ENERGY USE FOR LIGHTING

Lighting accounts for about five to ten percent of total energy use, or $50 to $150 per year in the typical home. If a home has extensive outdoor lighting or if any lights are left on all night, the annual lighting cost could be considerably higher. In any case, there are several new energy-saving lighting technologies, described in this chapter, that every homeowner should consider.

How light output, energy use, and efficiency of lights are measured

To understand the energy use of lights – and the savings that can be realized by switching to more efficient lights – we have to understand how light and electricity use are measured. Because we are used to incandescent lamps, which are rated according to their wattage, most of us think of wattage as a measure of light output (a 100-watt light bulb produces much more light than a 60-watt bulb).

Wattage is not a measure of light output. Wattage is a measure of power input. Light output is measured in lumens. A standard "75 watt" bulb uses 75 watts of power to produce about 1200 lumens of light. An 18- watt compact fluorescent bulb uses only 18 watts of power to produce about the same level of brightness (1100 lumens).

The efficiency of lamps can be confusing. With most other energy users around the home (heating systems for example), there is a maximum amount of energy contained in the fuel being burned. The amount of energy we actually get out from that heating system is a measure of its *efficiency* (80%, 90%, etc.) (see Chapter 5). But with lighting, the upper limit is not so obvious. As a result, the term *efficacy* is often used instead of efficiency. Efficacy

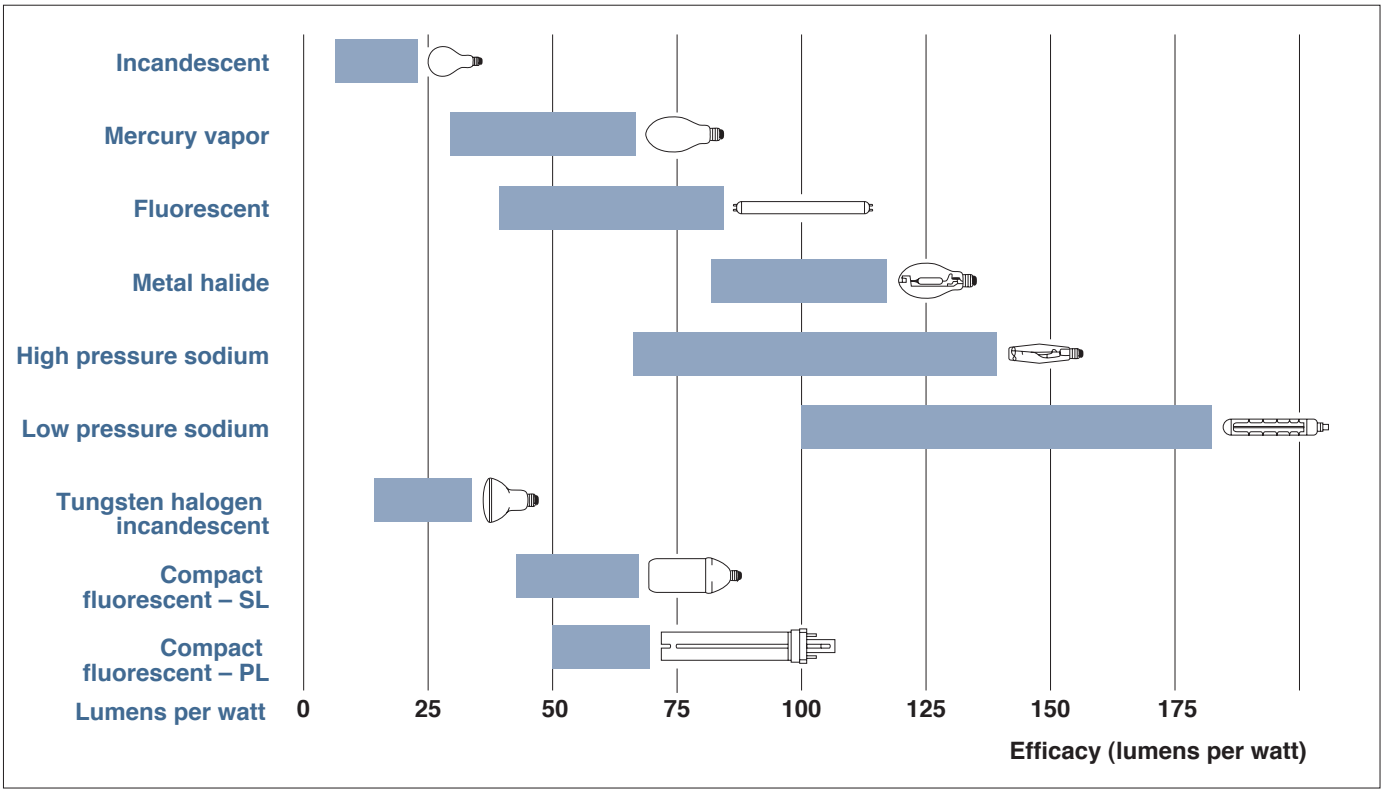

Figure 3-1 - The energy performance of lamps is expressed as efficacy which is a measure of light output, in lumens, per watt of electrical input (lumens per watt). The efficacy of a regular incandescent light bulb is only a fraction of the efficacy of a fluorescent bulb.

is the lumen output divided by the watts of power input (lumens per watt). Standard incandescent lamps produce 10 to 20 lumens per watt, while fluorescent lamps produce 50 to 90 lumens per watt, and high-pressure sodium lamps as much as 140 lumens per watt.

