Rocky Mountain Institute's

Home Energy Briefs

#2 LIGHTING

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When it comes to lighting your home, quality is more important than quantity. The type and placement of a light source create mood and atmosphere that affect your experience. Moreover, each room is a unique environment, designed for both diverse and specific activities that require diverse and specific lighting. In terms of energy efficiency, there are many designs and technologies that can not only meet all your lighting needs, they can do so using less electricity.

This Brief gives an overview of steps to take in making your home lighting more energy efficient while maintaining and improving lighting quality:

- **Designing with all factors accounted for** (e.g., room characteristics, sources of light, types of tasks, etc.) is a critical first step toward efficient lighting.
- **Compact Fluorescent Lamps (CFLs) and fixtures** have been rapidly evolving in recent years and are a fundamental technology to incorporate into any efficient lighting design.
- **Halogen IR (infrared)** and **PAR (parabolic aluminized reflector) bulbs** fit certain lighting niches if integrated correctly. Likewise, ending the use of halogen *torchieres* is a key goal for reducing energy waste and improving fire safety.
- Besides the source, many other considerations factor into **the light we use and how efficiently it is generated**. Using sensors, dimmers, creative daylighting, or even simply painting a wall, can significantly enhance a home.

WHY USE EFFICIENT LIGHTING?

Lighting accounts for 5–10 percent of the total energy use in an average U.S. home and costs $50–150 a year in energy bills.[1] Lighting is responsible for using about a fourth of all electricity consumed in the United States, of which 20 percent goes to extra air conditioning to remove unwanted heat (from lighting). In fact, more than 90 percent of the energy consumed by a standard incandescent bulb is given off as heat, while only 10 percent is converted into light! Moreover, lighting technology has been advancing rapidly, and more efficient lighting can play an important role in lowering our overall electrical consumption.[2]

LIGHTING DESIGN

Providing efficient lighting is not just about using a different type of bulb. Rather, it is about improving the quality of the home while paying less for the improvement in the long run. E SOURCE, an energy-efficiency information service, conducted an analysis of lighting options for an office to show the importance of doing a "whole-system" upgrade as opposed to implementing only one component of a retrofit.[3] The study showed that only replacing the original lights with more efficient bulbs yielded energy savings of 35 percent with a payback of 4.7 years. Yet, when the light fixtures themselves were upgraded to deliver the light more efficiently, occupancy sensors were added to lower burn time, and photocells were installed to utilize dimmable ballasts during daylight hours, the energy savings jumped to 86 percent with a payback time of 3.2 years! Other studies have had similar results in residential settings.[4] Energy savings of 26 percent—achieved by simply

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replacing the bulbs—grew to 57 percent when the replacements were coupled with lighting controls and fixture retrofits.

Another study conducted by the Lighting Research Center showed that a house designed with energy efficient lighting systems had better light levels overall (as defined by the Illumination Engineers Society (IES)) when compared with a traditionally lighted house.[5] In addition, the same analysis showed that the energy-efficient lighting was accepted as well or better than standard lighting by 78 percent of the study's 706 participants.

NEW GENERATION OF COMPACT FLUORESCENT LAMPS

Compact fluorescent lamps (CFLs) are the most common and multi-functional energy efficient bulbs on the market. There are now hundreds of different CFL styles. Whereas the first generation CFLs cost $20–25 per bulb and were available in only two or three styles, CFLs today are cost competitive with conventional incandescent bulbs ($3–9 apiece). They can be used almost anywhere, from ceiling-mounted fixtures to recessed cans to decorative and vanity fixtures. CFLs are also available for outdoor fixtures, 3-way lamps, some dimmer-controlled fixtures, table lamps, torchieres, and wall sconces. Additionally, modern CFLs provide a range of colors, including incandescent-like colors. Consumers put off by the slightly higher initial cost of CFLs should note that they last up to thirteen times as long (10,000–12,000 hours) as standard incandescents (750–1,500 hours), and use about one-quarter of the electricity. Thus, one CFL can also eliminate the need to produce, install, remove, and dispose of over a dozen standard incandescent bulbs. To top it off, each CFL you install can save you over $50 in electricity costs over the lifetime of that bulb. For example, if you replaced five 75-watt bulbs in your house with CFLs, you could save over $250 over eight years!

