Chapter 7 Lighting and Appliances

This chapter discusses lighting and home appliances. Lighting and appliances account for 10% to 50% of residential energy use, depending on climate and the energy efficiency of the home. A home with an efficient shell in a mild climate uses a larger percent of its energy for lighting and appliances than one with an inefficient shell in a severe climate.

Annual Electrical Energy: Kilowatt-Hours

Appliance	Low Estimate	High Estimate
Lighting	200	2000
Refrigerator	500	2000
Clothes Dryer	300	1500
Clothes Washer*	100	1000
Television	100	600
Well pump	250	750
Hot tub / spa	1000	2500
Computer	50	400

* Includes water heating.

Energy Information Administration, Lawrence Berkeley Laboratory, and utility sources.

See "Analyzing Annual Energy Costs" on page 277 and "Annual Average Household Energy Cost by Region (1997)" on page 14 for more information on percentage of energy used for lighting and appliances.

Lighting

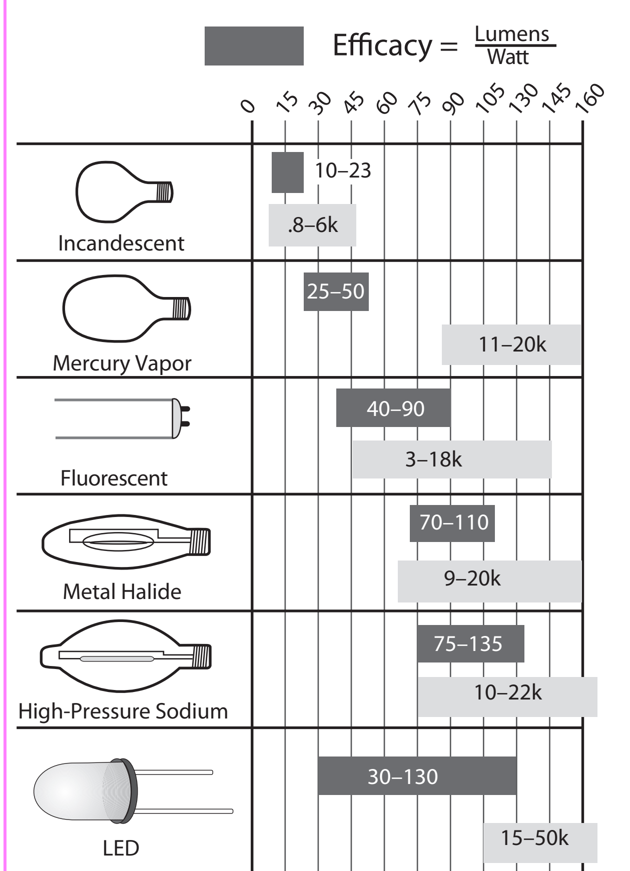
Homes are the setting for various visually-intensive tasks such as sewing, office work, crafts, and cooking. More people are working at home and need lighting suited for their vocation. Lighting also provides outdoor security and night time visibility. Retrofits consist mainly of replacing the existing lamps or fixtures with more efficient models.

To choose the best lighting options, it helps to understand basic lighting principles and terminology.

Efficacy (efficiency)

Lighting efficiency is known as *efficacy* and is measured in lumens per watt.

Efficacy and Lifespan



Efficacy and lamp life vary widely among the common lighting types.

Illumination

A lumen measures light output from a lamp. All lamps are rated in lumens. For example, a 100-watt incandescent lamp produces about 1750 lumens. Dividing a lamp's number of lumens by its watts gives efficacy — a measurement of lighting efficiency.

The distribution of light on a horizontal surface is called its illumination. Illumination is measured in footcandles. A footcandle of illumination is a lumen of light distributed over one square foot of area.

The amount of light required, measured in footcandles, varies according to the difficulty of a visual task. Ideal illumination is the minimum footcandles necessary to comfortably perform a task at the maximum practical rate of speed without eyestrain.

In the past, illumination of 100 footcandles was thought to be minimum for visual tasks in the workplace. Now, the Illuminating Engineering Society says that 30 to 50 footcandles is adequate for most home and office work. Difficult and lengthy visual tasks, like sewing for extended periods of time, requires 200 to 500 footcandles. Where no seeing tasks are performed, the lighting system needs to provide only security, safety, or visual pleasure — from 5 to 20 footcandles.

Lighting Uses

Three categories of lighting by function are ambient lighting, task lighting, and accent lighting.

