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LIGHTING

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ENERGY SMARTS: LIGHTING

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The quality and quantity of light around us determine how well we see, work, and play. Light affects our health, safety, comfort, and productivity. For many households, lighting accounts for a large percentage of the utility costs. With new lighting technologies, it is possible to reduce energy costs from 30 to 60 percent while enhancing lighting quality (U.S. Department of Energy, 1995). Many of these new lighting technologies have been implemented at the Utah House, a sustainable building demonstration facility owned by Utah State University.

LIGHTING TERMINOLOGY

With so many options available, it is important to understand basic lighting terms when choosing from today's lighting technologies. The technical term for a light bulb is a lamp. The light output or amount of light produced by a lamp is measured in lumens. For example, a 100-watt incandescent lamp emits 1750 lumens of light. Wattage, measured in watts (W), is the measurement of electricity. It is important to recognize that the functionality of lamps is in their light output (lumens), rather than the amount of energy they consume (wattage). A kilowatt-hour (kWh) is a quantitative measure of electrical current flow equivalent to 1,000 watts being used continuously for a period of 1 hour and is the unit most commonly used to measure electrical energy.

Efficacy is a lighting term used to indicate optimal lamp efficiency. It is measured by dividing the amount of output in lumens by the number of watts (lumens ÷ watts). This lumen-per-watt ratio (lpW) is one of the most important factors in judging and selecting lamps for fixtures. The higher the lpW, the better. For example, the typical incandescent 75-watt lamp produces about 1,210 lumens. That's around 16.1 lumens per watt (1750 ÷ 100 = 17.5). By comparison, a 27-watt compact fluorescent lamp produces 64.8 lumens per watt.

Color Rendering Index, Chromaticity (Kelvin Rating), Color Temperature are used to gauge light quality produced by a lamp or fixture. The Color Rendering Index (CRI) is a system used to rate a lamp's ability to portray object colors. A light source with a rating of 100 has the same color rendering qualities as sunlight. The higher a lamp's CRI rating, the richer the colors. Generally, standard incandescent lamps have a CRI rating of 100 and fluorescent lamps are in the range of 60 to 95. Advances in technology have greatly improved the color rendering of fluorescent lamps. A common misconception is that all fluorescent lamps are "greenish or bluish" in color and do not have very good color-rendering ability; however, this is no longer the case. Fluorescent lamps are produced that have a "warm" quality, comparable to the light output of incandescent lamps. Chromaticity, a parameter used to indicate light quality, refers to the pattern of visible wavelengths emitted by the lamp, and is measured in units or degrees Kelvin (K). Most lamps fall in the range of 2200 to 7500 K. The lower a lamp's Kelvin rating the more it will create a visually "warm" atmosphere. Many households prefer to use "warm white" lamps in their homes because rooms and people look better in warm light. The higher a lamp is rated on the Kelvin scale, the "cooler" it will appear, creating bluish tones that some people find uncomplimentary to a room. Color Temperature is a description of the "warmth" or "coolness" of a light source. A "warmer" light source will have a lower correlated color temperature than a "cooler" light source with a higher correlated color temperature. Using the Kelvin scale, 2,000 K to 3,500 K provides "warm light quality" and 4,100 K to 8,000 K provides "cool light quality," as seen in Table 1.

Full spectrum lamps are fluorescent lamps having a CRI of 80 or better and a color temperature of 5000-6500 K. They are designed to provide the most accurate colors; however, they do not replicate natural sunlight. Full spectrum lamps are much more costly than regular lamps and require more electricity for a given level of light output.

LIGHTING SOURCES AND ENERGY-EFFICIENCY

The most common lighting sources used in homes today are daylighting, incandescent, halogen, fluorescent, high intensity discharge (HID), sodium-xenon, and light emitting diodes (LEDs). Each type of lighting offers advantages and disadvantages in terms of use, efficacy, light quality, and energy efficiency.

Daylighting

The most cost-effective and energy efficient mode of indoor lighting is from sunlight and is often referred to as daylighting. Daylighting optimizes the use of natural light rather than artificial light and thus can be an important part of energy-savings for a residential home. Homes can be designed to take full advantage of the sun's light during daylight hours by maximizing desired light through windows, sky lights, and sun tubes. A single skylight can provide as much light as a dozen or more lamps, and the light quality is unsurpassed because it is natural light.

