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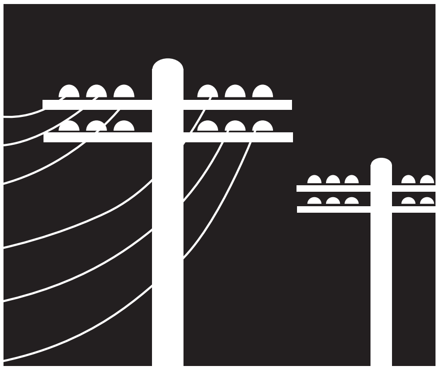

Energy Conservation in Agriculture

Energy-Efficient Agricultural Lighting

Scott Sanford

Proper lighting can increase productivity, ensure safety, security and improve morale. Many older barns have sub-standard lighting that could be improved with energy efficient lamps. Such lights would boost milk production and profits and increase personal and fire safety.

The most common types of lamps used in agricultural enterprises are T-12 fluorescent, incandescent and high intensity discharge (HID) such as mercury vapor and high-pressure sodium lamps. There are several new technologies available that can reduce energy consumption and improve light output. These include T-8 fluorescent lamps, pulse-start metal halide HID lamps and compact fluorescent lamps (CFL). You should evaluate your lighting requirements by asking the "W" questions: What? Where? When? Why do I light an area?

This publication will help you determine if lighting is necessary and what types of lamps and fixtures are appropriate.

Lamp ratings

Lamp output is measured in units of lumens or foot-candles—a unit of measurement for luminous energy or lamp output. Light fixtures may diffuse the lamp output differently depending on the use of reflectors and refractors, so manufacturers of fixtures supply photometric data to map the distribution of light from different fixture styles. (One foot-candle equals one lumen per square foot)

Correlated color temperature index

Lamps are rated for the color of light that they emit using a correlated color temperature index (CCT). The CCT index is a description of the color appearance of the light emitted by a lamp, relating its color to the appearance of light from a reference source. This index is expressed in degrees Kelvin (K). A lower numerical value indicates a lamp that emits an orange/red or "warm" light while a higher numerical value indicates a bluer or "cool" light.

Some examples of typical CCT values:

- High pressure sodium—1900 K
- Incandescent—2800 K
- Halogen—3000 K
- Cool white fluorescent—4100 K
- Daylight simulating fluorescent—5000K.

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Color rendering index

The color rendering index (CRI) uses a scale of 0 to 100 that indicates the perceived color of an object viewed with a light source as compared to the object viewed in sunlight. A value of 100 would be equivalent to sunlight and 0 would indicate that the colors are not distinguishable from each other. When selecting lighting for an area, it is important to consider the degree of color recognition that is required to complete tasks. A low CRI value makes it hard for humans to differentiate between colors.

Light loss factor

The light loss factor (LLF) is a measure of the light output near the end of the lamp's life compared to its initial lumen output. It is expressed as percentage of the initial lumen output. LLF takes into account the decrease of lumen output as the lamp ages, the amount of dirt in the environment and how often the fixture is cleaned, as well as the decrease in lamp output as the ballast ages. This is an important factor if the lighting system needs to provide illumination above a minimum level; for example, to provide artificial lighting for plants or "long day lighting" for dairy cows. The initial light level will be higher than the design value in order to have a light level greater than the required minimum value in 2 or 3 years when the lamps are nearing the end of their useful life.

Average rated life

This term refers to the mean (average) time it takes for a lamp to burn out; the time at which 50% of the test lamps are burned out and 50% are still working.

Why light?

There are many good reasons to provide lighting, including worker safety, better task manipulation, improved quality of work, product inspection, security and increased productivity. Each of these may require different light intensity (lumens or foot-candles), degree of whiteness, color-rendering level or types of lamps and fixtures.

What is the best type of lighting?

The best lighting provides the needed amount and type of light to perform a task or increase productivity at the minimum annual cost (operating and fixed costs).

What areas are to be lit?

Areas that may benefit from lighting include animal housing, driveways, offices, milking parlors or storage space. Each has its own requirements for light levels and type of lighting. Is the area warm or cold, are the ceilings high or low, is there constant or occasional activity, does activity involve precision work or is general lighting sufficient? All these considerations factor into the lighting decision.

