



HOME LIGHTING

Minnesota Department of Commerce Energy Information Center

Lighting has changed significantly since Thomas Edison invented the light bulb in 1879 – now more types of light bulbs are available to fulfill a variety of lighting needs. However, even with the advances in lighting the incandescent bulb continues to be standard in many homes. Unfortunately incandescent bulbs are very inefficient and can account for as much as 15 percent, or about \$100, of a home’s yearly energy usage.

Types of lighting

Compare cost and efficiency

Compare color and quality

Four lighting strategies

Room-by-room lighting ideas

Outdoor lighting

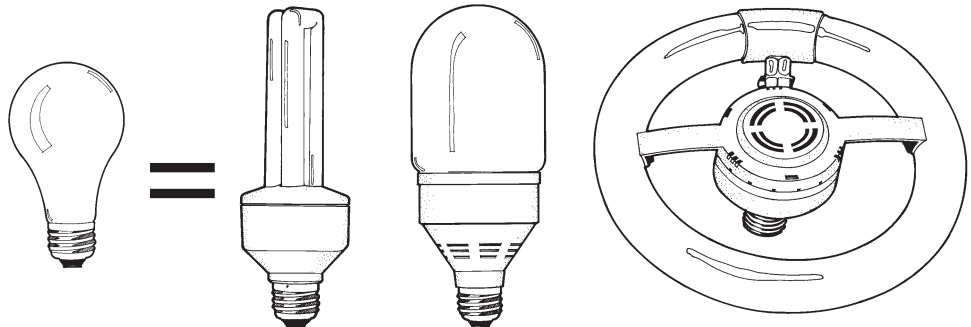
New lighting products are not only more energy efficient, they offer many more possibilities to improve the quality of lighting our homes, indoors and out. This guide looks at some of the new technologies for residential lighting, compares the cost benefits, identifies four basic strategies to apply, then provides specific examples of how to put the new strategies into practice throughout the home—room by room.

Types of indoor lighting and how they work

An incandescent bulb is usually made of clear or frosted glass, screws into a “medium base” socket, generally lasts from 750 to 1000 hours, and emits a warm white light. The word “incandescent” translated from Latin means “glowing with heat.” Light is produced when the electric current heats the bulb’s filament; 90 percent of the energy is used to heat the filament and only 10 percent goes into making light. Therefore, most of the energy used by the bulb is given off as waste heat, not light.

Common replacements

Incandescent Watts (lumens)	Compact Fluorescent Watts (lumens)
60 (900)	16 (900)
75 (1200)	20 (1100-1200)
100 (1750)	30 (1600-1800)



Compact fluorescents come in a variety of shapes and sizes to fit different fixtures.



Related Guides:

- Low Cost/No Cost Ideas
- Attic Bypasses

Seal recessed lighting fixtures to prevent air leaks

Heated indoor air can leak through unsealed recessed light fixtures and cause numerous problems, in addition to heat loss.

When warm air leaks into the unheated attic, moisture condenses and can drip back onto the light fixture and ceiling. The heated air also creates warm spots on the attic roof interior, which on the exterior can cause ice dams along the roof eaves. Air leaks in ceiling fixtures also can contribute to a reduced flow of combustion air, contributing to dangerous backdrafting of the furnace and water heater.

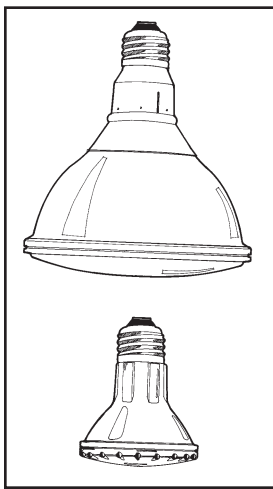
All recessed light fixtures are not created equal. Underwriters Laboratories (UL) rates recessed fixtures, so look for a UL-listed fixture with an IC rating, meaning that an airtight box can be built around the fixture.