The Spectrum of Light

There are other factors in choosing an electric lamp besides power use, issues related to the pleasantness of the light produced. In order to understand these factors, one must know something about the spectrum of light and other electromagnetic radiation.

The color of light depends on its wavelength. Visible light has a wavelength ranging from about 380 nanometers (deep violet) to 840 nanometers (deep red). A nanometer (nm) is one-billionth of a meter. Light at wavelengths just below 380 nm is ultraviolet (the light that causes sunburn), while light at wavelengths just above 840 nm is infrared (radiant heat). Other parts of the spectrum include things such as radio waves, microwaves, and x-rays. Visible light is the only part of the spectrum that we can see, so in measuring lamp lumens only the visible part of the spectrum is considered.

Objects, when heated, become "incandescent": that is, they glow visibly. Most incandescent objects emit light with a continuous spectrum, that is, they emit light at every wavelength simultaneously. The hotter an object is, the lower the wavelength (more blue-violet) the light it emits. On Figure 8-2, the spectrum of sunlight (sun surface temperature about 8000°F) is spread from ultraviolet to infrared, with the highest levels in the visible range. The spectrum of an incandescent lamp (filament temperature about 4000°F) has its highest levels in the invisible infrared. It is no coincidence that the highest levels of sunlight are in the visible range: our eyes have evolved to use the available light!

The continuous spectrum of incandescent objects produces a very pleasant light because it has a full range of colors. The disadvantage of this light is that much of its energy is wasted in the infrared or the ultraviolet,

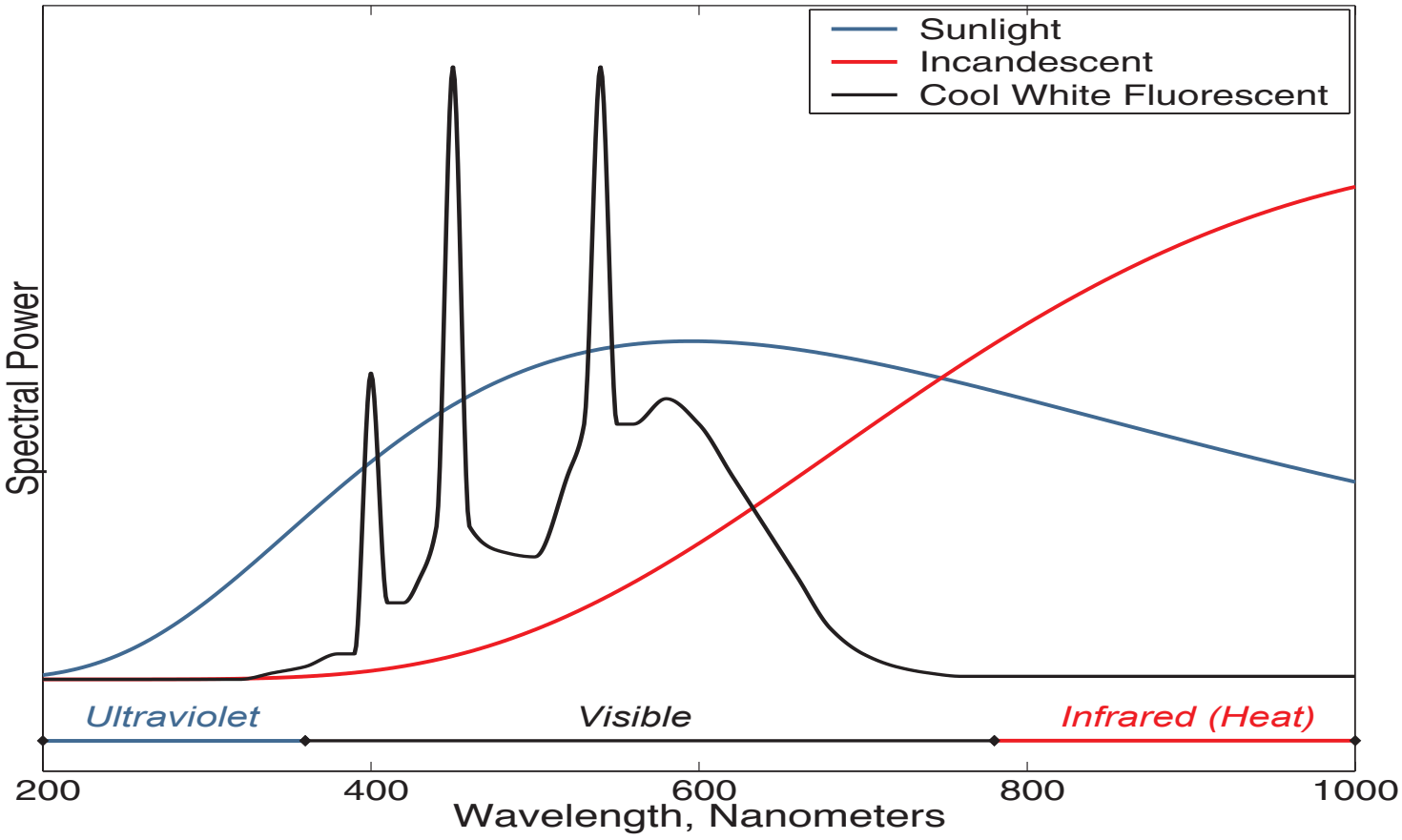

Figure 8-2 - Spectra of sunlight, incandescent light, and cool white fluorescent light.

rather than used as visible light. This is particularly true of incandescent lamps, most of whose energy goes into heat.