What is the duration of lighting?

How long lighting is needed depends on the situation. Many times it may only be for short periods while a task is being completed, while applications such as "long day lighting" in dairy barns require lamps to operate for up to 18 hours per day.

What percentage of time will there be work activity or movement in the target area? Do the lights need to be on all of the time or just when there is activity in the target area? If the answer is only when there is activity, the lighting might be controlled with a motion sensor and use of an incandescent or halogen lamp for the instant-on feature. However if there is frequent movement that would cause the lights to be operated more than 30% of the time, you will save energy with a high-pressure sodium lamp, operating it during all hours of darkness. Assess the needs of each area to determine the required duration of lighting.

What is the amount of light needed?

Different tasks require different levels of lighting. An area that is lit for precision work requires a higher light intensity than security lighting or machinery storage.

The chart on the next page shows some of the tasks on dairy and poultry farms and examples of recommended lighting levels. For recommended lighting levels for other areas and tasks refer to ASAE Standard EP344.2 or the *Illuminating Engineering Society Handbook*.

What types of lamps are appropriate?

Lighting is quantified by two indexes: Color Rendering Index (CRI) and Correlated Color Temperature Index (CCT). The CCT is not as important as the CRI which indicates how colors are rendered or detected by humans as compared to natural sunlight.

If you need to differentiate between colors to properly perform a task, then a lamp with a high CRI value would be required. A CRI value of 80 or higher is required for color matching. For general farm lighting where some color detection is needed, a CRI of 50 or higher would likely be sufficient. In areas where color detection is important, such as treatment pens, milking parlors or egg sorting facilities, a CRI of 70 or higher would be recommended.

The air temperature will also affect the choice of lamps since some, such as fluorescent lamps, have minimum starting temperatures. Areas requiring instant-on lighting will limit the use of high intensity discharge lamps as they take several minutes to fully illuminate. The use of compact fluorescent lamps would be limited if the area to be lit gets cold—less than 32˚F or 0˚F, depending on CFL rating.

What types of fixtures are required?

Inside any animal housing or processing facility with high humidity, the fixtures must be water- and dust-resistant. Plastic, fiberglass or stainless steel housings are preferred because of their resistance to corrosion. Incandescent and compact fluorescent lamps should be enclosed in sealed globes; linear fluorescent lamps should be enclosed in sealed fixtures.

Task	Intensity / Light level
Free stall	15-20 foot-candles
Tie stall barns	
Feed alley	15-20
Center alley	20-50
General livestock housing	10
Holding area	10-20
Milking parlor—general	20
Operator's pit	50 (at cow's udder)
Milk room	20
Manual wash sink	100
Vet/treatment area	
General	20
Treatment or surgery area	100
Utility room	20
Office area	50 (desk top)
Machine storage	10
Farm shop—general repair area	50
Exterior—security	0.5-1
Exterior—active areas	3-5
Poultry barns	20
Egg packing and inspection	100
Inside incubators	50
Loading & storage areas	20
Restroom	20

Where should the fixtures be mounted?

In agricultural enterprises, consider what could hit or come into contact with the fixtures. For example: A cow might accidentally strike fixtures mounted down the center of a tie stall barn, but moving the fixtures over the manure gutter would likely remove this risk. However, this may require the use of twice as many fixtures with a single lamp versus two lamps per fixture to provide proper light level.

How many fixtures are needed?

The number of fixtures will depend on the lighting level required, the type of fixture used, type of lamp used, mounting height, the reflectance values of the surfaces to be illuminated, height of the work plane and the amount of variation in light levels that can be tolerated. In general, a lower number of fixtures will be needed with higher wattage lamps but more variation of light level will occur. Lower wattage fixtures will require more fixtures but provide a more uniform light level.

Work with a reputable lighting contractor who has a lighting design program that can account for the different parameters as well as calculate the fixture location and the expected light level variation. Refer to "Design Considerations" for information on reflectance values. Most lighting contractors will have little experience with agricultural requirements so you'll likely need to provide them with this information.

Types of lamps

Fluorescent lamps

Fluorescent lamps come in a variety of diameters, lengths, shapes, color temperature ratings and minimum operating temperature ranges. The diameter of a fluorescent lamp denoted in eighths of an inch indicates the lamp series. For example, the commonly used T-12 lamp is 12/8's of an inch (1.5") in diameter while a T-8 is 8/8's of an inch or 1" in diameter.