Ambient lighting provides security and safety, as well as lighting for tasks that occur throughout the lighted space.

Task lighting provides light at the work area. Illumination levels should be high enough for accurate task execution in task areas — not throughout the entire lighted space.

Accent lighting illuminates walls so that their brightness contrasts less with brighter areas, like ceilings and windows. Accent lighting is also used to make the space more visually comfortable.

Lighting Color

Lamps are assigned a color temperature depending on their "coolness" or "warmness." People perceive colors at the blue-green end of the color spectrum as cool and those at the spectrum's red end as warm. Morning light from the north is more bluish than southwest evening light.

Cool light sources are preferred for visual tasks, since they produce better contrast at the printed page, workbench, or other task. Warm light sources are preferred for living spaces, because they are more flattering to people's skin and clothing.

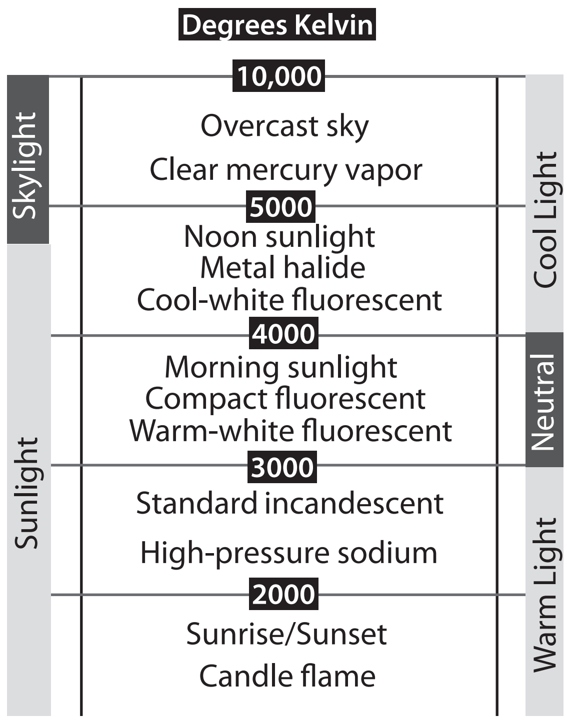
Color Rendering Index

Lighting Type	Color Rendering Index
Incandescent	97–100
Fluorescent (Standard)	52–62
Fluorescent (T-8 & CFL)	81–90
Mercury vapor	22–52
Metal halide	60–90
High-pressure sodium	25–65

***Color rendering* —** The color of light from a lamp and that light's ability to render correct color are separate and independent characteristics.

Artificial light sources vary widely in what is called the color rendering index (CRI). Incandescent lamps are rated at CRI of 100 — nearly equal to sunlight — while some high-pressure sodium lamps have a CRI of 22.

Color Temperature



Color temperature compares an artificial light source to sunlight and skylight.

Light's color rendering ability is not related to its color temperature. Blue north skylight, white noon sunlight, and a red sunset all have perfect color rendering (a CRI of 100), because our eyes are designed to read the colors of objects illuminated by sunlight.

Light Quality

Light quality describes how well people in a lighted space can see to do visual tasks, and how visually comfortable they feel in that space. High lighting quality is characterized by fairly uniform brightness and the absence of glare. Light quality is important to energy efficiency because spaces with higher lighting quality need less illumination.

For example, direct intense sunlight streaming through windows of a room with chocolate brown carpets and dark wall paneling will likely give too much contrast in brightness. The eye's pupil will have to constantly adjust its diameter as the eye wanders through the differing brightness of contrasting areas. Making this area visually comfortable would involve a high illumination level and many electric lights.

Now consider a room bathed in soft light. You can hardly tell where the light is coming from because no area of the room appears much brighter than another. The walls, ceiling, floor, and work surfaces are light colored. People can perform tasks faster and with fewer mistakes with this type of high-quality lighting. Lighting this area requires far less electric lighting than the previous example because of its superior lighting quality.

Glare — Eliminating glare is essential for good lighting quality. Glare comes in at least three varieties: direct glare, reflected glare, and veiling reflections.

Direct glare is strong light from a window or bright lamp shining directly into your eyes. Reflected glare is strong light reflected off a shiny surface into your eye. Veiling reflection is glare from a work surface like a printed page or computer screen.