The light coming from the phosphor coating of a fluorescent lamp is not produced by heating the coating. The ultraviolet rays coming from the gas in the lamp strike the phosphor molecules, which then emit visible light. The difference between this light and incandescent light is that it is produced over a few narrow ranges of frequencies, as shown on Figure 8-2 for a typical "cool white" fluorescent lamp. Most of the light energy coming from the fluorescent lamp is in the visible range. This is also true for other high-efficiency lamp types such as metal-halide, sodium, and mercury vapor.

Lamps with a limited spectrum use their input energy much more effectively because they don't waste energy on invisible infrared and ultraviolet light. The disadvantage of these lamps is that within the visible region the spectrum is not smooth, but spiky, so that the light is stronger in some colors than in others. As a result, the light is less pleasant and colors appear less vivid. The worst case is with low pressure sodium lamps (sometimes used for streets and parking lots) which emit a single-color orange light. In low-pressure sodium light you don't see colors at all – just different shades of orange.

Since the invention of fluorescent lights, scientists and engineers have been working to improve the phosphors' color spectrum. The ultimate goal is to provide a spectrum that is nearly continuous in the visible region, but doesn't waste any energy in the ultraviolet or infrared. As new fluorescent phosphors are developed they come closer and closer to this goal.

Besides working for a continuous spectrum, lamp developers have learned to change the "color temperature" (the equivalent temperature for an incandescent source) of the light that phosphors produce. For professional lighting designers, manufacturers specify lamp color temperatures. For consumers, the colors are described using terms such as "Daylight" for lamps that try to simulate sunlight, "Cool White" for lamps that are slightly less blue, and "Warm White" for lamps that have a more yellowish light similar to that of incandescent bulbs.

The quality of fluorescent lamp light has reached a level where it is satisfactory for most situations in your home. For some tasks where excellent color perception is very important – sewing, applying makeup, etc. – incandescent light is still preferred.

Energy-efficient lighting options

Compact fluorescent lights

Fluorescent lamps produce light by passing an electric charge through a glass tube filled with mercury vapor. The mercury vapor is energized and gives off ultraviolet (UV) light. The UV light is absorbed by a special phosphor coating on the inside of the glass tube, which fluoresces, emitting visible light.

The most important innovation in home lighting during the past forty years is, without a doubt, the compact fluorescent light. First introduced in the United States in 1980, the compact fluorescent light is a miniaturized version of the straight-tube fluorescent. Instead of a 2-foot, 4-foot, or 8-foot fluorescent tube with separate ballast in a light fixture, manufacturers have packaged both ballast

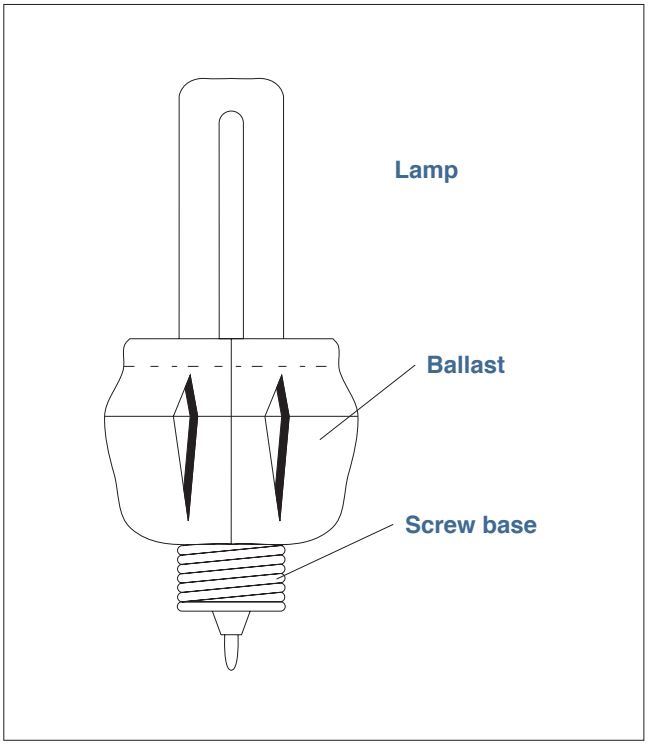

Figure 8-3 - Compact fluorescent lights offer high quality light and excellent energy efficiency in a size that can fit into many fixtures designed for incandescent bulbs.

and fluorescent tube (lamp) into a unit slightly larger than a standard light bulb.

While compact fluorescent lights are still bigger than standard light bulbs, many can fit into conventional light fixtures. Because most compact fluorescent lights use high-quality phosphors, the light quality is excellent – almost indistinguishable, in most cases, from incandescent light. Compact fluorescents light instantly, but take a minute or two to come to full brightness. Compact fluorescent lights last much longer than incandescent bulbs – generally at least ten times as long. Many are now sold with 5 and 7 year guarantees!

Ordinary compact fluorescent lamps can replace incandescent lamps in most fixtures, though they are too large for some. Special, but widely available, compact fluorescent lamps are needed for three-way fixtures and for fixtures with dimmers. Compact fluorescent lamps should not be used on fixtures with photocells unless the photocells are rated for fluorescent lamp service.The major drawback to compact fluorescent bulbs is that they are expensive to buy – anywhere from $5 to $20 per bulb, depending on the type. But, as we shall see, the high initial cost is more than offset by the savings in energy that these bulbs offer, and by the fact that one compact fluorescent will outlast ten or more regular incandescent bulbs.