Fluorescent lamps are available in the following sizes: T5, T6, T8, T9, T10, T12 and T17. The lamps can be straight or linear, U-shaped or circular, from 6" to 96" long with color temperatures from 2750˚K to 7500˚K and minimum operating temperatures from -20˚F to 50˚F.

T12 fluorescent lamps have been commonly used in most applications but the newer T8 and T5 lamps are more energy-efficient, providing more lumens per watt than T12 lamps. T5 fluorescent lamps are the most efficient fluorescent lamps, but they generate too much heat to be used in sealed fixtures that are required in agricultural enterprises. They are more suitable for office space. A fluorescent fixture is made up of a frame, a ballast, lamp sockets and lamp(s). For agricultural buildings, corrosion-resistant, moisture-resistant, dust-proof fixtures are a must. Sealed fluorescent fixtures similar to figure 1 should be used in animal housing or milking parlors.

T-8 fluorescent lamps

The fixtures for T-8 lamps look similar to the commonly used T-12 lamps except that the bulbs are 1" in diameter instead of 1.5". The T-8 lamps provide about 15% more lumens per bulbs and the ballasts for the T-8 lamps are 40% more efficient than T-12 lamps ballasts.

Most standard T-8 ballasts can start in temperatures as cold as 0˚F compared to 50˚F for a standard T-12 ballast. This means the standard T-8 lamps can be used in some cold applications, such as a tie stall dairy barn, avoiding the need for less-efficient high output ballasts. The-T-8 lamp uses an electronic ballast that operates at high frequency and eliminates the annoying flicker associated with T-12 electromagnetic ballast when ambient air temperatures are cooler.

Electronic ballasts are available for T-12 fixtures from lighting distributors. If the correct fixtures are being used (dust- and moisture-resistant), a T-12 fixture can be converted to use T-8 lamps by replacing the lamps and ballast. The same sockets are used for both T-8 and T-12 lamps. If a T-12 fixture is of the high output (HO) type which uses a double recessed socket (type R17d), one could replace the sockets or lamp bases with a single pin type (type Fa8) for 96" fixture or medium bipin bases (type G13) for 48" fixture so a standard T-8 lamp can be used.

Figure 1. Sealed fluorescent fixtures should be used in animal housing or milking parlors.

Generally, T-12HO fixtures are used in cold locations (<50˚F) which is unnecessary if the correct T-8 ballast has been selected since the T-8 ballasts are designed to work down to 0˚F with a few exceptions (check package labeling).

If you need the same lighting level provided by T-12HO lamps, specify high-output T-8 ballast and bulbs with recessed double contacts (F17d type ends) which have starting temperatures down to -20˚F or install additional standard T-8 lamp fixtures provided the temperatures are greater than 0˚F. With an average life of 20,000 hours, a T-8 lamp lasts 65% longer than a T-12 lamp, reducing maintenance costs.

Compact fluorescent lamps (CFL)

CFL lamps are direct replacements for incandescent bulbs, having the same medium screw base as a standard incandescent lamp. From a performance basis, they use 75% less power for the same amount of lighting and have an average life of 6,000 to 10,000 hours—6 to 10 times longer than an incandescent lamp.

Their color rendering index (CRI ~82) and correlating color temperature (CCT~2700K) is similar to that of incandescent lamps. The compact fluorescent lamps available today are second generation and come in more compact sizes. Some have diffusing covers to hide the fluorescent bulb, so aesthetically they can be used in more places. These bulbs can typically start at temperatures down to 32˚F (some to 0˚F—check packaging for rating) but take a few minutes to warm up and get to full output when the ambient temperature is low.

The standard CFL should not be used in livestock housing unless it is installed in a sealed fixture such as a jelly jar (see figure 2). Some manufacturers have developed specialized CFLs for use in livestock housing. One example is shown in figure 3. A dimmable CFL is now available which may be useful in animal facilities that require precise control of lighting levels such as poultry barns.

