incandescent systems, conventional HID lamps may require cool-down and warm-up times before they may be repetitively switched off and on. These times may add up to 15 minutes, depending on the lamp type. Therefore, in order to have HID lights on occupancy sensors, bi-level technology must be used so that the lamps are not completely shut off when an area is unoccupied. Bi-level controls allow ballast to operate at a fraction of the power when there is no occupancy, keeping them ready to be turned to full power when needed.

Energy usage cost savings for a conference room with 12 ballasts containing a total of 48 four-foot conventional fluorescent lights is approximately $100 per year. Many times, occupancy sensors are neglected because of the small annual cost savings. However, it is vital to bear in mind that these savings can add up to significant amounts as sensors are installed in several rooms. For this example, the office area for the facility would be occupied approximately 12 hours per day for five days a week with $0.03/kWh marginal cost of energy.

The aforementioned example indicates an energy usage cost savings of approximately $100 per year. However, there would also be a demand cost savings of approximately $85 per year. Demand cost savings were not considered for occupancy sensors, since it is hard to predict whether or not the lights would be shut off during peak demand.

Daylighting

Daylighting is the optimization of natural light to illuminate a room. According to DOE, the use of daylighting, in conjunction with energy efficient lighting technology, may reduce the power usage from artificial lighting by more than 50%. This reduction in energy usage does not affect the lighting level of the room. Sunlight is also considered a healthier light, thus it may improve worker productivity. Studies show that daylighting decreases the energy necessary to heat and cool a building. Daylight provides less heat to a room than artificial lighting, thus it saves energy when cooling is necessary. A well-designed sunlit office can also use solar energy to decrease the heating load on HVAC equipment during the winter. Daylighting alone does not save lighting energy; it must be used in conjunction with other technology. Dimming sensors should be installed in the lighting system to control artificial lighting levels according to available sunlight. A great number of daylighting technologies are available to enhance occupant comfort and transmission of natural light. Some easy changes can be done to existing buildings, like adding skylights, more translucent walls, or changing shading devices.

Minimal Necessary Illumination Levels

It is common to have excessive lighting levels in some areas of industrial facilities. The best practice is to measure existing lighting levels and make corrections accordingly. Minimum lighting levels should be set according to standards and not based on personnel opinion. It is also common to have areas unnecessarily lighted. Such areas can be enclosed offices within the production area that still have HID lighting on top, thus only illuminating its ceiling. The correction can be as simple as disconnecting a ballast. Furthermore, to decrease the amount of unnecessary illumination, task lighting can be used in the areas that need high lighting levels or special light color. When task lighting is installed, the overall lighting for the area should be reduced to maximize savings. Task lighting commonly uses efficient fluorescent lamps and ballasts and is frequently installed over workbenches and near machinery.

Disconnecting a 400-watt HID ballast that is normally functional without need for the entire year, can amount to approximately $150 in annual savings. Disconnecting several unneeded ballasts can greatly improve lighting efficiency in a plant.

RESOURCES

Printed Material

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On-Line Tools

American Council for an Energy Efficient Economy: www.aceee.org

Centre for Analysis and Dissemination of Demonstrated Energy Technologies (CADDET): www.caddet.org

U.S. Department of Energy, Energy Efficiency and Renewable Energy (EERE): www.eere.energy.gov

Energy User News: www.energyusernews.com

Lawrence Berkeley National Laboratory, The Energy Analysis Department: http://eetd.lbl.gov/EA.html

Sustainable by Design: www.susdesign.com

Technical Information Services: www.ntis.gov

Organizations

Alliant Energy: www.alliantenergy.com

Energy Center of Wisconsin: www.ecw.org

Energy Ideas: www.energyideas.org

Florida Solar Energy Center: www.fsec.ucf.edu

Illuminating Engineering Society of North America (IESNA): www.iesna.org

Iowa Energy Center: www.energy.iastate.edu

Iowa State University Industrial Assessment Center (IAC): (515) 294-3080 or www.me.iastate.edu/iac

Lighting Research Center: www.lrc.rpi.edu

MidAmerican Energy: www.midamericanenergy.com

Rocky Mountain Institute: www.rmi.org