Most compact fluorescent lamps are integral – that is the ballast and lamp are a single unit. Integral lamps use electronic ballasts and are less expensive and more readily available than separate magnetic ballasts. Modular compact fluorescent lamps have separate magnetic ballasts and lamps. The advantage to buying ballasts and lamps separately is that the magnetic ballasts have lifetimes 5 to 7 times longer than that of the lamp. So just replacing the lamp, when it has burned out, instead of the whole unit might be more cost effective.

The disadvantage of modular lamps is that there is no single standard mount to connect the lamp to the ballast. As a result, you must generally replace the lamp with one made by the same manufacturer.

All fluorescent lights contain small amounts of mercury. You should never dispose of burned out fluorescent lamps in the trash can. Take them to a recycling center and dispose of them with other household hazardous wastes such as batteries, solvents, and paints.

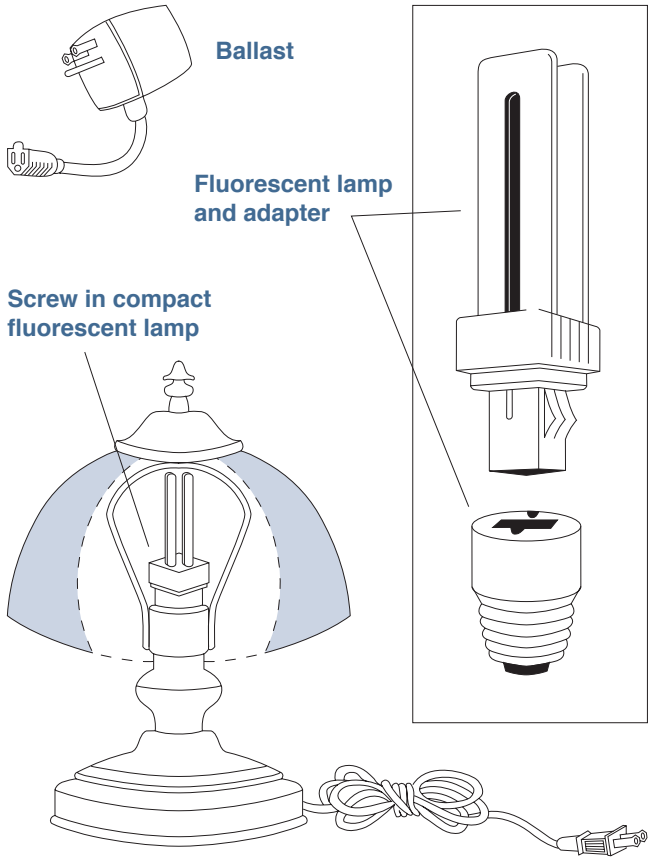

Figure 8-4 - Ballasts that plug into the wall solve the problem of compact fluorescent lights that are too big or too heavy for some fixtures.

Savings with Compact Fluorescents

A single 75 watt incandescent bulb, used an average of six hours per day, costs about $12 per year to operate. An equivalent 18 watt compact fluorescent bulb used for the same number of hours costs less than $3 per year to operate – a savings of $9 per year in electricity. If you keep lights on for longer periods of time, the yearly savings will be greater, up to about $36 if the light is on all the time.

More expensive to buy; Cheaper to own

Although it is hard to adjust to paying $15 or $20 for a light bulb, a simple example shows how compact fluorescent lights actually cost much less to buy and use than conventional incandescent bulbs.

An 18 watt compact fluorescent light replaces a 75 watt incandescent. Over its 10,000 hour lifetime, it will consume a total of 180 kWh of electricity. At 7.3¢ per

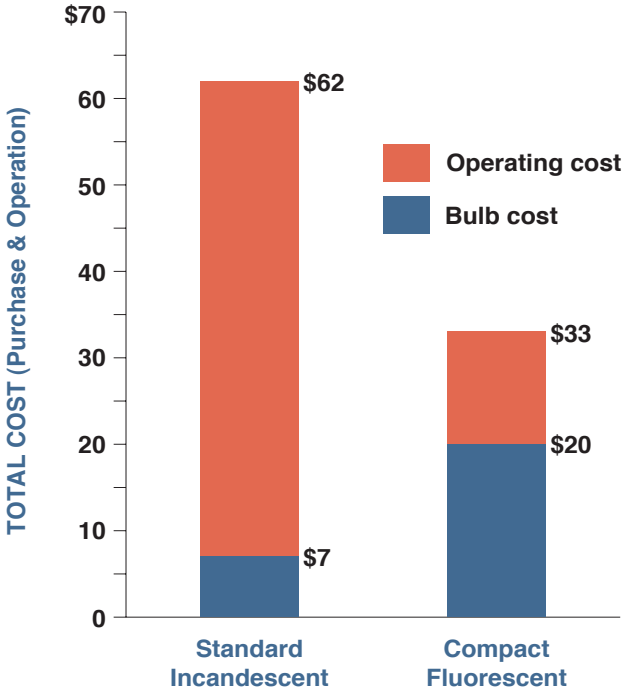

Figure 8-5 - Compact fluorescent lamps are more expensive to buy than incandescent bulbs, but they are much less expensive to own because of their much lower operating costs.

kWh, the total operating cost is about $13. Add to that the $20 cost for the bulb, and your total lighting cost for that fixture is about $33.

