High School Energy Inventory: Lighting Technology Primer

The amount and quality of light around us affects our health, safety, comfort, and productivity. Our country spends more than $37 billion each year on electricity for lighting, but technologies developed during the past 10 years can help us cut lighting costs by 30% to 60% while enhancing lighting quality and reducing environmental impacts. In a typical indoor lighting system, 50 percent or more of the energy supplied to the lamp can be wasted by obsolete equipment, poor maintenance, or inefficient use.

Lighting Principles and Terms

Some basic lighting terms are:

Lamp: a lighting industry term for an electric light bulb, tube, or other lighting device.

Illumination: the distribution of light on a horizontal surface. Illumination is measured in footcandles.

Lumen: a measurement of light output from a lamp (often called a bulb or tube). All lamps are rated in lumens. For example, a 100-watt incandescent lamp produces about 1750 lumens.

Footcandle: a lumen of light distributed over a 1-square-foot (0.09-square-meter) area.

Ideal Illumination: the minimum number of footcandles necessary to perform a task comfortably and proficiently without eyestrain. The Illuminating Engineering Society says that illumination of 30 to 50 footcandles is adequate for most home, office, and school work.

Efficacy: the ratio of light output from a lamp to the electric power it consumes. Efficacy is measured in lumens per watt (LPW).

Glare: excessive brightness from a direct light source. Types of glare include direct glare, reflected glare, and veiling reflections. Direct glare results from strong light from windows or bright. Reflected glare is caused by strong light from windows or lamps that is reflected off a shiny surface. Veiling reflection is a special type of reflected glare that can obscure contrasts and reduce task clarity. Veiling reflections occur when light is reflected from a work surface, a printed page or a computer screen.

Light Quality: a measurement of how well people in a lighted space can see to do visual tasks and how visually comfortable they feel in that space. Light quality is important to energy efficiency because spaces with higher quality lighting need less illumination. High-quality lighting is fairly uniform in brightness and has no glare.

Relamping: replacing an existing lamp and/or fixture to save energy.

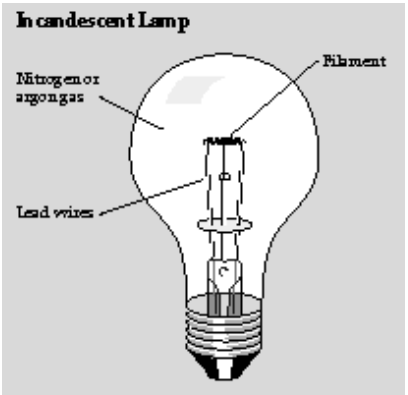
Types of Lighting

The four basic types of lighting are incandescent, fluorescent, high-intensity discharge, and low-pressure sodium.

Incandescent lighting is the most common type of lighting used in homes. Basic types of incandescent lights are standard household, tungsten halogen, and reflector lamps.

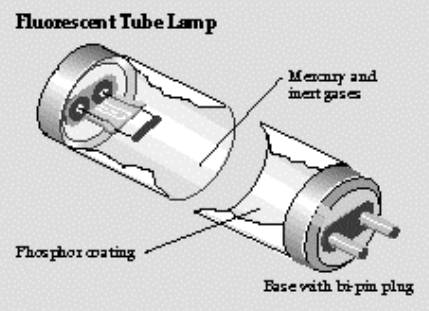
A standard incandescent lamp uses electric current to heat a tiny coil of tungsten wire inside a glass bulb to produce light. Compared with other types of lighting, Standard incandescent lamps, also known as the “A-type light bulb,” have the shortest lives and convert most of the electricity used to power them into heat rather than light.

Tungsten halogen lamps are more energy-efficient than standard incandescent lamps. They have a gas filling and an inner coating that reflect heat. Together, the filling and coating recycle heat to keep the filament hot with less electricity. These lamps are much more expensive than standard incandescents and are primarily used in commercial applications: theater, store, and outdoor lighting systems.



Household incandescent lamps are the least expensive to buy, but they are the most expensive to operate.