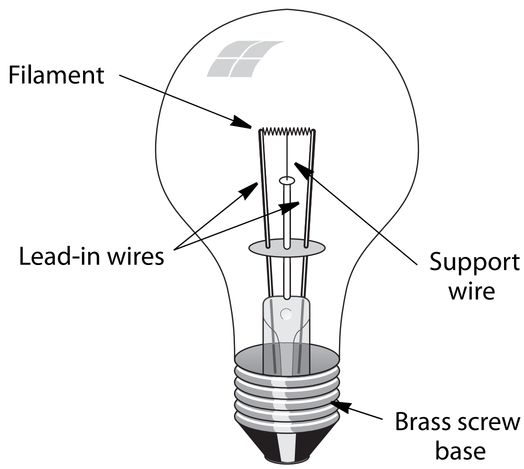
Types of Lighting

There are four basic types of lighting: incandescent, fluorescent, high-intensity discharge, and low-pressure sodium.

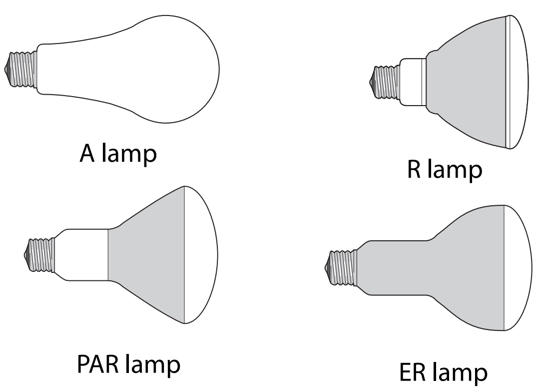
Incandescents dominate residential lighting, fluorescents dominate commercial indoor lighting, and high-intensity discharge lighting dominates outdoor lighting. These lighting types vary widely in their construction, efficacy, color characteristics, and lamp life.

Incandescent — Incandescent lamps are the oldest, most common, and most inexpensive lamps. Incandescent light is produced by a white-hot coil of tungsten wire that glows when heated by electrical current. The type of glass enclosure surrounding this tungsten filament determines its light beam's characteristics.

Incandescent Lamps



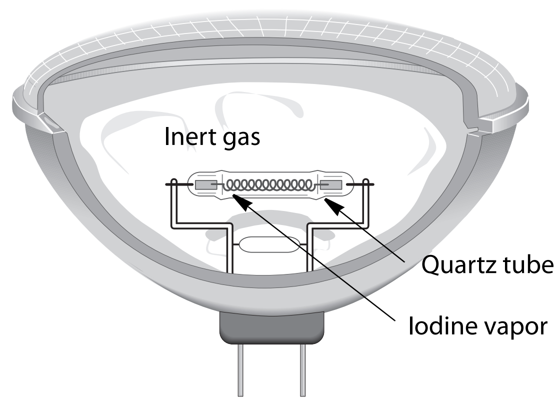
The electric circuit in the incandescent light bulb starts at the base, travels through the lead-in wires and filament, and back to the base. One lead-in wire is soldered to the base's center bottom, and the other to the brass rim.



Choosing the right type and wattage of incandescent lamp is essential to getting the most light out of an incandescent fixture for the electricity it consumes.

Incandescent lamps have the shortest service life of the common lighting types. All incandescents are relatively inefficient compared to other lighting types. However, significant savings are possible — if you select the right incandescent lamp for its purpose.

Incandescent Quartz Reflector



Quartz-type incandescent bulbs last longer because the quartz tube preserves the filament. The reflector design delivers more light out of the fixture toward the area needing illumination.

Referred to by lighting experts as the A-type light bulb, these lamps are the most common and the most inefficient light source available. Larger wattage bulbs are more efficient than smaller wattage bulbs. Long-life bulbs, with thicker filaments and lower efficacy, are a common variant.

Tungsten halogen lamps are considerably more expensive than standard incandescents and are primarily used in commercial applications. This newer type of incandescent lighting achieves better efficacy than standard A-type bulbs. Its gas filling and heat-reflective inner coating recycle heat to keep the filament hot with less electricity. Tungsten halogen lamps can replace larger standard reflector lamps in stage/theater, store, and outdoor lighting systems.

Reflector lamps (Type R) are used for flood lighting, spot lighting, and down lighting. The lamps are specifically designed to spread light over a specific area. Reflectors are used mainly indoors for stage/theater, store, flood lighting, spot lighting, and down lighting.

Parabolic reflectors (Type PAR) are used for outdoor flood lighting. Ellipsoidal reflectors (Type ER), which focus the light beam about 2 inches in front of their enclosure, are designed to project light down, out of recessed fixtures. ERs are twice as efficient as PARs for these fixtures.

