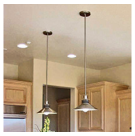
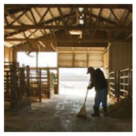
A4050

Energy Efficiency Series


Lighting Technology:

LED Lamps for Home, Farm and Small Business

Scott Sanford

July, 2014

For more than forty years, light emitting diodes, or LEDs, have been used as indicator lights in many electronic devices. LEDs are long-lasting, tough and energy-efficient and have now been adapted for general lighting purposes. LED lamps are made of clusters of individual LEDs and are available in warm white, soft white, cool white and daylight as well as different colors. They are available in Edison base (screw-in) and as spotlights, floodlights, linear tubes and specialty lamps (such as candelabras). LEDs are instant-on lamps that require no warm-up and many are dimmable. LED lights are highly directional, which can help reduce wasted light in certain applications.

Figure 1. Screw-in LED lamps.

Diffused light is usually desirable in a home, so manufacturers have developed LED lamps that are encased in a diffuser or consist of several LEDs pointed in different directions to spread the light (see Figure 1). New LED designs may appeal to those who object to the standard compact fluorescent (CFL) twist design.

Figure 2. Decorative LED lamps.

Figure 2 illustrates decorative LED lamps designed for residential use. Because LEDs don't have a filament like an incandescent bulb, and can take some bumps and jarring without being damaged, they make excellent shop trouble-lights. New LED lamps have been coming on the market almost monthly and suit many general lighting applications where incandescent or compact fluorescent lamps have traditionally been used. The long life of LEDs is one of their major advantages. Some have a rated life of more than 100,000 hours, which means they will last almost half a human lifetime. An LED lamp rated for 100,000 hours and used 8 hours per day should last about 34 years.

Midwest Rural Energy Council

UW Extension
Cooperative Extension

College of Agricultural & Life Sciences
University of Wisconsin-Madison

Figure 3. LED jelly jar with heat-dissipating design.

LED lamps are cold-loving and increase their light output by 20% as the temperature drops from 75°F to -20°F. This makes them an excellent choice for use in free-stall barns, cold storage facilities or refrigerated display cases. By contrast, the light output of fluorescent lamps can decrease 50% or more in cold weather. LEDs are sensitive to heat, but that is rarely a problem in the upper Midwest where ambient air temperatures are moderate. LED lamps and fixtures are designed with heat sinks and sometimes with forced-air convection to aid in keeping them cool. They are not ideal for use in jelly jar enclosures or other sealed fixtures unless they are specifically designed to dissipate heat, like the one shown in Figure 3.

"The light output of fluorescent lamps can decrease 50% or more in cold weather."

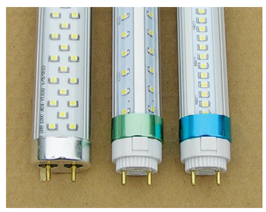


Figure 4. LED tube lamp.

Many companies make LED tube lamps (Figure 4) to replace T8 linear fluorescent lamps. If you have a 4-foot T12 or T8 fixture that is in good condition and that has the correct type of housing for the application, it can be converted to accommodate an LED tube lamp and its driver after the fluorescent lamp and ballast have been removed. The fixture will need to be rewired and may require a driver be mounted in the fixture housing if the manufacturer has not incorporated the LED driver in the tube. (The National Electrical Code requires fixtures in animal housing or other damp environments to be rated water-resistant and to have a cover with a gasket.) High bay LED fixtures (Figure 5) are available to replace mercury vapor or metal halide high bay fixtures.

Figure 5. LED high bay lamp.

Watts versus lumens

We are accustomed to judging a lamp's brightness by the number of watts it uses, but the watt is actually a measure of energy use, not brightness. The lumen is the unit of measure that indicates a lamp's light output. For instance, a typical 60-watt incandescent bulb emits about 850 lumens of light, yet an 11-watt LED lamp emits about that same number of lumens. Table 1 lists the lamp wattage and typical light output of different types of lamps. LEDs use 76% to 83% less energy than halogen or incandescent bulbs and 15% to 20% less than compact fluorescent lamps.