Recently, manufacturers have begun producing airtight recessed fixtures and airtight kits to be used with standard recessed lights to stop this unwanted air leakage.

Proper insulation is very important. For recommended measures to ensure air tightness, refer to the Home Energy Guide "Attic Bypasses" or contact the Energy Information Center.

Tungsten-halogen (T-H) is another type of incandescent bulb that provides a whiter light and a higher light output over time than regular incandescents. Unlike earlier versions, the new T-H bulbs will operate on standard household current (120 volts) and screw into standard sockets. The new bulb design, encasing the tungsten filament within a glass capsule, has also eliminated the health risks associated with ultraviolet radiation.

Fluorescent light bulbs produce light by activating light-emitting phosphors enclosed within the bulb. The electric current flowing between the electrodes at each end of the bulb stimulates the phosphors that coat the inside of the tube. This produces more light and less heat for each unit of energy used. All fluorescent lights require a ballast to convert ordinary household current to the proper voltage needed to start and maintain the light. Magnetic ballasts may flicker at start-up, while modern electronic ballasts provide an "instant on" feature. To increase energy efficiency, replace light fixtures that have magnetic ballasts with ENERGY STAR fixtures. Old ballasts may contain PCBs and should be treated as hazardous waste and properly disposed of at a county collection site. If trying to increase energy efficiency, sometimes lower wattage fluorescent linear bulbs can be used in fixtures. Examine the ballast to identify if it will power bulbs of a lower wattage; for example, a ballast may indicate that 34W, 35W or 40W bulbs can be used.



Tungsten-halogen reflector lamps (bottom) are 40% more energy efficient than incandescent PAR-lamps (top).

When shopping for a replacement fluorescent linear bulb, most people only look for wattage and length. However, it is helpful to know what the rest of the product specifications mean. Product specifications might vary depending on the manufacturer. For example, a product description might list: F32T8/TL730. The first set of numbers, F followed by 32, is the approximate length of the bulb. The second set of numbers, T followed by 8, indicates the diameter of the bulb, which is measured in one-eighths of an inch increments (a T-8 bulb is 8/8ths or 1 inch in diameter). The smaller the diameter, the more energy efficient the bulb is because it converts more electricity into light. Many manufacturers will abbreviate the numbers for color rendering (amount of illumination) and color temperature (whether a light is "warm" or "cool"). In the previous example, F32T8/TL730, the 7 is an abbreviation for a color rendering of 70 (on a 100-point scale) and the 30 is an abbreviation for a color temperature of 3,000. Other manufacturers might list the same information as: F032/730K or F32T8/SP30. All of these bulbs offer the same wattage, diameter, color temperature and color rendering. Additionally, some manufacturers describe color rendering and temperature as cool white (CW) or warm white (WW). Fluorescent bulbs should be treated as hazardous waste and properly disposed of at a county collection site.

Compact fluorescent light bulbs (CFLs) work the same way as fluorescent linear tube lights. They come in many shapes and sizes and most can replace incandescent bulbs in standard light fixtures. Using CFLs will save money in two ways: they use less energy—75 percent less, and they last longer—10 times longer, than incandescents. The long-life feature makes CFLs especially useful in light fixtures that are hard to reach, including recessed fixtures, cathedral ceiling fixtures and outdoor fixtures. All CFLs will use less energy than incandescent bulbs, but CFLs with the ENERGY STAR label will offer the most savings. All major manufacturers offer CFLs with the ENERGY STAR label, which means the bulb has met strict requirements for energy efficiency and performance.

Reflector lamps (R-lamps), most often seen in recessed ceiling or track lighting fixtures, are either incandescents, halogen or compact fluorescent. The bulb is partially coated with aluminum or silver to direct more light out of the bulb. An improved ver-

sion, with more precise reflectors, is the PAR lamp (parabolic aluminized reflector). They are available in spot or flood light versions and are also used outdoors for security or decorative lighting.