Fluorescent — The glow of a fluorescent tube is caused by electric current conducting through mercury gas. Fluorescent lighting is used mainly for indoor lighting. Fluorescent lights need controlling devices, called ballasts, for starting and circuit protection. Ballasts also consume energy.

Fluorescent lights are approximately three to four times as efficient as incandescents, and their lamp life is about ten times greater.

Energy savings for existing fluorescent lighting are achieved by relamping, replacing ballasts, and replacing fixtures with more efficient models.

Tubular fluorescent lamps are the next most popular lamps after A-type incandescents. The two most common types of tubular lamps are 4-foot-long 40-watt lamps and 8-foot-long 75-watt lamps.

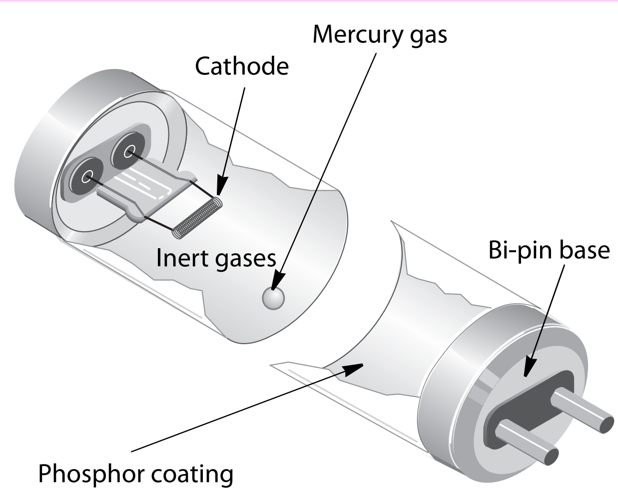
Tubular fluorescent fixtures and lamps are preferred for ambient lighting in large indoor areas, because they create less direct glare than incandescent bulbs. Long, narrow fluorescent lamps distribute light better than small round lamps. Improved fluorescent lighting features include: electronic ballasts; thinner, energy-efficient tubes known as T-8s; improved coatings for better efficacy and color rendition; and dimmable ballasts.

Compact fluorescents (CFLs) are the most significant recent lighting advance for homes. They combine the efficacy of fluorescent lighting with the convenience and universality of incandescent fixtures. Recent advances in CFL design also provide more natural color rendition and less flicker than older designs.

CFLs can replace incandescents roughly three to four times their wattage. When introduced in the early-to-mid 1980s, CFLs were bulky, heavy, and too big for many incandescent fixtures. But newer models, with lighter electronic ballasts, are only slightly larger than the incandescents they replace.

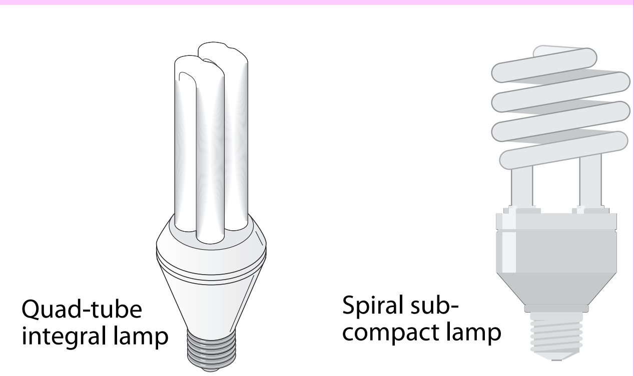
CFLs come in integral and modular designs. Integral CFLs combine ballast and lamp as a single disposable unit. Modular designs feature a separate ballast that will survive several lamp replacements before it wears out.

Fluorescent Lamp Operation



A minute amount of mercury mixed with inert gases conducts electric current, stimulating the phosphor coating on the glass tube to emit light.

Compact Fluorescents



Compact fluorescent lamps (CFLs) come in integral or modular designs. The tubes are twin-tube or quad-tube designs. CFLs screw into incandescent fixtures and save up to 75% of the electricity used by incandescent lamps.

High-intensity discharge — High-intensity discharge (HID) lamps sport the highest efficacy and longest lives of any lighting type. They are used for outdoor lighting and for large indoor areas, like arenas.

HIDs use a very intense light-emitting electric arc to produce their light. HID lamps require ballasts. They don't come on immediately when switched because their ballast needs time to establish the electric arc.