High intensity discharge (HID) lighting

Most farms have at least one of these lighting up the yard at night. A mercury vapor (MV) light is one type of HID lamp. However, the mercury vapor lamp is the least efficient of HID lamp types and poses a greater environmental risk than other lamp types such as high pressure sodium (HPS) lamps and metal halide (MH) lamps. HPS lamps emit about 95 lumens/watt while MH lamps emit about 60 Lumens/watt. A mercury vapor lamp emits only 32 lumens/watt, the lowest of the HID type lamps but has been favored because of the bluish/white light it emits versus the less favored orange light of a HPS lamp.

The metal halide lamp provides the best color rendering light and should be considered for replacing MV lamps in areas where color recognition is important, such as in a dairy freestall barn. Many lamp manufacturers have sodium or metal halide retrofit lamps that can be used to directly replace a mercury vapor lamp without replacing the fixture but these lamps are expensive costing as much as a new HPS or MH fixture with lamp.

A 100-watt HPS lamp can provide 2.5 times more light than a 100-watt mercury vapor lamp while a 100-watt metal halide lamp produces 155% more lumens. A typical 175-watt mercury vapor yard light can be replaced with a 100-watt HPS lamp that produces 25% more light with 43% less electricity.

Metal halide lamps are available in a standard version and a pulse-start version. The pulse start is newer technology that results in up to 50% longer lamp life, about 8% more lumens per watt, faster warm up and restarts and up to 33% less lumen depreciation over the lamp life (less light loss as the lamp ages). Use pulse-start lamps for any new installations of MH fixtures. Pulse start metal halide lamps are not interchangeable with standard metal halide lamps because a different ballasted is required. Therefore, if you are adding new fixtures to an existing installation, it is recommended that all fixtures be upgraded to pulse start ballasts and lamps to eliminate inventory issues.

Low bay HID fixtures are typically used in freestall barns (figure 4). They should be a wide distribution type and be rated for damp envronments.

How an HID lamp works

An HID lamp consists of an arc tube (sometimes called a discharge tube) filled with a gas. In the case of a metal halide (MH) lamp, it contains a starting gas (usually argon), mercury and metal halide salts. When the lamp is operating, a high voltage is applied to the gas mixture in the tube, causing it to vaporize and emit light and UV energy. The outer jacket or bulb

Figure 2. Standard CLF should not be used in livestock housing unless it is installed in a sealed fixture.

Figure 3. Some manufacturers have developed specialized CFLS for livestock housing.

Figure 4. Low-bay HID fixtures are used in freestall barns.

provides a stable thermal environment for the arc tube. If the HID lamp is turned off, it has to cool before it will re-light or re-strike which can take 4 minutes for a pulse-start metal halide lamp and up to 20 minutes for other types of HID lamps.

HID lamp failure

Because High Intensity Discharge lights do not have a filament to burn out like an incandescent bulb; they don't just stop working but instead just fade away as they age. If the lamp lumen output is severely degraded the lamp should be changed. The second indication that re-lamping is needed is frequent shutting down and re-striking while power is applied to fixture.

The table below will help you compare the different lamp types with respect to efficiency, life, color characteristics and starting temperatures.

Applications and design considerations

Reflectivity is a measure of the amount of light that is reflected off the internal surfaces of a building. The surface reflectivity levels influence the number and spacing of light fixtures.

A new facility may have a high level of reflectance but since dirt accumulates quickly on the walls, ceiling and floors, more conservative values than found in a new barn need to be used.

The recommended reflectance value for walls ranges from 0% in a freestall barn with the side curtains open to 10% for tie stall barns. A ceiling reflectance value of 0% is normally used because the lighting fixtures typically used in barns direct all light downward with no back lighting and/or the ceiling is dirty or not used. Floors are generally manure covered and reflect little light; a value of 10% for dairy barns would be a conservative estimate. Reflectance values are required by lighting design programs to calculate the number and placement of fixtures.