High intensity discharge (HID) lamps produce light by passing an electric current through gas under pressure. Because they can operate throughout a wide temperature range they are often used for outdoor security lighting. Mercury vapor lights, known for their blue-green color, have been used for outdoor lighting since the 1930s. They are being replaced, however, by high-pressure sodium lamps, which produce a golden colored light and are very efficient.

Compare cost and efficiency

Why would a person spend \$5 to \$20 to purchase a CFL bulb rather than incandescent for 50 cents? Because CFLs use 75 percent less energy to operate, they last up to 10 times longer, and they produce more lumens (light) per watt (electricity used) than incandescent bulbs. Although CFLs cost more initially, they are a better bargain in the long run.

The two basic pieces of information needed to find the best buy are printed on the light bulb package: watts and lumens. Watts, often the only number people look at when buying a light bulb, indicates how much energy the bulb consumes but nothing about the light output. The average lumens is the amount of light given off by the bulb. To determine a bulb's efficiency, look at the amount of lumens per watt. Surprisingly, some bulbs that are labeled as long-life may last longer, however light output is significantly lower.

For example: A 75-watt incandescent bulb uses 75 watts of electricity to provide 1,200 lumens. A 20-watt compact fluorescent uses only 20 watts of electricity, one-fourth the amount, to provide the same 1,200 lumens. To determine the real cost of lighting, add the cost of the bulb (initial cost plus replacements) and the electricity cost.

Compare the operating cost of a single 20-watt CFL and a 75-watt incandescent for 10,000 hours.

	Bulb cost (Initial x replacement)	Electricity cost (10,000 hours)	Total
75W Incand.	\$1 X 13 = \$13	\$48.75	\$61.75
20W CFL	\$20 X 1 = \$20	\$13.00	\$33.00

Compare color and quality of light

The quality of light produced by a bulb can vary depending on the light source, and is expressed in two ways: color temperature and color rendering.

Color temperature (or correlated color temperature, CCT) is measured in degrees Kelvin, and may or may not be listed on the product package. Light bulbs with a number below 3500K are considered "warm," and are more reddish in color; light bulbs with a number above 4000K are considered "cool," and are more bluish in color.

Color rendering is measured by the Color Rendering Index (CRI), which rates the amount of illumination compared to a light source with a known CRI. Only lights with the same temperature rating are compared with each other.

A simple way to find a light bulb that will produce the best color temperature and color rendering for most lighting needs is to look for an ENERGY STAR light, which will have a CRI of 80 or higher and a color temperature between 2700K and 3000K.

Evaluate your home's lighting needs

To evaluate the home's current lighting conditions, tour the home in the evening and turn on the lights as you go from room to room. Is each area receiving adequate amounts of lighting?

Lighting generally falls into one of three categories:

Accent lighting. Use accent lighting to highlight specific objects, such as artwork, shelves or plants. It can also illuminate wall surfaces in a soft wash of light or accentuate the texture of the surface.

Task lighting. Direct light to specific activity areas with task lighting lamps and fixtures. Lights under cabinets to illuminate kitchen work surfaces or a reading lamp next to that favorite chair are two common examples of task lighting.

Ambient lighting. Distribute light broadly throughout a space with ambient lighting fixtures, such as the traditional single ceiling fixture located in the center of a room. Ambient lighting by itself is still adequate for general activities that are not visually demanding, but will not give the quality of light needed for reading or sewing.

To make sure areas of the home meet desired lighting needs, choose and locate accent fixtures



Money Isn't All You're Saving

ENERGY STAR bulbs, fixtures tax exempt

Now purchasing an ENERGY STAR light CFL or fixture will bring even more savings: Qualifying products are exempt from Minnesota state sales tax if purchased before Aug. 1, 2005.

The ENERGY STAR label indicates that the product has met strict performance requirements outlined by the U.S. Department of Energy and the Environmental Protection Agency. In fact, one requirement for ENERGY STAR CFLs is that they carry a minimum 1-year warranty. Advanced technology enables CFLs to use 75 percent less energy than a standard incandescent bulb and last up to 10 times longer.