HID fixtures can save 75% to 90% of lighting energy when they replace incandescent fixtures. Significant energy savings are also possible by replacing old mercury vapor lamps with newer metal halide or high pressure sodium lamps.

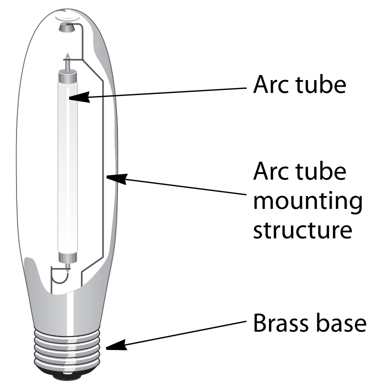
Mercury vapor — the oldest type of HID lighting — was used primarily for street lighting. Mercury vapor lamps provide about 50 lumens per watt. Their light is very cool — a blue/green white. Mercury vapor light renders colors poorly. Most mercury vapor lighting has been replaced by metal halide lighting.

Metal halide lamps are similar in construction and appearance to mercury vapor. The addition of metal halide gases to mercury gas within the lamp results in higher light output, more lumens per watt, and better color rendition than mercury vapor.

Metal halide lamps are used where color rendition is important: for indoor lighting of large areas like gymnasiums and sports arenas, for example, or for outdoor areas like car sales lots.

High-pressure sodium lighting provides 90 to 150 lumens per watt, the highest of common light sources. High-pressure sodium lamps are reliable and have a very long service life. Their color is a warm white. Their poor color rendering makes high-pressure sodium limited in its application to outdoor lighting where color rendering isn't important.

High-Intensity Discharge Lamp



High-intensity discharge lamps, including high-pressure sodium, metal halide, and mercury vapor, have high efficacies. They have arc tubes and external ballasts.

Light emitting diodes — Light emitting diodes (LEDs) are the newest type of lighting. Commonly available LED lamps provide light with efficacies of 25-100 lumens per watt, similar to fluorescent lamps. However, some architects and lighting designers achieve 130 lumens per watt in custom applications. In early 2014 LED manufacturers achieved efficacies of up to 200 lumens per watt.

Unfortunately, the efficacy of LEDs varies widely depending on the design of the lamp, the design of the LED luminaire or fixture, the fixture's proximity to what it is lighting, and other factors. Also, there aren't many highly efficient LED products available for common light fixtures. Also, the initial cost of LED lighting is high compared with other lighting systems.

The future for LEDs looks hopeful, but the choices of products and applications may require too much design and investment to make LEDs a practical choice for the general public, except for custom applications.

Lighting Energy Efficiency

Lighting accounts for 20% to 25% of all American energy consumption. An average household dedicates 5% to 10% of its energy budget for lighting, while commercial establishments consume 20% to 30% of their total energy use for lighting.

In a typical residential or commercial lighting installation, 50% or more of the energy is wasted because:

- Illumination levels are too high.
- Lamp size and type are not optimized for their use.
- Lights remain on too long because of carelessness or inadequate control.
- The lighting system is dirty, antiquated, or inefficient.

Saving lighting energy requires either reducing electricity consumed by the light source or reducing its on-time:

- Lowering wattage by replacing lamps (called relamping) or replacing entire fixtures.
- Reducing the light source's on-time by improving lighting controls and educating lighting users to turn off unneeded lights.
- Replacing electric lights with natural light (daylighting).
- Allowing lower initial illumination levels and preserving illumination and light quality by simple lighting maintenance.

Relamping — Relamping means substituting one lamp for another to save energy. You can decide to make illumination higher or lower when relamping. The new lamp's lumen output should fit the tasks performed in the space.

Many incandescent lamps are mismatched to their tasks. Some have excessive wattages — creating unnecessarily high illumination. This can be corrected by smaller-wattage lamps.

Other existing incandescent lamps are not the best type of lamp for their application. A-type light bulbs can often be replaced with improved lamp designs, like reflectors or tungsten halogen lamps.