Comparison of lamp types (data adapted from manufacturer's literature)

Lamp type	Lumens/watt @ mean lumens	Average life (hrs)	Color	CRI	CCT (K)	Starting temp. (F)	Instant On	Wattage range
Incandescent	7-20	750-1000	White	100	2800	> -40°F	Yes	25-200
Halogen	12-21	2-6000	White	100	3000	> -40°F	Yes	45-500
Mercury Vapor	26-39	24,000	Bluish	15-50	3800-5700	-22°F	No	50-1000
Compact Fluorescent	45-55	6000-10,000	White	82	2700	32°F or 0°F	Yes *	14-29
Metal Halide	41-79	10,000-20,000	Bluish	65-70	3000-4300	-22°F	No	150-1000
Pulse Start Metal Halide	60-74	15,000-30,000	Bluish	62- 75	3200-4000	-40°F	No	100-750
T-12 Fluorescent	62-80	9000-12,000	White	52-90	3000-5000	50°F	Yes	30-75
T-12 High Output Fluorescent	30-70	9000-12,000	White	52-90	3000-5000	-20°F	Yes	25-110
T-8 High Output Fluorescent	81	18,000	white	75	3000-5000	-20°F	Yes	86
High Pressure Sodium	66-97	24,000	Yellow-orange	22-70	1900-2100	-40°F	No	35-1000
T-8 Fluorescent	76-100	15,000-20,000	white	60-86	3000-5000	50°F or 0°F	Yes	25-59

* Requires warm-up to reach full output at cooler temperatures.

Dairy barns

For lighting in a freestall barn or shop areas with ceilings greater than 12 to 20 feet, a low bay type HID fixture design for a wide distribution pattern would be suitable. This type of fixture usually has a diffuser to spread the light horizontally. In a freestall barn, the lights can be controlled by a clock or photo sensors.

For lighting tie stall barns, parlors and milk rooms, T-8 fixtures designed for wet and dusty environments are required. To get the recommended 15-20 foot-candle lighting level in a typical tie stall barn, an 8-foot single T-8 lamp fixture would need to be installed in each feed alley and an 8-foot, two T-8 lamp fixture in the center alley, all at 8- to 9-foot spacing.

Different lighting fixtures distribute the light in different ways, so consult a lighting contractor to calculate the correct spacing and mounting height for a particular fixture and barn layout. A reputable lighting contractor will have access to lighting design software that will consider the size of the space to be lit, reflectance values of the internal surfaces, lamp mounting height, Light Loss Factors, required lighting levels. Use the reflective values stated on the previous page and the photometric data from the fixture to be used to determine the fixture spacing for the required lighting level.

Figure 5. Hubbel skycap reflector increases light reaching the ground.

Yard lights

Many farms have a yard light at a central location on the farmstead. These lights are turned on by a photo-control and operate on a year round basis for an average of 12 hours per day.

A large proportion (about 30% or more) of the light from a typical yard light never makes it to the intended target; the light goes up or sideways. If a fixture is used with a full cut-off parabolic reflector such as the Hubbell Skycap (see figure 5), 47% more light will make it to the ground, (see figure 6). This means that the fixture could be replaced with a lower wattage lamp and still maintain the same illumination of the target area.

If the lamp type was changed from a mercury vapor to a sodium or metal halide lamp, the wattage could be reduced further because these lamps emit at least 40% more lumens per watt.

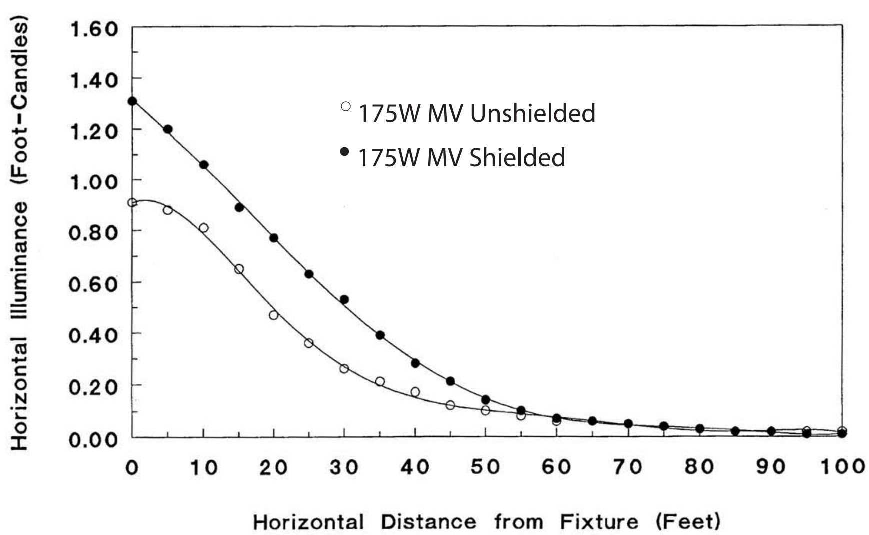
The typical 175-watt mercury vapor yard light uses about 200 watts when the ballast losses are included. This amounts to 876 kWh of electricity per year or $78 per year cost at $0.085/kWh.