Many types of ENERGY STAR light fixtures are available, including table and floor lamps, ceiling fixtures, outdoor lights, recessed lights and architectural lights. To find products and stores that sell them, visit the ENERGY STAR web site at www.energystar.gov.



Money Isn't All You're Saving

Replace torchiere lamps with ENERGY STAR torchiere lamps

Halogen torchieres are popular because they are inexpensive to purchase; however, they are expensive to operate. In fact, yearly energy costs to operate the lamp can exceed the original purchase price of the lamp.

Additionally, standard halogen torchieres are a safety hazard. The light operates at 1000 degrees F or higher, which presents a fire risk because if the torchiere tips or falls over, that is hot enough to ignite curtains, furniture or other household materials.

ENERGY STAR-qualified fixtures meet safety guidelines and operate at much cooler and safer temperatures and offer an energy-efficient alternative. ENERGY STAR torchieres are available for less than \$40, making replacement of the halogen torchiere a great investment.

In one year of operating the torchiere lamp for four hours a day:

Halogen torchiere:
300w bulb = \$35/year

ENERGY STAR torchiere:
65 w bulb = \$7.95/year

(cost of electricity—
\$0.08/kWh)

first, then choose and locate task lighting fixtures. If additional light is still needed, use ambient lighting fixtures.

The new technology and how to use it: 4 strategies

Strategy 1: Replace standard incandescent light bulbs with ENERGY STAR labeled CFLs.

No other new product in the lighting industry has had as great an impact as the ENERGY STAR labeled CFL. Modern CFLs have taken the best aspects of fluorescents—high efficiency and long life—while eliminating previous problems of poor color, flicker and noise. Achieve the most benefit by switching to ENERGY STAR labeled CFLs wherever high wattage incandescent bulbs are used more than three hours per day—often in the kitchen and family room.

Some specialty CFLs can now be used with dimmer switches. More and more types of CFLs will work well outdoors in Minnesota's cold climate.

Strategy 2: Replace standard incandescent ceiling fixtures (especially in the kitchen and laundry area) with ENERGY STAR labeled fluorescent fixtures.

ENERGY STAR labeled light fixtures, when used with ENERGY STAR CFLs, help save money on utility bills and offer long life, convenience, better quality and safety than standard fixtures. Over their lifetimes, ENERGY STAR-qualifying fixtures will cost less than half as much to operate and can even eliminate the need to replace up to 40 standard incandescent light bulbs over the life of the fixture.

ENERGY STAR-rated fixtures are available in many styles including table lamps, torchieres, wall sconces, under-cabinet lighting and outdoor security lighting. Some indoor fixtures are dimmable or have two-way switches, and all outdoor fixtures have photosensors (they turn on at night, off in the morning) and some also have motion sensors.

Any fixture bearing the ENERGY STAR label must meet safety and reliability guidelines and offer minimum warranties of two years—well above industry standard. In addition, these fixtures operate at much lower temperatures than many traditional lamps so they reduce fire risks.

Strategy 3: Replace incandescent spot and flood lights with “T-H” PAR lamps. Or better yet, with compact fluorescent floodlights.

These new arrivals on the market in R-30 and R-40 sizes can easily replace many spot and flood lights used indoors. In places where fluorescent lighting cannot be used, tungsten-halogen (T-H) lighting is a good choice. Basically a more efficient form of incandescent lighting, although not as efficient as fluorescent, “T-H” bulbs produce a crisp light that brings out the colors of furnishings.

In recessed ceiling or track lighting fixtures, a good replacement is the new generation of ENERGY STAR CFLs with a parabolic aluminized reflector (PAR). These bulbs are up to 75 percent more energy efficient than incandescent reflector lamps.

In outdoor fixtures use halogen floodlights with a built-in photo-sensor, which will automatically turn itself on at dusk and off at dawn. This floodlight has a rated life of 3,000 hours, which is 50 percent longer than the typical rated life of regular floodlights.

Strategy 4: Use automatic lighting controls in dining rooms, hallways—or anywhere light is needed.