Table 1. Relationships: Kelvin Rating, Color Temperature, Common Light Sources, Color Rendering Index

Kelvin Rating	Color	Common Light Sources	Approximate CRI
8000K	Dark blue		
7500K	Blue		
7000K	Blue		
6500K	Blue	Overcast sky	
6000K	Blue		
5500K	Blue	Daylight, metal halide HID 5500K	60
5000K	Light blue	5000K fluorescent	80-90
4500K	Light blue-white	Cool white fluorescent 4200K	65
4000K	White	Std. clear metal halide HID 4000K	60-90
3500K	Light yellow-white	1 hour from duck/dawn 3400K	
3000K	Yellow	Halogen 3000K	95
2500K	Orange	Standard incandescent 2700K	95
2000K	Dark orange-red	High pressure sodium HID 2200K	25
1500K	Dark red	Candlelight 1500K	

(Adapted from: Venture Lighting, 2005; Mischler, G. 1998-2005; Energy Outlet, 1996)

Table 2. Energy Costs of Incandescent and Fluorescent Lamps

	Standard Incandescent	Compact Fluorescent
Energy consumed (watts)	100	23
Rated lamp life (hours)	1500	12000
Cost per bulb and fixture**	$0.48	$3
Life of bulb*	1.0	8.2
Energy use per year* (kWh)	109.5	29.2
Operating cost per year (at $0.085/kWh)	$9.30	$2.50
Savings per year	n/a	$6.80
Payback time for price of CFL (years)	n/a	1.2
Total life cycle costs	$80.34	$28.79
Total life cycle savings		$51.52

(Adapted from: Rocky Mountain Institute, 2004)

Many people believe that exposure to natural daylight is conducive to good health and increased productivity. Studies have shown that in classrooms and the workplace, productivity increases and absenteeism decreases in spaces with ample daylighting (Raiford, 1997-2004).

Incandescent

Standard incandescent lamps are the most common and inefficient light source available. They operate using a tungsten filament inside a glass bulb. When the electricity heats the tungsten filament, the heat causes the filament to glow and emit light. Only 10 percent of the electricity used by an incandescent lamp is used to create light, the rest (90 percent) is lost as heat. Even though incandescent lamps cost less to purchase, they are the most expensive type to operate (see Table 2). They use between 25-100 watts to produce light, last from 750 to 1,000 hours, and must be replaced several times per year. Some "long life" lamps exist with thicker filaments, but they are still more expensive to operate than other lighting sources.

Halogen

A halogen lamp is a more efficient incandescent type of light. It has a filament that is surrounded by halogen gas with an inner coating that reflects heat inside the bulb. The halogen gas filling and the coating "recycle" energy within the bulb to keep the filament glowing with less electricity. Halogen lamps last over twice as long as incandescent and often have a reflector to improve the focus of the light. They give off a bright, white light. Halogen lamps have a high color temperature and a CRI of 100.

There are several categories of halogen lamps such as reflector and multifaceted reflectors. Reflector (PAR) lamps are most well-known for display lighting, high-ceiling areas, and outdoor floodlighting. PAR lamps rely on both the internal reflector and prisms in the lens for control of the light beam. They have aluminized glass reflectors which direct the heat generated by the lamp to the front of the bulb and towards what you are lighting. These lamps are ideal for areas where lighting is not in close proximity to the area being illuminated because they get very hot. They also put out UV light than can turn some plastic items yellow (Pegasus Associates, 2000-2005).

Multifaceted reflectors (MR) are another type of halogen lamp, often referred to as "puck lights" and "low-voltage halogen." The multifaceted reflector is an arrangement of pressed glass facets, covered by a reflective coating. These facets provide control by reflecting light from the filament to create a concentrated beam of light. Because these lamps are often low-voltage, they do not use a great deal of energy (Rensselaer Polytechnic Institute, 2004). These halogens are much smaller in diameter (2-inches) at the reflector opening. Also, because of the glass reflector used in these halogen bulbs, about 85% of the heat generated by them is dissipated to the rear of the bulb (away from what you are lighting). This means that you can have the fixtures much closer to what you're displaying without worrying about excessive heat generated by the lamp. Lastly, the lumen-to-watt ratio is quite high. A 50-watt MR-16 halogen will give about the equivalent light level of a standard incandescent 100-watt lamp (Eclectic Lighting, 2005).

Fluorescent

Fluorescent lamps are designed as either single or multiple tubes, or can be the more familiar twister thaT can screw into incandescent sockets. The light produced by a fluorescent lamp is caused by an electric current conducted through mercury and inert gases. Fluorescent lighting is used mainly indoors, both for ambient and task lighting. However, fluorescent lights are being used outdoors where special ballasts are made to withstand outdoor temperature fluctuations.

Modern fluorescent lights are one of the most efficient options around; they can be four to five times more efficient than incandescent lighting and last ten times longer. They emit the same amount of light output (lumens) as an incandescent and use only one-quarter (or less) the energy, as seen in Table 3. Fluorescent lamps last 10,000 hours, which is more than 10 to 15 times longer than incandescent lamps. Newer fluorescent lights can produce a “warm” appearance, similar to that produced by incandescent lamps.