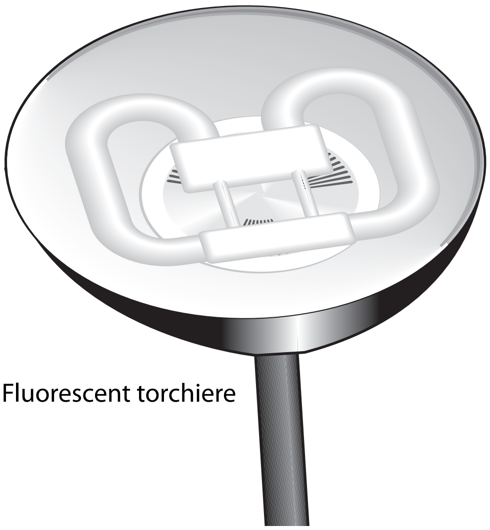
When used in recessed fixtures, standard A-type bulbs and reflector lamps waste energy because their light gets trapped. For big energy savings, a 75-watt ellipsoidal reflector (ER) will replace a 150-watt standard reflector. ER lamps are designed to force light out into the room by focusing it in front of their lens. However, ER lamps are less efficient at delivering light out of shallower fixtures, so only use reflectors or parabolic reflectors in shallow fixtures.

For energy savings of 60% to 75%, standard A-type bulbs can be replaced with CFLs. A standard 18-watt CFL replaces a 75-watt, A-type lamp. Some CFLs also are packaged in the same glass diffuser shells as incandescents. As with incandescents, use CFLs packaged as ERs for recessed fixtures. Use reflector or parabolic reflector CFLs for flood and spot lighting.

Energy-saving fluorescent lamps incorporate better electrodes and coatings than older fluorescent lamps. They produce approximately the same lumen output with substantially lower wattage.

The two most common energy-saving fluorescent lamps correspond to the two most common standard fluorescent lamps. Common 40-watt, 4-foot lamps and 75-watt, 8-foot lamps can be replaced with energy-saving lamps of 34 watts and 60 watts, respectively. Energy-saving lamps for less common fluorescent fixtures are also available.

Fluorescent Torchieres Replace Halogens



Halogen torchieres employ wattages as high as 400 watts, making them a significant heat source in summer and a fire hazard because of the high lamp temperature. Fluorescent torchieres are a logical and energy efficient replacement for these inefficient halogen incandescent lamps.

Replacing fixtures — Matching new replacement lamps to existing fixtures and ballasts can be tricky, especially with older fixtures. Buying a new fixture gives the buyer matched parts that can produce superior energy savings, reliability, and longevity over relamping.

Much has been learned about fixture design since the energy crises of the 1970s. Many common indoor fixtures trap a significant portion of light inside the fixture, while many outdoor fixtures tend to spray much of their light beyond the intended area, causing light pollution.

New incandescent fixtures are designed to push more of their light out into the room. Others use smaller tungsten halogen lamps.

Advances in indoor fixture design include brighter reflectors and better reflecting geometry. New fluorescent fixtures feature more efficient electronic ballasts and thinner tubes.

New high-intensity discharge outdoor fixtures are designed to push all their light towards the ground, where it's needed. Replacing old mercury-vapor fixtures with new high-pressure sodium or metal halide fixtures is a popular and cost-effective energy retrofit.

Improving lighting controls — Lighting controls are devices for turning lights on and off or for dimming them. The simplest type of lighting control is a standard snap switch. Other controls are photocells, timers, occupancy sensors, and dimmers.

Some specific applications of lighting controls are summarized here.

- Snap switches encourage people in large shared spaces to extinguish lights in unused areas.
- Mechanical or electronic time clocks automatically light and extinguish indoor or outdoor lights for security, safety, and tasks like janitorial work.
- Crank timers, spring driven timers similar to old oven timers, limit lights to short durations where the need for light is brief.
- Photo cells activate switches or dim lights depending on natural light levels. Photocells switch outdoor lights on at dusk and off at dawn, for example. Advanced photocells gradually raise and lower fluorescent light levels with changing daylight levels.
- Occupancy sensors activate lights after sensing a person, and extinguish lights after detecting no human presence for some specific time — 15 minutes for example. They are popular for lightly used areas, like storage areas and outdoor areas. Occupancy sensors offer security advantages over continuous lighting — the abruptly switched lights startle intruders and alert residents and neighbors to motion in the area.
- Dimmers reduce the wattage and output of incandescent and fluorescent lamps. Dimmers

increase the service life of incandescent lamps significantly. Dimming incandescent lamps reduces their lumens more than their wattage. This makes incandescent lamps less efficient as they are dimmed. Dimming fluorescents requires special dimming ballasts and lamp holders. Dimming fluorescents does not reduce their efficacy.

Daylighting — Daylighting means using daylight for indoor lighting. Modern buildings designed for daylighting typically use 40% to 60% less electricity for lighting than conventional buildings.