A number of easy-to-install lighting controls are available that will increase lighting flexibility, home security and energy savings:

- Electronic dimmers, especially popular in dining rooms, regulate the brightness of incandescent and tungsten halogen lights and can create an informal, relaxed atmosphere—and they save energy. The lower the brightness, the lower the energy consumption.
- Motion sensing light switches turn lights on and off automatically when someone enters a room, offering “no hands” light control for hallways, bedrooms and other areas where lights are inadvertently left on, or as part of a home security system.
- Electronic timers provide precise, automatic on-off control of light fixtures and are often used for home security. For instance, timers will turn specific lights on automatically at dusk and off at “bedtime” making the house appear occupied when you are away from home.

Putting the strategies to work at home

Experts know that the right lighting can dramatically change the look and feel of a room. Listed below are several ideas to enhance the beauty of the home and to increase lighting energy efficiency—room by room.

In the kitchen ...

- Mount low-profile fluorescent tube fixtures under wall cabinets located above work surfaces to provide the required light for food preparation and clean-up. They should be mounted as close to the front of the cabinet as possible to avoid countertop glare. A good choice is a thin T5 fluorescent tube lamp.
- Use recessed ceiling fixtures or track lighting with the new generation of ENERGY STAR CFL-PAR bulb or 45-50 watt T-H PAR 38 flood lamps over a work island or open counter. (See Sidebar: Spot or flood lights—What's the difference?)
- Use a pendant fixture over a kitchen table or center island and equip the fixture with an ENERGY STAR labeled CFL approved for dimmer use.
- For ambient lighting, choose ceiling-mounted ENERGY STAR labeled fluorescent fixtures and use ENERGY STAR labeled lamps (choose medium to warm color). Select a ceiling fixture that directs some of the light up toward the ceiling. This minimizes the “gloomy” look of a dark ceiling and can make a small room feel larger.

In the dining room ...

- Combine a decorative fixture or chandelier over the dining table with other fixtures that provide ambient light. A hanging fixture by itself usually becomes a source of glare if it is used to brightly illuminate the entire room.
- Use the new generation of ENERGY STAR CFL-PAR in recessed ceiling or track fixtures as accent lighting to highlight a painting or to illuminate a buffet. CFL floodlights used in recessed cans or similar fixtures can orient the light in a particular direction. A 15-watt CFL is the replacement for a 60 to 65 watt incandescent bulb.
- Install separate dimmer switches for each type of lighting to provide maximum flexibility.

In the living room or family room ...

- Use CFLs with high light-output bulbs in reading lamps next to furniture. The circular style (30-watt) with an electronic ballast will produce 2200 lumens, equivalent to a 150-watt incandescent bulb.
- Use a technological breakthrough—small, bright, and long-life fluorescent reflectors are available today. A 23-watt R-25 reflector is more compact than the 75-watt R-30 reflectors it typically replaces in spotlights and track lights, and it has a rated life of 15,000 hours, which is 50 percent longer than other compact fluorescent reflectors. For track lights or spotlights, particularly those that are hard to reach, there is no better choice. Also use CFL flood lights in recessed fixtures over game tables or activity areas. Add dimmer switches for maximum light control and energy savings.
- Try a lighting technique called “wall washing” for ambient lighting. Look for the new recessed ceiling fixtures made for compact fluorescent lamps or use a decorative wall bracket with fluorescent tube fixtures. Directing the light toward ceilings and walls reflects light throughout the room. (Note: This is not as effective in rooms with dark colored walls.)

In the bedroom ...