Table 1. Energy use (watts) and light output (lumens) of various general-purpose lamps.

Lumens	Incandescent	Halogen	Compact Fluorescent	LED
465-600	40	28	9	8
750-940	60	43	13	10-12
1050-1170	75	53	18	14-17
1490-1675	100	72	23	22
2680-2800	150	(not available)	42	26

Cover images: home lighting, David Springer; farm building, UW–Madison CALS; small business lighting, Greensburg Greentown. Four LED lamps and two decorative lamps, Scott Sanford.

Above images: Jelly jar, Scott Sanford; LED tube lamp, J 'n J Sales, LLC; LED high bay lamp, J & D Manufacturing

Don't get sticker shock!

LED lamps cost more than other types but when their low energy costs and low replacement costs (due to their long life) are taken into account, they are economical. The best way to illustrate this is with examples.

TIE-STALL DAIRY BARN EXAMPLE

A dairyman wants to upgrade his dairy barn's lighting because the 100-watt incandescent bulbs he's been using are no longer available (due to the nationwide phase-out of general-purpose incandescent bulbs). The 200-foot by 34-foot tie-stall barn currently has three rows of 100-watt incandescent bulbs spaced every 10 feet for a total of 60 fixtures. The lights are used an average of 8 hours per day and the electricity cost is $0.12 per kWh. The lamp replacement options include halogen (a more efficient type of incandescent bulb), CFL, screw-in LED lamps, 4-foot T8 fluorescent tube fixtures and 4-foot LED tube fixtures. The objective is to supply as much light as the incandescent lamps provided, or more. Table 2 shows the energy use, light output, lamp life and per-lamp cost of each option.

Table 2. Lamp specifications.

Lamp Type	Power use in watts	Light output in lumens	Lumens/ watts	Lamp or bulb life in hours	Cost per lamp or bulb
Incandescent	100	1,530	15	750	$1.20
Halogen	72	1,490	21	1,000	$1.75
CFL	26	1,550	60	8,000	$6.50
LED screw-in	22	1,700	81	25,000	$55
4-ft T8 fluorescent	68	5,600	81	20,000	$3.50
4-ft LED tube	46	4,600	100	100,000	$70

The current incandescent bulbs supply approximately 92,000 lumens of light (60 bulbs). Halogen, CFL and LED screw-in bulbs would replace incandescent bulbs on a one-to-one basis, supplying approximately the same amount of light, and would not require new fixtures or rewiring. T8 fluorescent and LED tube lamps produce more light per lamp/fixture than incandescent, halogen or CFL lamps, so fewer would be needed to provide the same amount of light. Producing the same amount of light would require seventeen T8 fixtures or twenty LED tube fixtures, but to make an even number for spacing on three rows we increase the fixture numbers to eighteen or twenty-one, respectively. An installation cost of $100 per fixture is assumed for T8 or LED tube fixtures, along with a cost of $100 for a 4-foot wet-location

Barn image: USDA Dairy Forage Research Center;

T8 fixture, or a cost of $190 for a 4-foot LED tube fixture (including lamp and driver). Both the fixture and installation costs are amortized over 10 years. Costs of electricity, lamp replacement (without labor) and installation (for the T8 and LED tube fixtures) are included.

Table 3. Tie-stall barn example lighting options and savings compared to incandescent option.

Lamp Type	Electricity cost ($/yr)	Annualized lamp replacement cost (4/yr)[4]	Annual cost ($/yr)	Savings ($/yr)	$ per 100 lumens
Incandescent	$2,102	$280	$2,382	–	$2.60
Halogen	$1,514	$307	$1,821	$561	$2.04
CFL[1]	$547	$285	$831	$1,551	$0.89
LED screw-in	$463	$385	$848	$1,534	$0.79
4-ft T8 fluorescent[2]	$429	$378	$807	$1,575	$0.82
4-ft LED tube[3]	$338	$315	$653	$1,729	$0.68

1) Life expectancy lowered to 4,000 hours based on experience in damp environments.
2) 18 fixtures.
3) 21 fixtures.
4) Does not include labor cost for lamp replacement but includes fixture cost for 4-foot T8 and LED fixtures.