In order to function, fluorescent lights use electronic ballasts, which last longer, are quieter, and more dependable than the older magnetic ballasts. Just a few years ago, fluorescent lights had the bad reputation of making a buzzing sound due to the magnetic ballasts. Today they are much quieter.

Compact fluorescent lights (CFLs) are a variation on the fluorescent tube. They work the same way, but are designed to put out more light than larger fluorescent lights. Not only do they operate using a fraction of the energy of incandescent or halogen lamps, but also do not put off as much heat. CFLs consume less energy than incandescent light and can also emit a “warm” quality of light. A 75-watt incandescent lamp will put off about the same amount of lumens as a 20-watt CFL. Though more expensive to purchase than incandescent lamps, prices have fallen in recent years. By using CFLs one can quickly recoup purchase cost and save money due to significantly lower operation costs and the longer life of the lamp.

High-Intensity Discharge (HID)

High-Intensity Discharge (HID) lamps use an electric arc to produce intense light. They also require ballasts, and may take a few seconds to produce light once turned on because the ballast needs time to establish the electric arc. When compared to other lamps, they are one of the most energy efficient and have a long service life. HID lamps and fixtures can save 75 to 90 percent of lighting energy

Table 3. Comparing Light Output

Standard Incandescent (Wattage & Lumens)	Compact Fluorescent (Wattage & Lumens)	Reduced-Wattage Incandescent (Wattage & Lumens)	Halogen (Wattage & Lumens)
25 (220)	5 (210-250)	--	--
40(460-505)	7 (400)	34 (410)	42 (665)
60 (870-890)	13 (700-900)	52 (800)	52 (885)
75 (1190-1220)	18 (1100-1250)	67 (1130)	72 (1090-1300)
100 (1750)	27 (1550-1800)	90 (1620)	100 (1600-1880)
150 (2850)	32 (1800-2100)	135 (2580)	--

(Adapted from: Byrne, J., 1994)

when replacing incandescent lamps and fixtures, and can last up to 40,000 hours.

The three most common types of HID lamps are mercury vapor, metal halide, and high-pressure sodium. Mercury vapor is the oldest type of HID lighting and used primarily for street lighting. Mercury vapor lamps provide about 50 lumens per watt and cast a cool blue/green, white light. Metal halide lamps are similar to mercury vapor lamps, only they have higher light output, more lumens per watt, and better color rendition than from mercury lamps. High-pressure sodium lamps are becoming the most common type of outdoor lighting. They provide 90 to 150 lumens per watt. Their color is warm, and their color rendition ranges from poor to fairly good depending on the design and intended use (Osram-Sylvania, 2004). They are used to light parking lots. However, this type of lighting is becoming popular in residential and commercial security lighting, landscape lighting, and decorative lighting. These lamps are also used as grow lights for plants due to the color temperature that closely resembles sunlight. High-pressure sodium light bulbs come in wattages from 35 to 1000 watts. The life of these lamps typically ranges from 16,000 to 24,000 hours.

Sodium-xenon

The new sodium-xenon lamp is very energy efficient and has the capability to switch to approximately half output which reduces power usage by up to 35 percent, depending on the particular lamps. Reducing light output can save considerable energy when full light is not needed. The lamp has a high efficacy (65 lumens per watt). The color of the lamp is around 3200 K, similar to that of incandescent, and has a moderate color rendering ability. In addition these lamps require low maintenance as they have an average life of 5,000 to 15,000 hours and are ideal for a location where warm color is desired.

Light Emitting Diodes (LEDS)

Light emitting diodes, or LEDS, offer several advantages as a lighting choice. They last tens of thousands of hours and are ten times more energy efficient than standard incandescent lamps. In addition, they do not put off a great deal of heat, thus reduce air-conditioning needs. They are impervious to heat, cold, shock, vibration, can be waterproofed, and are extremely durable because no breakable glass is used in the construction.

Lighting Controls

Another way to save lighting energy is through the use of controls, such as dimmers, motion detectors, timers, and photo sensors. Lighting controls can save a great deal of energy. Dimmers allow the user to adjust the light level according to lighting needs. For example, while dining or watching TV less light is needed, and dimming can improve the setting, as well as save energy.

Motion detectors, also called occupancy sensors, turn lights on when movement is in the sensor area. When an area is not in use or there is no movement, lights will automatically turn off. Motion detectors are especially effective in restrooms, public areas, and other places where lights are often not turned off. Outdoor motion sensors are also used not only to save energy, but also for home security. Not only are occupants and visitors prevented from walking in the dark, but motion detectors alert home-owners of unwelcome intruders.

Timers turn lights on and off at times set by the user. These are often used for security. Lights can turn off and on even though someone may not be in the home.