Fluorescent lighting is used primarily in commercial, institutional, and residential indoor lighting systems. Fluorescent lights are about 3 to 4 times as efficient as incandescent lighting and last about 10 times longer. A fluorescent tube produces light when electric current is conducted through mercury and inert (chemically unreactive) gases. Fluorescent lamps operate most efficiently when they are used for several hours at a time.

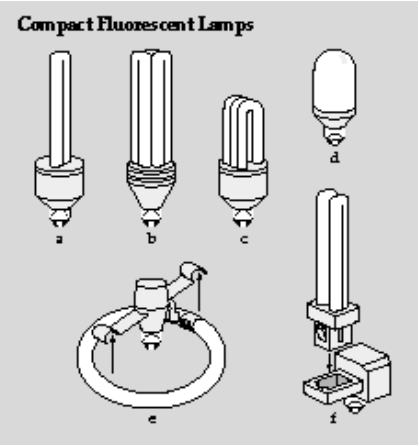


In fluorescent tubes, a very small amount of mercury mixes with inert gases to conduct the electrical current. This allows the phosphor coating on the glass tube to emit light.

Fluorescent lights require the use of devices called ballasts for starting and circuit protection. Ballasts control the electricity used by the lamp, and they typically consume 10 percent to 20 percent of the total energy used by light fixtures and lamps. One way to increase the energy savings of fluorescent lights replacing their ballasts.

Tube fluorescent lamps are the second most popular lamps after standard incandescent. The two most common types of fluorescent tubes are 40-watt, 4-foot (1.2-meter) lamps and 75-watt, 8-foot (2.4-meter) lamps. Tubular fluorescent fixtures and lamps are preferred for lighting in large indoor areas because their low brightness creates less direct glare than do incandescent bulbs.

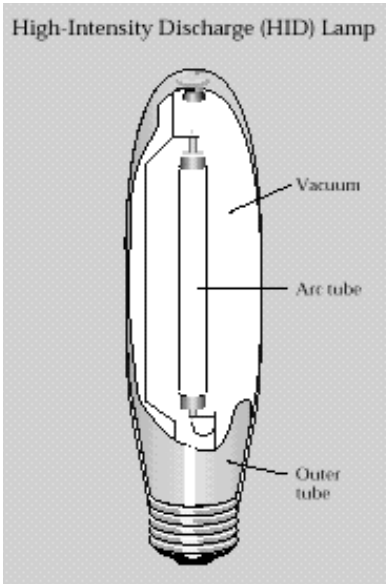
Compact fluorescent lamps are the most significant lighting advance in recent years. They combine the efficiency of fluorescent lighting with the convenience and popularity of incandescent fixtures. Compact fluorescent lamps can replace incandescent lamps that are roughly 3 to 4 times their wattage, which can save up to 75% of the initial lighting energy. Although they usually cost 10 to 20 times more than comparable incandescent bulbs, compact fluorescent lamps last 10 to 15 times as long. The energy saving and long life of compact fluorescent lamps make them one of the best energy efficiency investments available.



Compact fluorescent lamps come in a variety of sizes and shapes including (a) twin-tube integral (b and c) triple-tube integral, (d) integral model with casing that reduces glare, (e) modular circline and ballast, and (f) modular quad-tube and ballast. They can be installed in regular incandescent fixtures, and they consume less than one-third as much electricity as incandescent lamps do.

Early versions of compact fluorescent lamps introduced in the 1980s were bulky, heavy, and too big for many incandescent fixtures. However, newer models with less heavy electronic ballasts are only slightly larger than the incandescent lamps they replace. Some types of compact fluorescents include a ballast and a lamp in a single disposable unit. Other types feature separate ballasts that can handle about five lamp replacements before they wear out.

High-intensity discharge lighting is used in outdoor lighting applications such as large indoor arenas. These lamps use an electric arc to produce very bright light. High-intensity discharge lamps can save 75% to 90% of lighting energy when they replace incandescent lamps and fixtures. They provide the highest efficacy and longest service life any lighting type. Like fluorescent lamps, high-intensity discharge lamps use ballasts. They take a few seconds to produce light when first turned on because the ballast needs time to establish the electric arc to produce light.