This analysis (summarized in table 3) shows that the incandescent and halogen lamps have the highest annual cost, with energy accounting for about 85% of that cost. This annual cost is more than twice that of any of the other options. The 4-foot LED tube fixtures have the lowest annual cost, 76% less than the incandescent bulbs. The CFL, LED screw-in and T8 fluorescent options are all a close second to the LED tube lamp. In the future, LED options should offer even further advantages since the cost of LED lamps is declining as manufacturing volume increases and new products enter the market.

YARD LIGHT REPLACEMENT EXAMPLE

The typical yard light is a 175-watt mercury vapor (MV) fixture. These fixtures are no longer being made and replacement ballasts have been discontinued. Possible replacements are high-pressure sodium (HPS) lamps or LED lamps. To match the lumen output of the original mercury vapor lamp, a 100-watt HPS or 80-watt LED lamp will be needed. Total power consumption (energy use of both lamp and ballast) of the mercury vapor lamp is 213 watts and of the HPS lamp is 130 watts.

In comparing the options we will assume that the lamps will be used an average of 12 hours per day for 365 days per year and that the cost of electricity is $0.12 per kWh. The cost of one replacement lamp for the MV and HPS options is included so that those options match the 50,000-hour lamp life of the LED option. The fixture cost is included for the HPS and LED lamps, annualized over 10 years at a discount rate of 7% annually.

Yard light image: Scott Sanford

Table 4. Yard lamp comparison.

Lamp Type	Watts	Fixture $	Lamp Cost**	Energy $*	Total Cost*
Mercury vapor	213	discontinued	$20	$112	$132
High-pressure sodium	130	$110	$32	$68	$100
LED	80	$490	$52	$42	$94

* Annualized costs.

** Includes lamp replacement and fixture cost.

Based on these assumptions, the LED lamps would reduce ownership costs by 28% compared to the MV lamp and by 5% compared to the HPS. (Labor costs to change lamps and lamp disposal costs for spent lamps for the HPS and MV lamps were not included.)

FREE-STALL BARN LIGHTING EXAMPLE

Metal halide lamps and T5 or T8 fluorescent lamps have typically been used for free-stall lighting. LED lamps have advantages over both these types of lamps. LED light output doesn't decrease in cold weather and lamp life is two to four times longer.

Table 5. Free-stall general purpose lamp comparison.

Lamp Type	Watts	Fixture $	Lamp/Fixture Cost*	Energy $*	Total Cost*
Pulse-start metal halide (PSMH) (250-w)	294	$325	$60	$154	$215
T5 – 4-lamp 54HO	245	$340	$50	$129	$179
LED	160	$740	$79	$84	$163

* Annualized costs.

Let's compare costs of a 250-watt pulse-start metal halide (PSMH) lamp, a T5 4-lamp low bay fixture using T54HO lamps, and an LED lamp in a low bay fixture. All these fixtures emit approximately the same amount of light. The fixture costs are amortized over 10 years at 7% interest. The re-lamping costs for the PSMH and T5 have been annualized and include $70 for lift rental and labor. The lamp life of the PSMH is assumed to be 24,000 hours, the T5 lamp life to be 30,000 hours, and 50,000 hours for the LED.

To equal the life of the LED lamp, the PSMH and T5 lamps will need to be changed once. For this analysis, it is assumed that the LED fixture will be replaced at the end of its life, approximately 12 years. This may seem short but there will likely be more efficient LED lamps by then so replacing the fixture might be economical. Installation costs

Barn image: UW-Madison CALS

(hanging and wiring) are expected to be the same for all fixtures so are excluded from the analysis. The lights are operated for 12 hours per day, 365 days per year at an electricity cost of $0.12 per kWh.