Table 1: Light bulb retrofit life-cycle cost analysis

	Standard incandescent "Long-life"	Compact fluorescent lamp "Triple twin"
energy consumed (watts)	75	20
rated lamp life (hours)	1,500	12,000
cost per bulb	$0.48	$8.39
life of bulb* (years)	1.0	8.2
energy use per year* (kWh)	109.5	29.2
operating cost per year (at $0.85/kWh)	$9.3	$2.5
savings per year	NA	$6.8
payback time for price of CFL (years)	NA	1.2
total life-cycle costs	$80.34	$28.79
total life-cycle savings		$51.52

* With an average use-rate of 4 hours per day

Source: RMI analysis

CFLs in low-usage areas

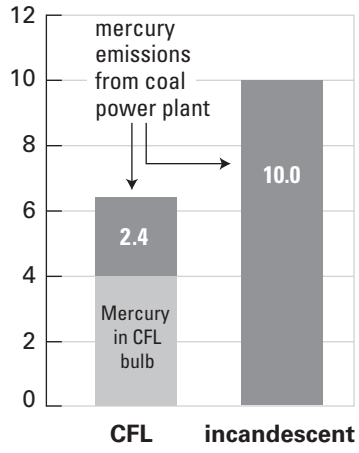
CFLs installed in high-usage areas will provide economic paybacks in a very short time. However, one should consider using CFLs in areas of low usage, even though the payback time will be longer. Some low-usage areas—such as closets—can become high-usage areas if turning off the light is consistently forgotten.

There is some confusion as to whether or not one should frequently turn a CFL bulb on and off. Turning a light on and off does wear out the coating inside the fluorescent lamp (slightly reducing the life of the bulb), yet it has been calculated that it is more economical and efficient to turn a light off if it will be out of use for more than 15–20 minutes.[6] Programmable ballasts that start the lamp gently are also available.

DEDICATED FIXTURES

While the savings achieved by just replacing incandescent bulbs with screw-based CFLs is significant, replacing the entire light fixture with one designed exclusively for a compact fluorescent lamp can be just as cost effective and may have many other advantages, as Table 2 illustrates.

Figure 1: Mercury emissions by light source over 5-year life (milligrams of mercury)



Source: U.S. EPA, June 2002.

One of the drawbacks of screw-based CFLs is that they are often replaced with incandescent lamps because consumers are still not in the habit of keeping an inventory of CFLs. Also, as each type of bulb has a particular light distribution pattern, using fixtures designed for CFLs maximizes total optical performance.

There is also an issue of overheating if the CFL bulbs are installed in an incandescent fixture, which would cause the bulb to put out less light over time. Some screw-based CFLs experience a 20 percent reduction in light output if placed base-down (ballast-down), such as in a table lamp. Using dedicated fixtures eliminates problems—thermal and glare issues—associated with using a fixture designed for a different bulb.

Using dedicated CFL fixtures offers a more thorough solution to lighting issues than just using screw-based CFL bulbs. Also, replacement bulbs are cheaper and smaller because the ballast is a separate part of the fixture. And, they last 40,000 hours. If all the households in the United States replaced five 100-watt fixtures with 23-watt CFL fixtures, the electricity saved would power more than three cities the size of New York City, day in and day out.

In a modern compact fluorescent bulb, there are about 4 milligrams of mercury, prompting concern about the release of this toxin. Yet the use of CFLs actually creates a net *reduction* (see Figure 1) in the amount of mercury released over its lifetime.[7] That's because the largest source of mercury in the air is coal-burning power

Table 2: Light bulb and fixture retrofit life-cycle cost analysis

	Standard A lamp incandescent wall scone	Compact fluorescent lamp wall scone
energy consumed (watts)	100	23
rated lamp life (hours)	1,500	12,000
cost per bulb and fixture**	$0.48	$26.87
life of bulb* (years)	1.0	8.2
energy use per year* (kWh)	146.0	33.6
operating cost per year (at $0.85/kWh)	$12.4	$2.9
savings per year	NA	$9.6
payback time for price of CFL (years)	NA	2.8
total life-cycle costs	$105.84	$50.33
total life-cycle savings		$55.51

* With an average use-rate of 4 hours per day
** It is assumed the fixture for the incandescent is already installed

Source: RMI analysis

Table 3: Comparison of different retrofits

Screw-based CFLs

advantages

- Easily replace incandescents
- Available in most local stores
- Save energy and money
- Many types available

disadvantages

- Over-heating can reduce the light output by 20 percent
- Placement in a fixture designed for an incandescent can decrease performance
- Could be replaced by an incandescent

Dedicated CFL fixtures

advantages

- Optimize optical performance
- Eliminate thermal issues
- Ballasts have 40,000 hour lifetimes
- Replacement bulbs are cheaper
- Has to be replaced with a CFL
- Available in most home improvement stores
- Many types available
- Save energy and money

disadvantages

- Initial cost is higher
- More labor is initially required
- Thermal issues can occur; less in plug-in fixtures

Source: RMI analysis

plants. Using an efficient CFL bulb instead of an incandescent bulb will reduce the amount of mercury released directly into the atmosphere by coal-burning power plants by 36 percent. Also, if the CFL is recycled at the end of its life, the amount of mercury released is reduced by 76 percent!