Over the same 10,000 hour period, a 75 watt incandescent bulb, with the same light output, would require 750 kWh of electricity at a cost of $55. Also, since incandescents only last about 750 hours, you would also need to replace the bulb 12 times at a cost of about $7, making your total cost $62, compared to $33 for the compact fluorescent (Figure 8-5). Thus, over its expected lifetime, a compact fluorescent light bulb saves about $29 and the work of changing 12 lightbulbs!.

Energy-efficient incandescent bulbs

Incandescent bulbs are the familiar "light bulbs" that are currently used for the vast majority of home lighting applications.

In an incandescent bulb, light is produced by heating up a wire filament made of tungsten until it glows white-hot, giving off visible light. In a typical incandescent lamp, 90% of the electricity is converted into heat; only 10% into light. The percent light output can be even lower with long-life bulbs. As a light bulb ages, the tungsten filament gradually burns up, depositing a black coating on the inside of the bulb, further reducing light output.

Incandescent light bulb efficacy has been improved in recent years in a number of ways. With the so-called "Watt-Miser," "Econ-o-watt," or "SuperSaver" light bulbs, efficiency is boosted roughly 10-15% through the use of different gases in the bulb that help the filament burn hotter (putting more light in the visible range) and minimize blackening of the inside of the bulb. The actual efficacy in lumens per watt depends on the strength of the bulb – high-wattage bulbs burn much more efficiently than low-wattage bulbs.

Table 8-1 - Savings Achieved by Substituting Compact Fluorescent for Incandescent Lights

Replace 75-watt Incandescent with an 18-watt Compact Fluorescent	Savings After 1st Year	Savings After 2nd Year	Savings After 3rd Year	Savings After 5th Year	Savings After 10th Year
Lights on 2 hours per day	[16.21]	[12.42]	[8.64]	[1.06]	17.88
Lights on 4 hours per day	[12.42]	[4.85]	2.73	17.88	35.75
Lights on 8 hours per day	[4.85]	10.30	25.45	35.75	90.75
Lights on 12 hours per day	2.73	25.45	28.18	52.88	125.75
Lights on 24 hours per day	25.45	50.15	75.60	125.75	272.25

More significant are the tungsten halogen incandescent lamps. These lamps have the filament in a separate capsule within the glass bulb. The capsule contains halogen elements such as bromine and iodine to reduce the blackening of the glass as tungsten burns off the filament. Some tungsten halogen lamps also have a heat reflective coating on the glass that reflects heat back in toward the filament, making it burn more efficiently.

Another way to get easily focused task lighting or accent lighting is with low-voltage systems. Low-voltage incandescent and tungsten halogen lamps are not inherently any more energy efficient than their 120 volt counterparts, but because the filament is shorter and fatter, the light source is smaller and can be focused more precisely. This can provide some savings in situations where light is needed on a very specific area. These lamps also last longer.

Using halogen bulbs in torchiere floor lamps is a mistake. It is safer and more energy efficient to use Energy Star qualified compact fluorescent light bulbs in torchiere lamp fixtures. They burn much cooler and use 60% to 80% less energy.

Despite the fact that improved standard incandescent lamps and tungsten-halogen lamps have higher efficiency than old-fashioned light bulbs, their decreased energy use is small compared to what is available from standard and compact fluorescent lamps. For maximum energy efficiency, incandescent lamps should be used only where a very compact light source is needed or where excellent color perception is required.

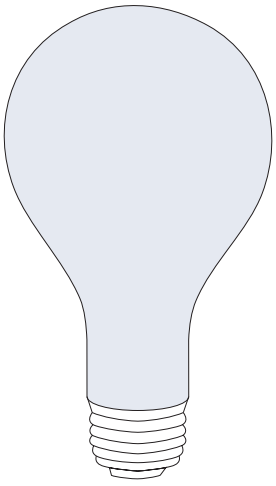

Figure 8-6 - Incandescent lamps, commonly called "light bulbs," give off 90% of their energy as heat, and only 10% as light.

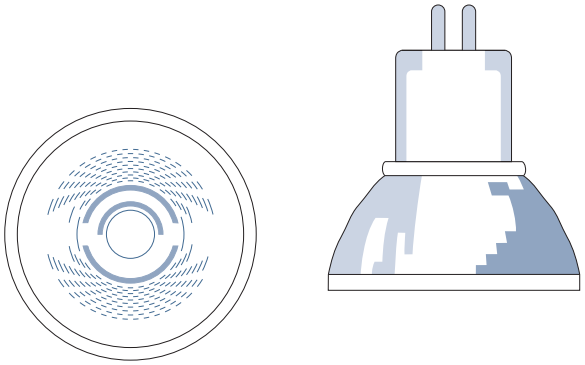

Figure 8-7 - Tungsten halogen lights are most common in reflector styles, though some are available in a more conventional light bulb style.

Improved straight-tube fluorescent lighting

While compact fluorescent lights are relatively new, straight-tube fluorescent lights have been around since the 1930s. Fluorescent lights have been used widely in commercial and industrial buildings, largely because of their dramatic energy savings over incandescent lights and the fact that they typically last ten to twenty times as long. They use just 1/4 to 1/3 as much electricity to produce a given quantity of light as incandescents. But because of problems with the light quality, fluorescent lights have not been a popular light source in homes – until recently, that is.

Improvements in fluorescent light quality have occurred on two fronts: the ballast that regulates the electric current going to the lamps, and the lamps themselves. There are three types of ballasts found in fluorescent light fixtures: standard magnetic ballasts, energy-saving magnetic ballasts, and electronic ballasts.