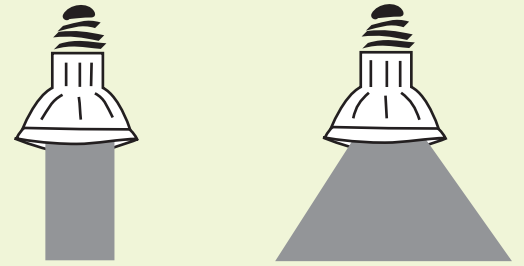
- Soft, ambient lighting is usually adequate and attractive for bedrooms, with an additional reading lamp or two at the bedside.
- In a master or guest bedroom, install one ENERGY STAR ceiling fixture using two ENERGY STAR 15-20 watt CFLs.
- Adding a light in the closet can be a useful method to avoid lighting the entire room. Although, be aware that there are safety code

Spotlights or floodlights—what's the difference?

When purchasing bulbs for recessed ceiling or track lighting fixtures, first decide if a “spot” or “flood” light is needed. You will be disappointed if you mistakenly purchase the wrong type.

Spotlights direct the light more intensely into a smaller, tighter beam. Use spot lights primarily for accent lighting applications, but never for ambient lighting.

Floodlights disperse the light into a wider beam—lighting a broad area less brightly than a spot light. Floodlights are most often used for ambient ceiling or track fixtures.



Closet lights must meet Building Code

According to the State's Building Code, certain precautions must be taken when installing lighting in closets. For instance:

- The bulb must be enclosed. Open bulbs cannot be used in a closet.
- Surface mounted incandescent fixtures must be at least 12 inches from shelves or clothing rods.
- Lamps in recessed fixtures and surface-mounted fluorescent fixtures must be 6 inches or more from shelves or clothing rods.

Contact the local building inspector for more details.

restrictions to placing fixtures and bulbs too close to clothing or other combustible materials. (See side bar: Closet lights must meet building code.)

- In a child's room use ENERGY STAR ceiling fixtures and ENERGY STAR table lamps, or use ENERGY STAR CFLs in standard lamps. ENERGY STAR CFLs produce up to 90 percent less heat than incandescent bulbs, so they are less of a fire or burn hazard and are much safer to use near children. Additionally, installing motion detectors will ensure that the lights are turned off when the room is not occupied.

In the bathroom ...

- Use ENERGY STAR linear fluorescent bulbs and fixtures on both sides of the mirror for the best cosmetic lighting. Fixtures using compact fluorescent bulbs can provide high-color rendering and match the "warm glow" of incandescence while using less energy. A second-best choice would be lighting located above the mirror.
- Provide lighting above bath and shower areas for safety—especially in larger bathrooms—with ENERGY STAR recessed or surface mounted ceiling fixtures.

Types of outdoor lighting and how they work

Recent developments in outdoor lighting have greatly expanded the possibilities to increase the safety, security and beauty of the home and property as well as saving energy. With Minnesota's cold, northern climate, check the light fixture or bulb for cold weather performance.

Installing a new fixture is not required to achieve automatic dusk-to-dawn lighting and improve the safety around the property. Many fixtures can use halogen floodlights with a built-in photo-sensor, which will automatically turn itself on at dusk and off at dawn. This floodlight has a rated life of 3,000 hours, which is 50 percent longer than the typical rated life of regular floodlights.

Additionally, ENERGY STAR CFL outdoor floodlights are available. These CFLs can provide the same amount of light, last longer, and consume less power than regular incandescent reflector lamps.

Low-voltage incandescent or tungsten-halogen fixtures and bulbs are popular for landscape lighting because of their safety (reduced shock hazard),

low energy cost, and easy installation. They run on a 12-volt current rather than the standard 120 volts and operate off transformers, similar to doorbells. Choose among tier lights, mushroom lights, floodlights, or high and low walk lights, many of which come mounted on stakes that push into the ground. For greatest efficiency and savings, operate these lights with motion detectors or programmable timers to limit their on-time and energy consumption.

Insect lights just don't work! Designed to trap and kill insects (specifically mosquitoes), they would seem a good choice for an outdoor light in Minnesota. Unfortunately, these lights usually attract mosquitoes in such large numbers that the kill rate is ineffective. Ultraviolet and blue wavelengths attract insects—yellow repels them. High-pressure sodium lights, with their golden yellow hues, would be a good choice. Or, any bulb with a yellow coating or a fixture with a yellow lens would also work as a repellent.