In a high-intensity discharge lamp, electricity arcs between two electrodes, creating an intensely bright light. Mercury, sodium, or metal halide gases act as the conductor.

The three most common types of high-intensity discharge lamps are mercury vapor, metal halide, and high-pressure sodium. Metal halide lamps are similar in construction and appearance to mercury vapor lamps, but they use metal halide gases (along with mercury gas) in the lamp. Adding metal halide gases inside the lamp produces greater light output, more lumens per watt, and better color than mercury vapor lamps. Metal halide lamps are used to light large indoor areas such as gymnasiums, sports arenas, and anywhere that color rendering is important.

High-pressure sodium lighting is becoming the most common type of outdoor lighting. High-pressure sodium lamps are very efficient (90 to 150 lumens per watt). Their efficiency is exceeded only by low-pressure sodium lighting. High-pressure sodium lamps are also reliable and have long service lives, and they produce a warm white color.

Low-Pressure Sodium lamps are used where the color of light is not important, such as in outdoor security land highway lighting applications. Low-pressure sodium lamps work somewhat like fluorescent lamps. They are the most efficient form of artificial lighting available, have the longest service life, and maintain their light output better than any other type of lamp. A wide selection of low-pressure sodium lamps exists, and they vary in their construction, efficiency, color characteristics, and lamp life. Low-pressure sodium lamps produce colors as tones of yellow or gray.

Replacing Lamps and Fixtures

When relamping (substituting one lamp for another to save energy), a decision can be made to increase or decrease the level of illumination. When relamping a large space, the new lamps should first be tested in a small area to ensure adequate illumination, occupant satisfaction, and compatibility of the new lamp with the old fixture.

Matching replacement lamps to existing fixtures and ballasts can be tricky, especially with older fixtures. Buying new fixtures made for new lamps produces greater energy savings, reliability, and longevity compared to relamping alone.

Relamping Incandescent Fixtures

Much is now known about fixture design. Many indoor fixtures waste energy by trapping a significant amount of light inside the fixture, while many outdoor fixtures tend to disperse much of the light they produce beyond an intended area.

New incandescent fixtures are designed to “push” all the light they produce out into the room. Advances in indoor fixture design include brighter reflectors and better reflecting geometry.

Many incandescent lamps are mismatched to their tasks. Some have high wattages which result in unnecessarily high illumination and energy waste. This can be corrected by using lamps with smaller wattages. Standard incandescent lamps can often be replaced with improved lamps. And, for energy savings of 60% to 75%, many incandescent lamps can be replaced with compact fluorescent lamps.

Standard incandescent lamps can be replace with compact fluorescent lamps in spaces where light is needed for long periods of time. New compact fluorescent lamp fixtures have built-in electronic ballasts and polished metal reflectors which improve light output and energy savings.

Relamping Fluorescent Fixtures

Although fluorescent lamps are generally energy efficient, there are new, more efficient fluorescent lamps that use better electrodes and coatings to produce about the same lumen output at a lower wattage. Common 40-watt and 75-watt lamps can be replaced with energy-saving lamps of 34 watts and 60 watts, respectively. Energy-saving lamps for less-common fluorescent fixtures are also available.

If the ballasts in fluorescent fixtures need to be replaced, improved electromagnetic ballasts and electronic ballasts can be used to raise the efficiency of the fixture 12 percent to 30 percent. Improved electromagnetic ballasts reduce energy loss, fixture temperature, and system wattage. Because they operate at cooler temperatures, they last longer than standard electromagnetic ballasts.

Electronic ballasts operate at a very high frequency that eliminates flickering and noise. They are even more efficient than improved electromagnetic ballasts. Some electronic ballasts even allow use of dimmer switches, which are usually not recommended with most fluorescent lamps.

Improving Lighting Controls

Lighting controls are devices for turning lights on and off or for dimming them. The simplest type is a standard snap switch. Other controls are photocells, timers, occupancy sensors, and dimmer switches.

Standard snap switches, located in numerous convenient areas, are made to turn off lights in unused areas. Photocells turn lights on and off in response to changes in natural light levels. For example, photocells turn outdoor lights on at dusk and off at dawn. Advanced photocells gradually raise and lower fluorescent light levels with changing levels of daylight.