LEDs: THE NEW FRONTIER

Light-emitting diodes (LEDs), also known as "solid-state" devices, are an emerging technology with significant potential for energy savings and longevity. LEDs have already become the standard in many low-energy applications, such as headlamps, cell phones, bicycle lights, and more recently, Christmas lights.

LEDs are made from materials such as silicon and nickel in a process similar to that used for manufacturing computer chips. LED technology has been growing in popularity in recent years because LED lights offer longevity, durability, and efficiency. Today they come in a wide range of colors, although white LEDs have become available only in recent years.

As with any lamp source, LEDs' light output decreases over time. Modern LEDs have the potential to last ten times longer than CFLs, depending on the type of application, the type of LED, and the product in which they're used—some LED table lamps use only 5 watts. Screw-in LED bulbs are available in various sizes, and even LED Christmas lights are available, but they are costly. Check the resources section on p. 6 for more information.

HALOGENS

Halogen lamps are high-output incandescent lamps that screw into standard sockets. IR and PAR lamps (which use an infrared coating that recycles waste heat within the lamp) can be up to 50 percent more efficient than standard incandescent bulbs. They emit a whiter light than standard incandescent bulbs, making them a good choice for illuminating work requiring high visual acuity or where color rendition is important, such as lighting works of art. Halogen bulbs last twice as long as standard incandescents, lose less than 10 percent of their brightness over their lifetimes (compared to 25 percent for standard incandescent bulbs) and can cost less than $5 each.

HALOGEN TORCHIERES

If you could only make one change to your home lighting, replacing any halogen *torchieres* is the number one energy and money saver. Furthermore, it could save your life.

The six-foot tall lights have become popular because of their appearance, indirect light, versatility, and low initial cost. However, their 300-watt tungsten halogen bulbs operate at around 970ºF (520ºC—you bake cookies at 350ºF!) at efficacies of 18–20 lumens per watt (LPW), which is only slightly better than incandescent bulbs. The high operating temperature makes this type of lamp a dangerous fire hazard. Indeed, they have been banned at two-thirds of all colleges and universities in the United States because they are so dangerous.

Today, there are many high quality CFL torchieres that consume only 50–80 watts with efficacies of 61–86 LPW. Their operating temperature is much lower, averaging 104ºF (40ºC). This means that replacing halogen torchieres with CFL models can remove the fire danger *and* save you money. Table 4 shows the comparative economics of torchieres. By switching to an efficient CFL torchiere, the amount of carbon dioxide saved each year equals the amount emitted by driving a medium-sized car 743 miles.[8]

DAYLIGHTING

Economics, health, and aesthetics all favor the maximum use of daylighting in our homes. In fact, studies have linked the effective use of daylighting to improved worker productivity and better performance in schools.[9] These are clear indicators that our well-being is linked to daylighting. High-quality daylighting requires a design that eliminates glare and unwanted solar gain, and distributes the light evenly and effectively. Natural daylight actually produces less heat per unit of illumination than electric lights, reducing cooling bills as well as the demand for electricity. Also, windows incorporating spectrally selective glazing and tints, or low-e coatings, make daylighting compatible with the cooling and heating requirements of any given climate. If replacing your windows is not an option, you can add films to your existing windows to allow the desired amount of light and heat into and out of your home. (For more information on windows, see *Home Energy Brief No. 1: Building Envelope*.)

Depending on your lighting needs, another alternative to artificial lighting is a lightshelf. Lightshelves are flat surfaces attached

Table 4: Cost of different torchieres					
Lamp type	**Initial cost of torchiere ($U.S.) [a, c]**	**Electricity cost per year ($U.S.) [a]**	**Rated lamp life (hours) [b]**	**Replacement cost per lamp ($U.S.)**	**Approximate operating cost for five years ($U.S.) [a, c]**
halogen	15–20	44	2,000	5–8	234–243
incandescent A lamp	16–40	22	1,200–1,500	2	118–122
quad CFL	90	12	10,000	8	58
flat CFL	150	9	10,000	10	47
circular CFL	30–50	8	10,000	18	40
long CFL	600	14	12,000–20,000	15	69
metal halide	375	10 [d]	15,000	25	50 [d]

a Assuming the torchiere is operated at full power (or highest switch setting) for four hours per day at 10¢ per kilowatt-hour. Based on rated active power.
b Information has been taken from lamp packaging or manufacturer's information.
c Includes cost of electricity and replacement lamps if necessary (based on rated lamp life).
d With the incandescent lamps switched off.