Magnetic ballasts are relatively inefficient and commonly produce an audible hum or buzz. Also, since they cycle on and off at 60 cycles per second, they produce a flicker that is noticeable to some people. Most ballasts sold in new fixtures are energy saving magnetic ballasts, which are 5-10% more energy efficient than older

Figure 8-8- Standard tube fluorescent lights are now available in a much wider range of color temperatures, and with much better color rendition than the typical "cool white" models.

standard ballasts, but even these can hum or buzz noticeably.

Far better from both an energy and aesthetic standpoint are the newer electronic ballasts, which are 25 to 35 percent more energy efficient than standard magnetic ballasts. Electronic ballasts are usually silent, and because they operate at 10,000 to 20,000 cycles per second, there is absolutely no discernable flicker. Even though electronic ballasts cost more than magnetic ballasts, they are a very good investment in homes, both because of the energy savings and because of user satisfaction.

The light quality of fluorescent lamps has also been significantly improved in recent years. New “rare-earth” phosphor coatings result in greater light output, whiter light that is closer to incandescent light in appearance, plus improved color rendering.

These higher-quality lamps are not as easily available as standard cool-white or warm-white lamps (you might have to order them through an electrical equipment supplier), and they will be more expensive, but they are strongly recommended for living areas.

HID lighting

High-intensity discharge (HID) lamps are similar to fluorescent lights in that an electric arc is passed through a gas. But in this case, the light produced is visible light, not UV, and no phosphor coating is required on the glass.

High-intensity discharge (HID) lighting is most commonly used along streets and highways, but it can be used for outdoor lighting where lots of light is desired but where color rendition is not crucial. The main advantage of HID lighting is its high efficacy when used for high-power floodlighting. As is the case with fluorescent lighting, HID lighting technology has advanced rapidly in recent years, with improvements in both light quality and efficiency. Although some HID lamps are significantly more efficient than fluorescent lamps, the improvement is not very great in the low wattage sizes that are most useful for homes.

Of the three HID light sources that are suitable for residential settings (mercury vapor, high-pressure sodium, and metal halide) mercury vapor is the most common, but the light quality is relatively poor and the energy efficiency the lowest (see Figure 8-1).

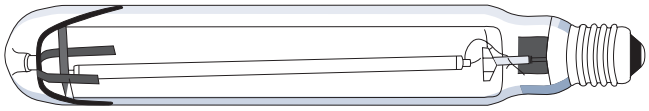

Figure 8-9 - High-intensity discharge (HID) lamps are generally used for outdoor lighting. Most HID lights are more efficient than fluorescent lights.

High-pressure sodium lights offer the greatest efficiency, but the light is yellowish in color. Metal halide is slightly less efficient than high-pressure sodium, but the light is much whiter— closer to the light from incandescent lights. All HID lamps require ballasts to operate, and most of these ballasts require relatively long warm-up periods.

The primary application for HID lighting around a home is for outdoor lighting where a lot of light is required, such as outdoor tennis courts and swimming pools.

Because of their long warm-up period, these lights are not practical for short intermittent uses, such as taking out the trash.

Energy saving lighting controls

So far we have discussed saving energy for lighting by using more efficient lamps. But there is another strategy that can be just as effective at saving energy and money: lighting controls that automatically turn lights off when they aren’t needed, or turn them on only when they are needed.

Lighting control strategies are most applicable to outdoor lighting, particularly if you are in the habit of leaving lights on all night or 24 hours per day. For those who currently tend to keep lights on all the time – or who

frequently forget to turn them off during the daytime – photocell controls can be used to turn the lights on at dusk and off at dawn. In buying photocell controls, one must be aware that their maximum power capacity (watts) is smaller for fluorescent lamps than for incandescent lamps.

If your primary need for outdoor lighting has to do with security, or for a few minutes of light now and then when you're putting out the trash or letting the dog in, motion detector controls might be a good investment. Motion detectors sense the motion of somebody walking up or driving within range of the detector and activate a switch to turn on the lights. Most can be set to keep the lights on for a specific period of time, such as three, five or ten minutes. The better products also include manual override features. The savings possible by installing motion detector controls depends on how long the lights would be left on unnecessarily without these devices.

Motion detectors, or slightly different occupancy sensors that sense the heat given off by occupants, are available for indoor use also. Products are available that replace a standard light switch and automatically turn lights off a few minutes after everybody leaves the room. With some occupancy sensors, you have to manually turn the lights on, while others control both the on and off. Be aware that the lower cost occupancy sensors may not prove very satisfactory– as you will quickly discover if the lights suddenly go out while you are sitting quietly reading.

Daylighting

Daylight is the ideal light source, both in terms of quality and energy use. A single skylight provides as much light as a dozen or more light bulbs, and the light quality is unsurpassed. Many people feel that exposure to natural daylight is conducive to good health. But too much natural lighting – especially glare – can be distracting, and, of course, this light source is only available during the daytime.

Skylights and windows have to be designed carefully so they don't contribute to overheating. The potential for overheating from skylights will vary, depending on the pitch of your roof and the direction it's facing. North-facing skylights on relatively steep roofs will generally not lead to overheating because the sun never shines directly down onto them. Skylights placed elsewhere may need some exterior shading placed over them in the summer. Greenhouse shading material is commonly used for this purpose.