Photo sensors are often installed on outdoor lighting so that lights come on when the sun goes down and turn off at sunrise. The most common examples of photo sensors are street lamps.

Figure 1. EnergyStar® Label

(Printed with permission from EnergyStar®)

ENERGYSTAR®

Some light fixtures are designed specifically for energy efficiency and can be identified by their ENERGYSTAR® label, a program sponsored by the U.S. Environmental Protection Agency (EPA) and Department of Energy (DOE) (see Figure 1). ENERGYSTAR® label is an indication that the particular lighting fixture or lamp uses less energy than traditional lighting products. To save the

Table 4. Life Cycle and Cost Comparisons

Bulb Type Watts/Lumens	Purchase Cost	Life	Lumens per Watt (efficacy)	Energy Cost of 8 Cents for 10,000 hrs	Lamp Cost Plus Electricity for 10,000 hrs
CF..15 watt/720 lumens	$3	10,000	48	$12	$15
Incandescent 60 watt/870 lumens	$.50	1,000	15	$48	$53
CF..30-watt/1,200 lumens	$4	10,000	60	$16	$20
Incandescent..75 watt/1,210 lumens	$.50	1,000	16	$60	$65
CF..27 watt/1,750 lumens	$5	10,000	64	$22	$27

most energy and money, replace your highest used light fixtures or lamps with energy-efficient models, such as fluorescent. The highest use fixtures used in the home are typically the kitchen ceiling light, the living room table light, floor lamps, bathroom vanity, and outdoor porch lamps.

Economic Benefits of Efficient Lighting

Though energy efficient lighting may cost more at the outset, when weighing the initial purchasing cost against its energy savings, long life, and reduced replacement and maintenance costs, the newer lighting technologies and techniques are much less expensive than incandescent lighting systems (Seaman, 2004). With new lighting technologies, it is possible to reduce energy costs from 30 to 60 percent while enhancing lighting quality and reducing environmental impacts (U.S. Department of Energy, 1995). Table 4 details life expectancy, life cycle costs, lumens per watt, and cost comparisons of incandescent to compact fluorescent lamps.

Health Impacts

Improper under-lighting can result in eye-strain or accidents. Improper over-lighting can result in headaches and annoyance, not to mention unnecessarily high electricity bills (see Table 5). Much evidence exists from research done in office buildings and schools where productivity increases and absenteeism decreases with exposure to indoor daylight (Solatube, 2005).

In addition, the power of daylight has been used to rejuvenate the body and mind, treating everything from lethargy to “winter blahs” to clinical depression. This has been suspected for thousands of years, but only recently have scientific studies noted the correlation. Patients who were exposed to natural light were significantly less depressed than those in artificial light. An estimated 90 percent of humans suffer from seasonal mood changes during the winter months and up to 10 percent of those suffer from the condition known as seasonal affective disorder, or SAD, characterized by fatigue, gloom, and change in appetite, fitful sleep and despair (Solatube, 2005).

Environmental Effects

Energy efficiency – delivering the same (or more) services for less energy – helps protect the environment. When we use less energy, less energy needs to be generated at power plants, which reduces greenhouse gas emissions and improves the quality of our air. Energy efficient lighting also reduces environmental impacts by reducing the need to build more power plants that contribute to air pollution (CO^2 emissions and other greenhouse gases).

Conclusion

Energy efficient lighting is a significant area of possible energy savings in the home. If some of the new technologies are adopted, consumers can reduce energy lighting

Table 5. How Much Light Do You Need?

Type	Incandescent	Fluorescent	Location
Ambient Lighting	2-4 watts per square foot of area. If counters or flooring are dark, double this amount. 175-200 watts for each 50 sq ft of floor space. A fixture with three 60-watt bulbs would satisfy this requirement.	1-1/2 watts per sq. foot of floor area. 40-watts for every 12 sq ft of floor space.	90 inches above the floor
Task Lighting			
Cleanup Centers/ Desk	150 watts	30-40 watts	25 inches above
Countertops	75-100 watts for each 3 running feet of work space	20 watts for each 3 running feet of work surface	14-22 inches above the work surface
Cooking Centers	150 watts	30-40 watts	18-25 inches above burners. Most range hoods have lights
Dining Table	100-120 watts	30-40 watts	25-30 inches above table

use and save money. The Rocky Mountain Institute (2004) estimates that the technology already exists to reduce energy consumption of lighting by 50 to 90 percent.

Not only will these adopted energy efficient lighting technologies save the consumer money on utility bills but will also reduce carbon dioxide and other green house emissions in the air. Most of the electricity generated in Utah comes from coal fired plants. If everyone in the U.S. used available energy efficient lighting technologies, the U.S. electricity demand could be reduced 25 percent and the savings would equal the output of 120 large power plants (Hassol, 1994).

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