Sunlight and daylight are free and readily accessible. However, using sunlight without causing glare and without overheating the building can be difficult. Glare can be avoided by using light shelves, wide window sills, walls, louvers, reflective blinds, and other devices to reflect light deeply into the building. Windows and skylights, carefully located away from the sun's direct rays, minimize overheating. New selective glazings transmit most visible light, while excluding most solar heat.

Lighting maintenance — Maintenance is vital to lighting efficiency. Light levels fall over time because of fixture dirt, room-surface dirt, and lamp aging. Together, these factors can reduce total illumination by 50% or more, while lights continue drawing full power.

Maintenance prevents this costly performance degradation. Follow these basic maintenance suggestions:

- Clean fixtures, lamps, and lenses every 6 to 24 months.
- Replace lenses if they appear yellow.
- Room dirt collects on surfaces reducing the amount of light they reflect. Clean or repaint small rooms every year and larger rooms every 2 to 3 years.
- Consider replacing all the lamps in a lighting system at once. This is called group relamping. Common lamps, especially incandescent and fluorescent lamps, lose 20% to 30% of their light output over their service life. Group relamping saves labor, keeps illumination high, and avoids straining fluorescent ballasts with dying lamps.

Optimization of Lighting

When making energy-efficient lighting changes, it often pays to redesign the building's entire lighting system. Optimizing utilization and efficiency will improve lighting quality, make visual tasks easier, and save 50% or more on energy costs.

You can often reduce light levels without reducing light quality by the following procedures:

- Redesign visual tasks. For example, begin using a better printer with darker lettering, or install light-filtering shades to reduce glare.
- Reduce light levels where there are no visual tasks. Provide minimum light necessary for safety, security, and aesthetics.
- Reduce light levels for visual tasks where those levels are currently excessive.

If you want to cut lighting energy consumption, while enhancing light quality, consider the following:

- Paint and decorate, using light colors.
- Establish ambient illumination at minimum acceptable level.
- Provide task lighting at optimal level, depending on the difficulty of visual tasks — for example, sewing requires more light than cooking.
- Increase the efficiency of lamps, ballasts, and fixtures.
- Improve light quality by reducing glare and brightness contrast.
- Use daylighting.

Appliances

Refrigerators, washers, and dryers use more than 80% of the appliance energy in most homes.

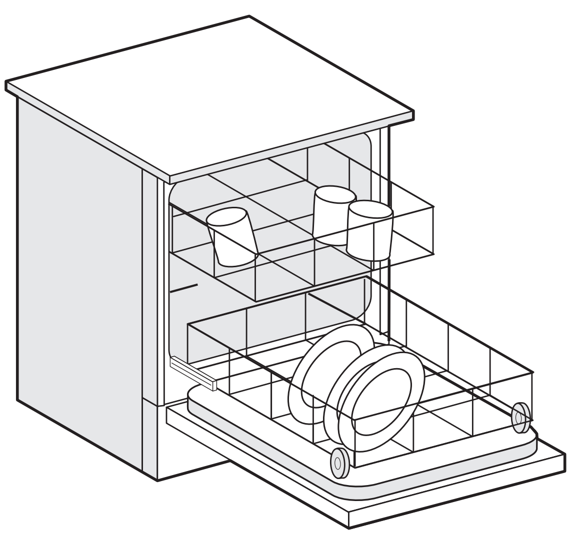
Dishwashers

Most of the energy (80% to 90%) used by dishwashers is actually consumed by the water heater. Your dishwasher may dictate the temperature setting of the water heater. Many older dishwashers require a water supply of at least 130°F to get dishes clean. Most newer dishwashers have a small water heater to boost water temperature to about 140°F. This saves water heating energy by reducing the required water temperature and standby losses of the water heater.

Like clothes washers, dishwashers conserve energy and water when using their low and medium cycles. Water usage varies from a low of 7 gallons to a high of 14 gallons per wash, from the light wash cycle to the heavy one.

See Chapter 9 Water Heating for more information.

Dishwasher



Running the dishwasher without a full load wastes energy.

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energy
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ENERGY STAR guidelines created by the Environmental Protection Agency and the Department of Energy are now a well-known indicator of energy efficiency.

Clothes Washers

The efficiency of clothes washers in using water and energy has increased dramatically since the mid-80s. Horizontal-axis clothes washers use far less energy and water than vertical axis machines. In fact, horizontal-axis machines save 50–75% of both energy and water, compared to most vertical-axis models. The horizontal-axis washers cost considerably more than vertical-axis ones, but will repay this initial investment in 7 years or less through reduction in energy and water costs.