Windows can also contribute to overheating. If not shaded, east and west facing windows can admit considerable amounts of unwanted solar heat in summer. Keep this in mind if adding windows and plan on either installing some type of summer shading device or using glass with low solar transmission.

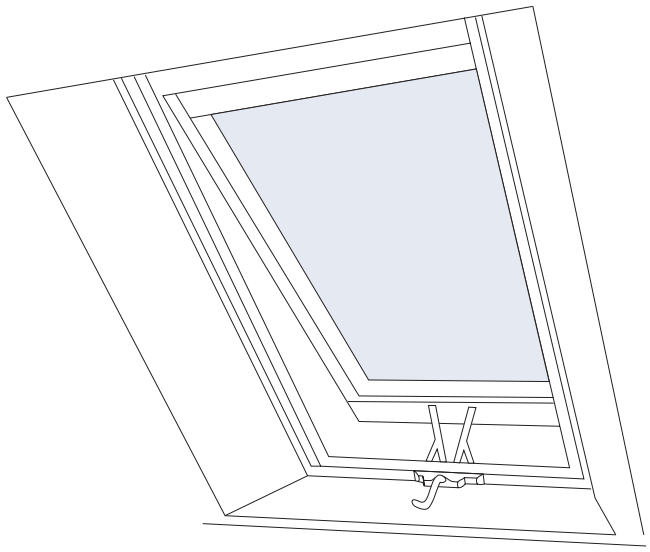

Figure 8-10 - Installing a skylight in a work or play area can significantly reduce the need for electric lights during the day.

Planning a new home to take maximum advantage of daylighting is best done during the design phase, when you or your designer can plan the layout of rooms and placement of windows and skylights to greatest advantage. There are many factors to take into account to provide optimal daylighting without causing overheating, so it's best to work with a designer experienced in this area. Glazing types, overhangs, vegetation, placement of windows, and room layout are all important factors for consideration.

A new way to add daylighting to a room is with a "skylight tube." These devices consist of a lens that is installed on the roof, an adjustable mirror-lined tube (10-20" diameter) that passes through the attic, and a light

fixture that installs in the ceiling. Skylight tubes bring daylight into the house with much less disruption of roof and ceiling construction than is required for ordinary skylights.

You can also make some changes in your existing home to better utilize natural lighting. Simple things that can be done include rearranging furniture to take advantage of light from windows, and replacing dark curtains with light-colored curtains or venetian blinds. More involved changes that can make a big difference might be cutting some of the sun-blocking trees or branches from around the house, and adding a skylight or two – particularly in an upstairs study, workroom, or home office that is likely to be used a lot during the daytime.

Whenever adding new windows or skylights, it is important to consider possible solar overheating and to install appropriate shading or other solar control measures.

Modern buildings designed for daylighting typically use 40 to 60% less electricity for lighting needs than do more conventionally designed buildings.

Solar powered lighting

Another way to power lighting – particularly outdoor lights – is to use solar energy. A photovoltaic (PV) panel uses the solar energy of the sun to generate electricity, which is stored in a battery. The energy stored in the battery can be used to provide electric power to the outdoor lights. Solar powered lights work very effectively as patio and walkway lights, security lights, and to accomplish different landscape lighting effects in the garden. Solar lighting is versatile because no wiring is required and they can be moved around to achieve different effects.

Energy Star qualified Light Bulbs, Fixtures, and Ceiling fans

Look for the Energy Star label if you are purchasing compact fluorescent bulbs, light fixtures, or ceiling fans. Energy Star labeled lighting products meet strict energy efficiency criteria without sacrificing performance. The Energy Star label is awarded to both hard-wired and portable light fixtures including table lamps, torchieres, suspended fixtures, ceiling fixtures, outdoor light fixtures, recessed, and security lighting. Energy Star qualified ceiling fans and fixtures use compact fluorescent light bulbs, which reduce heat output and energy consumption as well as protecting the environment by reducing air pollution and global warming associated with energy production.

Lamp Packaging Disclosures

Effective in May of 1995, the Federal Trade Commission's Appliance Labeling Rule required light bulb manufacturers to display information on packages to help consumers choose the most energy efficient light bulbs. This rule applies to all household light bulbs except small bulbs like night- lights and chandelier bulbs. The information provided includes:

- Light Output: how much light the bulb produces, measured in lumens.
- Energy Usage: the total electrical power a bulb uses, measured in watts.
- Design Voltage: if the bulb is not 120 volts, which is what most bulbs operate on.
- Average life in Hours: how long you can expect the bulb to last.
- Number of light bulbs in the package.

Lighting strategies for your home

The floor plans in Figure 8-11 represent a typical home, showing where different energy-efficient lighting strategies might be applied. Your home will of course differ considerably from what is shown here, but the ideas may be applicable.