The analysis reveals, see Table 5, that the LED lamp will reduce lighting costs by 24% compared to the PSMH lamp and by 9% compared to the T5 lamp.

Disposal and recycling

LED lamps do not contain mercury but do contain aluminum, copper and some toxic materials, including lead, nickel and arsenic. They are very rugged and unless smashed with a hammer will not release toxins. They are considered nontoxic and can be disposed as normal trash but contain an aluminum heat sink to aid in keeping the diodes below their critical temperature and should be recycled to recover the aluminum.

"LED lamps can be disposed as normal trash, but should be recycled to recover the aluminum."

New lamps can be purchased at building supply outlets, hardware stores or electrical distributors. They may qualify for energy efficiency incentives, check with your electric utility company or state energy office.

Measuring light output

Different lamp types produce different wavelengths (colors) of light. A lumen of light is a weighted average of different wavelengths based on the color sensitivity of the human eye, which is most sensitive to green and least sensitive to red and blue. White light is a mix of all colors but some types of lamps produce more of some wavelengths than others, even though the perceived color is white.

The typical light meter is optimized for incandescent bulbs, which emit a wide range of wavelengths. LEDs typically emit one wavelength. LEDs that emit true white-light are not available. To produce white light an LED makes use of a blue-emitting diode covered with a converter material that emits yellow light when stimulated by blue light. The mixture of blue and yellow is perceived by the human eye as white. Due to the difference in wavelengths produced by incandescent and LED lamps, a standard light meter will register lower lumen or

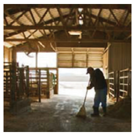
Screw-in LED lamp, Dennis Schroeder, NREL foot-candle levels of light from an LED than from an incandescent lamp emitting the same amount of perceived light. A light meter designed for LEDs is necessary to get an accurate measurement of their output.

The output of a lamp or bulb does not necessarily indicate the amount of useable light from a fixture. Some light is wasted or absorbed by the light fixture. LED lamp output is typically directional so less light is wasted and more of the total light output reaches the intended target area.

LED lamps emit light with a high color-rendering index (CRI). The CRI is a measure of the perceived color of an object when lit by a particular lamp compared to the same object's perceived color when it is lit by sunlight. Sunlight is indexed at a CRI of 100 and LED lamps are often rated at a CRI of greater than 90.

When replacing a lamp with low CRI qualities (such as a mercury vapor lamp) with an LED, the total lumen output from the LED lamp can usually be lower than the original lamp yet produce the same amount of perceived light.

"A light meter designed for LEDs is necessary to get an accurate measurement of their output."


Energy Efficiency
Series

Lighting Technology: LED Lamps for Home, Farm and Small Business

Reference to brand names and use of product photos are not an endorsement of any product, nor is omission of any product a condemnation.

References

Evaluating Light Output – Using Delivered Light to Specify and Compare LED Lighting Fixtures, Philips Color Kinetics, Burlington, MA, 2010.

Lighting Calculations in the LED Era, J.R. Benya, Cree, Inc., 2011.

The mission of the MREC is to initiate, develop, support, and coordinate education, research, and communication programs on significant and emerging rural energy issues for the consumer, energy suppliers, and allied industries through cooperative efforts of council members.

www.mrec.org

Author: Scott Sanford, Rural Energy Program, University of Wisconsin–Madison

Cooperative Extension publications are subject to peer review.

This publication is available from your county UW-Extension office (www.uwex.edu/ces/cty) and from Cooperative Extension Publishing (to order, call toll-free: 1-877-947-7827 (WIS-PUBS) or visit this website: learningstore.uwex.edu).

Graphic design by Jeffrey J. Strobel
UW–Extension Environmental Resources Center

Printed on Recycled Paper

UWEX Publication
A4050 I-07-2014

ERC Publication GWQ 067