If the MV lamp fixture is replaced with a 70-watt high pressure sodium fixture with a full cutoff reflector, the operating cost would be reduced to $39 per year. The cost of the fixture is estimated at $80–$100 for a 2.5-to 3.2-year payback.

Other ways to reduce the energy usage of yard lights is to use a half-night lighting photo-controller or replace the HID lamp with a motion detector and a halogen lamp.

Figure 6. Light distribution of MV Luminaire.

NEMA Type: Shielded vs. unshielded



Note: Hubbell Skycap retrofit (25′ MH) results in 47% more light on the ground in the zone 0-100 feet.

Half-night lighting photo-controller

In many cases, lighting is not necessary in the early morning hours as there is little animal or human activity. If this is the case, the dusk to dawn photo-controller that comes with a yard light can be replaced with a half-night lighting photo-controller.

The half-night controller measures the length of each night and switches the light off the second half of the night, saving half the electricity and reducing light pollution.

Based on the energy cost savings, the payback for the $30 investment for retrofitting a 175-watt mercury vapor yard light with a half night photo controller is about one year. The controller has a rated life of 13+ years. The DPN part-night photo-control is manufactured by Thomas & Betts and is available from your local electrical supplier (PN# DPN1242.6TMGN).

(These references are provided as a convenience and are not an endorsement by the University of Wisconsin.)

Motion detector and a halogen lamp

If a yard light is used for security or to light an area during short periods of activity such as walking between buildings, a halogen lamp and motion detector will provide light when needed for a few dollars per year.

If security is the major concern, parallel motion sensors can be installed to target many different areas. If motion is detected, numerous lights can be illuminated at once, thus surprising the intruder. This type of lamp is available at most electrical and building supply outlets.

If normal activity would cause the halogen lamp to operate more than 30% of the night, an HID lamp left on all night would be more cost effective because of it's higher efficiency.

Lighting for increased productivity

Long day lighting for dairy cattle

Research by Dahl and others have shown that dairy cows are sensitive to day length. Providing 16–18 hours of uninterrupted lighting at a level of 10–20 foot-candles followed by 6–8 hours of darkness can result in an increase in milk production of 5 to 16% (3.1 to 6.2 lb) according to research studies.

Josefsson (2000) estimates profit per cow of $62 for tie stall barns and $67 for freestall barns. In stall barns, long day lighting is accomplished by installing sufficient lighting over the feed manger and in freestall barns, the entire barn needs to be illuminated.

There is a publication on energy efficient supplemental lighting called *Supplemental Lighting for Improved Milk Production* available from the National Food and Energy Council (573-875-7155 or www.nfec.org) that provides information about the different types of fixtures available and the recommended layouts. For the latest research results on long-day lighting, visit the University of Illinois web site at http://il-traill.outreach.uiuc.edu/photoperiod/.

A fact sheet on long-day lighting is available from the Healthy Farmers, Health Profits project at the University of Wisconsin-Madison and can be found at http://bse.wisc.edu/hfhp/.

Greenhouse lighting

Providing supplemental lighting for plant growth can decrease growing times and reduce the risk associated with low sunlight level. Plant growth is directly related to the amount of light energy received on the leaf surfaces. Plants have a saturation level for the amount of light energy they can absorb; above this level, additional light will not increase plant growth. The saturation level varies with plant species.

Some of the typical applications of lamps and fixtures in a greenhouse are as follows:

- Fluorescent fixtures are often used in growth chambers because they are a linear light source rather than a point source; therefore, light distribution is more uniform.
- While “cool white” lamps encourage good plant growth, special grow lights enhance plant appearance because of the boarder spectrum of light.
- High intensity discharge (HID) lighting is common for general greenhouse lighting.
- Both metal halide (MH) and high pressure sodium (HPS) lamps are suitable for greenhouses. A combination of metal halide and high pressure sodium lamps in a one-to-one ratio is common with the MH contributing light in the blue-violet range and the HPS contributing light in the yellow-orange part of the light spectrum.