Energy Tips and Recommendations

1. Go through your house and make a list of which lights are on the most. The most-used lights are the best candidates for replacement with compact fluorescent lights. Compact fluorescent lights require special dimming ballasts and lamp holders in order to be used in dimming circuits.
2. Measure the light fixtures for those most used lights and then go to a lighting store or hardware store that carries a selection of compact fluorescent lights. Check the dimensions of the various types of compact fluorescents and buy one or two (don't

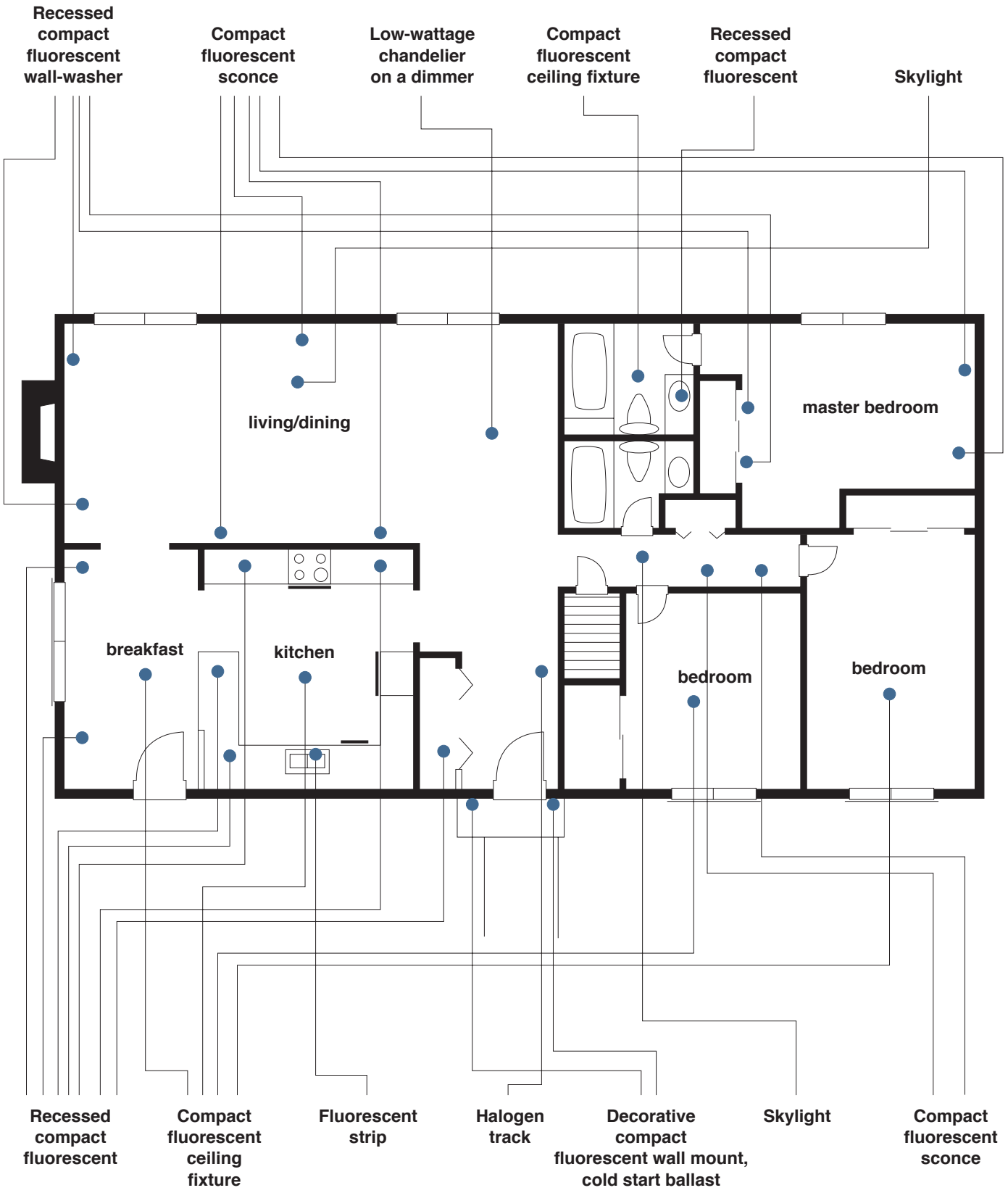

Figure 8-11 - Possible locations for energy-efficient lighting are shown in this typical floor plan.

buy a lot until you have made sure they will fit in your fixtures).

3. For situations where you need the highest quality light focused on a very specific area, consider tungsten halogen lights – either standard or low-voltage. Avoid using halogen lights in torchiere floor lamps – they can be a fire hazard.
4. Make use of natural daylighting whenever possible, especially in rooms that are used a lot during the daytime. In some situations you may need to rearrange your furniture to position your work-space by a window or under a skylight. In an upstairs room, you might want to consider putting in a skylight. (If you have an unheated attic above the ceiling, you will have to construct a light-well with insulated walls to allow the light to get down into the room.)
5. If you choose to continue using incandescent bulbs, use one high-wattage bulb in place of multiple low-wattage bulbs wherever possible. A 100-watt light bulb produces as much light as two 60-watt bulbs. Use incandescent bulbs that are energy efficient and avoid long-life bulbs.
6. If you tend to keep outdoor lights on all the time, buy and install a photo-sensor or motion-detector. Most hardware stores and building supply stores now carry these; if you can't find what you need there, try an electrical equipment dealer.
7. Utilize lighting controls and install timers, dimmers, and occupancy sensors in appropriate rooms.
8. If you need a lot of outside illumination (for a tennis court or swimming pool, for example), consider replacing incandescent lights with HID lights (either high-pressure sodium or metal halide).
9. Call your electric utility company to see whether they offer any incentives or assistance for purchasing compact fluorescent lights.
10. Use task lighting, which is focusing light on the area that you need light and avoid lighting up the entire room.
11. Turn off lights when not in use.
12. Clean fixtures, lamps, and lenses annually to remove dust and dirt that is preventing proper illumination and minimizing lighting efficiency.
13. Dispose of all fluorescent light bulbs properly.
14. Look for the Energy Star label when purchasing new lighting products.