Gas lights with mantles that are heated with natural gas are sometimes still used for outdoor decorative lighting. These lamps give out very little light for the energy consumed. Also, the cost of operating a gas lamp is expensive (four to 16 times as much as incandescents). It would be more economical to convert a gas light to an electric fixture with a low voltage conversion kit that includes a photocell. Or, convert to standard voltage and equip the lamp with photocell and motion detector controls or simply use an ENERGY STAR CFL.

High-pressure sodium lamps (HPS), characterized by a "golden" or yellow colored light, provide a highly efficient means to light wide areas, such as yards and building perimeters, and are a good replacement for older "blue-green" mercury vapor lighting. Recently, fixtures have been developed for high-pressure sodium lights that mount on the sides of outdoor buildings, which would be a good choice for lighting areas around garages, barns or other buildings. In animal production barns it is important to use fixtures rated for high humidity and damp conditions.

Solar electric or photovoltaic (PV) cells directly convert sunlight into electrical energy. Solar electric light systems collect and store energy from

the sun, then use the energy to produce light at night. They are most useful as an outdoor summertime light, especially for those who would otherwise have to pay for extending electrical wiring into their yards or to a remote site. Although, be aware that not all PV light kits are the same. Before purchasing, make sure the operating characteristics are compatible with Minnesota winter temperatures and the intended use.

Lighting controls are useful outdoors as well as indoors:

- Automatic timers allow lights to go off and on at specific times.
- Photocell controls, sensitive to natural light levels, will automatically turn lights on at dusk and off at dawn.
- Motion detectors can turn lights on and off when someone steps in and out of range.
- The best lighting option would be the marriage of a photocell control to energize the system and a motion detector to control the illumination.
- All controls must be protected from the weather. Be sure to check the operating temperature range before installing any outdoor lighting equipment. Higher quality products often include circuitry, which compensates for Minnesota's temperature ranges.

Where to buy efficient light bulbs:

When shopping at discount retail department stores, home improvement centers and hardware stores, let the managers know you're interested in ENERGY STAR products. There's nothing like demand to stimulate supply. Most commercial lighting suppliers, who supply light bulbs to businesses, will also sell to the public. Look in the yellow pages under "Lighting."

Check with the local electric utility. Many either sell efficient light products or offer rebates as part of a conservation program with the intent to delay or eliminate the need for building new power plants.

ENERGY STAR partner retailers and manufacturers are a click away through the ENERGY STAR web site at www.energystar.gov.

Common Replacements

Pole-mounted fixtures to replace older mercury vapor heads:

Mercury vapor	HPS	Light output (lumens)
250 watt	150 watt	14,400
175 watt	100 watt	8,850
100 watt	50 or 75 watt	3600-5600

Replacements for entrance, wall-mounted, or decorative post-top lighting:

Incandescent	HPS	Light output (lumens)
500 watt	100 watt	8,850
300 watt	70 watt	5,600
200 watt	50 watt	3,600
135 watt	35 watt	2,000

For more information:

Planning and Designing Lighting, Edward Effron (1986) – An excellent book for anyone interested in setting up an efficient, attractive lighting system. Easy to understand with excellent photographs and illustrations.

Basic how-to guides from Time/Life, Ortho or Sunset – These guides provide a good explanation of basic lighting concepts and selection of light sources.

For individual help with lighting design, check with a lighting specialty store where they often have trained designers on staff—although, be aware that energy efficiency may not be their top priority. Look under "Lighting Consultants" in the yellow pages.

Hundreds of manufacturers have design information for consumers available on their web pages. The best place to look is the ENERGY STAR web page: <http://www.energystar.gov/>

Additional resources include:

The Lighting Resource

P.O. Box 48345

Minneapolis, MN 55448-0345

<http://www.lightresource.com/>

Lighting Research Center

School of Architecture,

Rensselaer Polytechnic Institute

Troy, NY 12180

<http://www.lrc.rpi.edu/>