Mechanical or electronic timers use clock settings to automatically turn on and off indoor or outdoor lights for security, safety, and tasks such as janitorial work. Crank timers limit lights to short durations where the need for light is brief.

Occupancy sensors detect motion to activate lights when a person is in the area and then turn off the lights after the person has left. They are popular for areas that are not regularly used and offer security advantages over continuous lighting: when lights suddenly come on, they startle intruders and alert residents and neighbors to motion in the area.

Dimmer switches reduce the wattage and output of incandescent and fluorescent lamps. Dimmers also increase the service life of incandescent lamps significantly. However, dimming incandescent lamps reduces their lumen output more than their wattage. This makes incandescent lamps less efficient as they are dimmed. Dimming fluorescent lamps requires special dimming ballasts and lamp holders, but does not reduce their efficiency.

Daylighting

Daylighting means using sunlight for indoor lighting. Modern buildings designed for daylighting typically use 40% to 60% less electricity for lighting needs than do conventional buildings.

Sunlight is free and can be easily used to daylight a building. However, using sunlight without causing glare and without overheating a building can be difficult. Glare can be avoided with the use of window sills, walls, louvers, reflective blinds, and other devices to reflect light deep into the building. Windows and skylights can be located away from the direct rays of the sun to avoid overheating. For example, placing skylights on the north slope of a roof rather than on the southern may reduce unwanted heat transfer. Windows are also available with selective coatings that transmit visible light from the sun while blocking heat transfer.

Lighting Maintenance

Maintenance of light fixtures is vital to lighting efficiency. Light levels decrease over time because of aging lamps and dirt on fixtures, lamps, and room surfaces. Together, these factors can reduce illumination by 50% or more, while lights continue drawing full power. The following basic maintenance activities can help prevent this:

Clean fixtures, lamps, and lenses every 6 to 24 months by wiping off the dust. However, never clean an incandescent bulb while it is turned on. The water's cooling effect will shatter the hot bulb.

Replace lenses if they appear yellow.

Clean or repaint small rooms every year and larger rooms every 2 to 3 years. Dirt collects on room surfaces, which reduces the amount of light they reflect.

Consider relamping entire rooms or systems at one time. Common lamps, especially incandescent and fluorescent lamps, lose 20 percent to 30 percent of their light output over time. Many lighting experts recommend replacing all the lamps in a lighting system at once. This saves labor, keeps illumination high, and avoids overworking any ballasts with dying lamps.

Conclusion

Saving lighting energy requires either reducing electricity consumed by lights or reducing the length of time the lights are turned on. This can be accomplished by:

- lowering wattage by replacing lamps or entire fixtures
- reducing the amount of time lights are on by installing improved lighting controls and educating people to turn off lights when they are not needed
- using daylight when possible to reduce energy consumption of electric lights
- performing simple maintenance to ensure adequate illumination and light quality and to lower required levels of illumination where possible.

Lighting Facts

A 100-Watt incandescent lamp typically lasts for about 750 hours, while a 28-Watt compact fluorescent lamp lasts for about 10,000 hours (13.3 times as long). At an average electricity cost of $0.08 per kWh, the cost of operating 13.3 incandescent lamps over 10,000 hours is $80. The cost of operating a single 28-Watt compact fluorescent lamp over 10,000 hours at $0.08 per kWh is $22.40. Assuming a cost of $1.00 for each 100-Watt incandescent lamp, the total life-cycle cost (product cost plus electricity cost) of using 13.33 incandescent lamps for 10,000 hours is $93.33. Assuming a cost of $20.00 for one 28-Watt compact fluorescent lamp, the life-cycle cost of using 1 compact fluorescent lamp is $42.40.

Replacing one 100-Watt incandescent lamp with a 28-Watt with compact fluorescent lamp can:

- save 496 pounds of coal used as fuel to generate electricity
- reduce carbon dioxide emissions from a coal-fired power plant by 850 pounds
- reduce sulfur dioxide emissions by four pounds
- reduce nitrous oxide emissions by three pounds
- reduce mercury emissions by 40 p