Source: Adapted from Alma E.F. Taylor, *Alternatives to Halogen Torchieres*, Lighting Research Center

to the exteriors of buildings that bounce natural light through windows and deep into the building; they also reduce glare. In addition, light pipes, also known as solar pipes or tubes, are a simple type of alternative lighting technology and are available for under $400. These pipes last for years, require no maintenance, have a proven performance, and, of course, use no electricity. Light pipes have been used in homes to funnel light into dark hallways, bathrooms, kitchens, and living spaces with few or no windows.

TASK LIGHTING

Lighting a whole room so you can see what you're doing is similar to refrigerating a whole house to preserve perishable food. One of the most simple and effective ways to save energy while enhancing lighting quality is to provide more lumens only where they are needed while lowering light levels in the rest of the space. Task lights (swing-arm lamps, etc.) allow users to direct light where it's needed. They can be made to evenly light the papers on your desk while at the same time keeping glare off your computer screen. Many task lights are now available as dedicated CFL fixtures.

LIGHTING CONTROLS

Lighting controls such as dimmers, timers, and sensors ensure that lights are turned on when they are needed; they can also adjust light output to the desired luminosity. These controls can save a lot of energy if used properly.

- **Dimmers**: Dimmers actually extend the life of the bulb while saving you energy. Compact and tube fluorescents are available in dimmable fixtures.
- **Timers**: Timers save energy simply by turning lights on and off at pre-designated times.
- **Sensors**: Sensors turn lights on only when they are needed, but they are more precise than timers as they respond to actual conditions. Ultrasonic motion sensors turn lights on and off in response to movement; infrared sensors turn lights on and off in response to body heat; and photosensors turn lights on and off when ambient light levels fall below or rise above certain levels. There are also many solar powered outdoor lights on the market. These lights have zero operating cost as they store solar energy all day and use it at night. This technology has been proven for many years, even in cloudy conditions.

MORE LIGHTING EFFICIENCY POINTERS

Each room's characteristics will determine the lighting techniques that can be applied. While it may not be possible to change a room's solar orientation or location, other factors can be changed. For example, dark paint and carpet can be replaced with lighter colored paint and carpet to reflect more light. Also, periodically cleaning light fixture reflectors, diffusers, and/or lenses (using the methods recommended by the manufacturer) and replacing any components that have yellowed or lost their reflectivity will enhance a room's light.

SUMMARY

Improving the efficiency of your home lighting can not only reduce your electric bills, it can also improve the atmosphere, comfort, and safety of the room, as well as your ability to see. Recommended measures include replacing incandescent bulbs with more efficient CFLs, installing dedicated fixtures, using controls like dimmers and sensors, incorporating tasklighting and daylighting, and, most importantly, getting rid of those dangerous halogen torchieres.

ADDITIONAL RESOURCES

U.S. EPA's Energy Star — Provides information on available lighting and fixtures whose performance is backed by the government entity. Their website will point out products such as screw-based CFLs, dedicated fixtures, solar powered outdoor lighting and efficient halogen torchieres that can be found in many well-known retail outlets (www.energystar.gov/index.cfm?c=lighting.pr_lighting).

The Lighting Pattern Book for Homes, 2nd edition — Good source to find out more about the art of lighting. This book was produced by the Lighting Research Center, which is a part of the Rensselaer Polytechnic Institute's School of Architecture.

Local Utilities — To find out more about efficiency programs in your area, check out your local utility. Most utilities nationwide offer rebates for using more efficient lighting technologies (www.utilityconnection.com/index.asp).

Heschong Mahone Group — Conducts studies on the effects of daylighting and performance (www.h-m-g.com).

Earth911 — A site designed to help you find local recycling centers for CFLs, along with many other items. This website also provides mail-in sources if there is not yet a recycling center near you (www.earth911.org).

GE Lighting — Has created a 6-page pamphlet comparing traditional lighting appliances with new energy efficient options. This pamphlet is especially helpful in determining exactly what type of bulb or fixture is ideal for different applications in your home (www.gelighting.com/na/downloads/energystar.pdf). GE also provides a "Virtual Lighting Designer" program that visually compares different lighting options for individual rooms (www.gelighting.com/na/home/lsc.html).

Technical Consumers Products, Inc. — TCD offers many CFL bulbs and fixtures. They have also developed an LED desk lamp (www.tcpi.com or www.tcpi.com/pdf/Galaxe%20spec%20sheet.pdf).

Littlite — Produces small task lamps. Some of the lamps they offer are LEDs (www.littlite.com/products.php?category=10).

Lighting Resource Center (LRC) — Part of Rensselaer Polytechnic University, this university-based research center is a great source for everything related to lighting technologies, applications and products (www.lrc.rpi.edu).

NOTES

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