- Research at the University of Connecticut indicated that supplemental lighting can be accomplished for some crops with only four seconds of light per minute versus continuous lighting, resulting in an energy savings of 80%.

Proper disposal of fluorescent and HID lamps

Fluorescent and high-intensity discharge (HID) lamps use less electricity per unit of light emitted than incandescent lighting, which means few air pollutants such as mercury, lead, nitrogen oxides and sulfur dioxides from electrical generation plants.

Fluorescent and high-intensity discharge lamps all contain mercury, an environmental pollutant, but when properly managed and recycled, these lamps have less impact on our environment than incandescent lamps.

Wisconsin state law, as well as laws in many other states, prohibit the disposal of lamps and bulbs that contain heavy metals, such as mercury, in sanitary landfills. This ban includes fluorescent lamps (linear and U-tube), compact fluorescent lamps (CFL), mercury vapor lamps, metal halide lamps, high-pressure sodium lamps and low-pressure sodium lamps. They must be recycled or disposed of as hazardous waste. The good news is that they can and are being recycled.

The lamps should not be broken to prevent the release of mercury and are best stored in the packaging the replacement bulbs come in. There are a number of companies that recycle lamps to recover the mercury, copper, aluminum, brass and glass from the lights.

The mercury is distilled from the phosphor powder used in fluorescent lamps and reused in new lamps. Copper, aluminum and brass are smelted and reused for raw material in non-food contact products and the glass is purified and used to make fiberglass.

Contact your local waste hauler, recycling center or CleanSweep program coordinator for information on the collection of fluorescent and high-intensity discharge (HID) lamps. If they can't help you, contact your county or state waste management program about recycling locations or the Wisconsin DNR web site's Recycling Markets Directory at: http://www.dnr.state.wi.us/org/aw/wm/markets/.

For additional information on lamp disposal contact the Wisconsin Department of Natural Resources and ask for publication SW 195-03, *Safe Lamp and Bulb Management*.

Proper disposal of fluorescent and HID ballasts

Older fluorescent and HID lamp ballasts contain PCB or polychlorinated biphenyls which is regulated as a hazardous waste and cannot be disposed of in landfills per Wisconsin state law. Ballasts that do not contain PCBs are marked "NO PCB" and can be recycled (preferable) or disposed of in a landfill. If a ballast is not marked, it must be treated as if it contains PCBs.

If ballasts are leaking they require special handing. Contact your local hazardous waste response coordinator for assistance. Additional information can be found in the Minnesota Pollution Control Agency's publication *Managing Used Fluorescent Lamps, High-Intensity Discharge Lamps & PCB Ballasts,* Hazardous Waste publication #4.20, May 2000

Terminology

Average rated life—The mean time it takes for a lamp to burn out. The time at which 50% of the test lamps are burned out and 50% still work.

Ballast—A device used with electrical discharge lamps such as fluorescent and high-intensity discharge lamps to provide the necessary voltage, current and waveform for starting and operating the lamp. Ballasts can be electromagnetic or electronic depending on the type of lamp. Electronic ballasts have been available since the early 1980s and have the advantage of being more energy-efficient. because they operate at high frequencies (25-35 kHz), and emit less flicker, which is a factor with electromagnetic ballasts in cold weather.

Ballast factor—Over the life of a ballast the efficiency decreases slightly. The Ballast factor is a component of the Light Loss factor.

Color Rendering Index (CRI)—An international system used to rate a lamp's ability to render an object's true color as compared to sunlight using a scale from 0 to 100. A higher numerical value indicates a better color match. Numerical comparison, using the CRI of different lamps is only accurate if the Color Temperature Index values are similar. Differences of less than 5 points are usually not visible to the human eye. A CRI above 80 is required for color matching tasks.

Compact fluorescent lamp (CFL)—A device with small diameter fluorescent lamp(s), built-in ballast and a medium screw base for easy replacement of incandescent bulbs.

Correlated Color Temperature (CCT)—(Sometimes called chromaticity) is a description of the color appearance of the light emitted by a lamp, relating its color to the color appearance of the light from a reference source when heated to a particular temperature expressed in degrees Kelvin (K). A lower numerical value indicates a lamp that emits a red or orange light while a higher numerical value indicates a bluer light source. Some examples of typical CRI values: high pressure sodium—1900 K; incandescent—2800 K; halogen—3000 K; cool white fluorescent—4100 K; daylight simulating fluorescent—5000K.

Cutoff distribution is a classification system for the type of reflector and refractor used on outdoor lighting. The typical yard light is classified as "non-cutoff"—light projects in all directions from the light fixture. A "full-cutoff" classification would cover the lamp and reflect light such that no light is projected above the horizontal plane of the fixture.

Fluorescent lamp—A high efficiency lamp utilizing an electrical discharge to ionize gas inside the lamp tube, producing ultraviolet radiant energy which excites the phosphor coating on the inside of the glass, emitting visible light.

Foot-candle (fc)—The unit of illumination on a surface one square foot in area on which is uniformly distributed a flux of one lumen. Equal to 10.76 Lux (ASAE EP344.2 Dec 99).

Fixture—The framework that holds the lamp(s) and may contain a ballast(s), reflector, diffuser, mounting hardware and protective shielding.

Fixture efficiency—The ratio of light emitted from a fixture versus the light emitted by the lamp(s) contained in the fixture expressed as a percentage.

Halogen lamp—The correct description of a halogen lamp is a tungsten-halogen lamp, which is a high-pressure incandescent lamp containing halogen gases such as iodine or bromine. The halogen gases allow the filaments to operate at higher temperatures and higher efficiencies.

High intensity discharge (HID)—Pressurized gas inside an arc tube is ionized by current flowing between electrodes, resulting in the emission of light. There are three principle types of HID lamps:

- Mercury vapor—contains mercury plus small amounts of argon, neon and krypton gas.
- Metal halide—same as mercury vapor lamps, plus iodides of sodium and scandium or other rare-earth elements.
- High pressure sodium—contains sodium, mercury amalgam and xenon.

All HID lamps contain some mercury but the Metal Halide and High Pressure Sodium are considered more environmentally friendly because of the lower ratio of the mercury compared to the amount of light emitted and life of the lamp. All HID lamps need to be disposed in accordance with local and state disposal laws.

Illuminance—The density of light indicated on an area, measured in foot candles or lux.

Incandescent lamp—A device using a filament, usually coiled tungsten wire, which is heated by a flow of current to produces light.

Lamp—A generic term for a device that creates optical radiation (light), sometimes called a bulb. There are three categories of electric lamps: incandescent, fluorescent and high intensity discharge.

Lamp efficiency—The efficiency of a lamp expressed in light output per unit of input energy or lumens per watt. Generally, lamp efficiency increases with lamp size or wattage.

Lamp lumen depreciation factor—Over the life of a lamp or bulb the light output degrades from the initial installation until the end of its useful life. The LLD is a rating of the reduction of light output.

Light loss factor—Expressed as a percentage of the initial lamp output and takes into account the lamp lumen depreciation factor, the luminaire dirt depreciation factor and the ballast factor.

Lumen—A standard international unit of luminous flux or quantity of light. The unit of the time rate of flow of light (luminous energy) equal to the energy emitted through a unit solid angle (one steradian) from a uniform point source of one candela.(ASAE EP344.2 Dec99). Some examples: a dinner candle provides about 12 lumens while a 60 watt Soft White incandescent bulb provides 840 lumens.

Luminaire dirt depreciation factor—Dirt and dust collecting on the lamp or fixture will affect the usable light output. The LDD is a rating of how fast and the effect on light output.

Lux—An international unit of illumination. One lux is equal to one lumen per square meter.

Mean lumen—The average light output of a lamp over its rated life. The mean lumen ratings are measured at 40% or 50% of the rated lamp life depending on the lamp type.

Photometric data—A data set that maps the distribution of light output for a lighting fixture at distances from the light fixture. Each fixture will have a different data set depending on the use of reflectors and refractors.

Reflector—A built in reflective surface on a fixture.

Refractor—A built in lens that bends the light rays to distribute the light over a wider area or to reduce glare.

Work plane—The level at which the work is done and the level at which the design illumination is specified and measured. Typically the level is 2.5 feet above the floor for desk work but for tie stall barn milking operations one foot would more likely represent the work plane.

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