The Department of Energy used to rate clothes washers using an *Energy Factor* (EF). Energy Factor rates clothes washers by comparing the amount energy used to run the machine and heat the water, to the laundry capacity of the machine.

Now the DOE rates clothes washers using a *Modified Energy Factor* (MEF) and a Water Factor (WF). MEF and WF account for energy consumption like EF foes, but they also account for the cost of adding and removing water from the laundry.

- MEF: Cubic feet of clothes washed and dried per kilowatt-hour of energy used.
- WF: Amount of water used per washing cycle, divided by the capacity of the clothes washer.

MEF gives higher ratings to washers that leave washed clothes drier than for washers that leave more water in the clothes. WF gives lower ratings for washers that use less water per cycle. As of

February 1, 2013, the DOE ENERGY STAR criteria for clothes washers is 2.0 or greater, and a WF of 6.0 or lower.

Unfortunately, no one is suggesting any way of converting from energy factor to modified energy factor. However, comparing existing EFs and MEFs suggests that multiplying MEF by 1.6 or multiplying EF by 0.6 would provide approximate conversions to the other unit.

The Energy Guide Label, required on all new washers by the Federal Trade Commission, lists the cost of 416 loads, but this gives smaller machines an unrealistic advantage over larger ones. The Energy Guide Label may not list EF, MEF, or WF. These values are available from the manufacturer, American Home Appliance Manufacturers Association (AHAM), or the American Council for an Energy Efficient Economy (ACEEE).

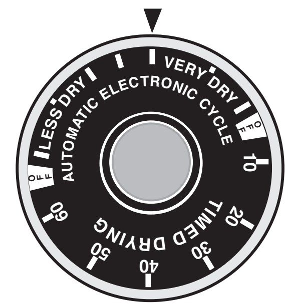
Most of the energy used by the American clothes washer originates in the water heater. Clothes washers often perform as well with cold water as with warm or hot water, especially with lightly soiled clothes. For best results, use an enzymatic detergent designed for cold water. Suds-saving cycles are also energy savers for lightly soiled clothes. Full clothes washers use energy most efficiently. With partial loads, experts recommend using the water-level controls that describe the load's size — small, medium, normal, or large. Some new washers have automatic controls to optimize water level.

Clothes Dryers

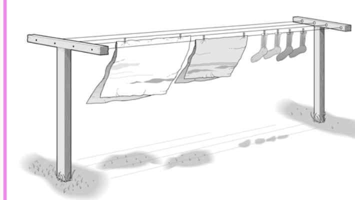
Line-drying laundry is the most effective way to save energy on clothes drying.

Gas clothes dryers operate more economically than electric clothes dryers. At average prices for electricity and gas, electric clothes drying costs 30–40¢ per load versus gas at 15–20¢ per load. Currently there isn't much difference in consumption between models of gas and electric clothes dryers.

Clothes Drying Decisions



The electronic cycle uses a heat or humidity sensor to sense dryness instead of a person choosing an approximate time, which may be too long.



Using clothes lines during dry weather can save energy and reduce electric peak load.

Mechanical clothes drying is one of the largest household users of energy. Dryer use often coincides with peak electricity demand.

Temperature-sensing or humidity-sensing dryer controls may save 5–15% over timed drying. When working correctly, these controls prevent over-drying. Controls that sense humidity are the most efficient.

Cleaning the dryer lint filter after each cycle minimizes drying time. Over time, lint collects in the vent, elements, and air passageways reducing airflow and increasing cycle time. Every few years, a dryer and its vent should be thoroughly cleaned.

Piping the dryer vent in smooth metal pipe, sealed at joints with silicon caulking, reduces drying time over piping with flexible vent.

Refrigerators and Freezers

Refrigerators are large energy consumers, accounting for 9% to 15% of a household's total energy consumption. A refrigerator runs day and night, 365 days a year. Refrigerator energy efficiency has improved tremendously in the past 15 years. Better insulation and weatherstrip, more effective controls, bigger coils, and better motors improve efficiency.

Compare the energy guide labels of different models when purchasing a new refrigerator or freezer. Appliances that have earned the ENERGY STAR qualification have better-than-average energy efficiency. The most efficient standard refrigerators use less than 500 kW-hours of electricity per year. However, you can special-order refrigerators that use half that much electricity.

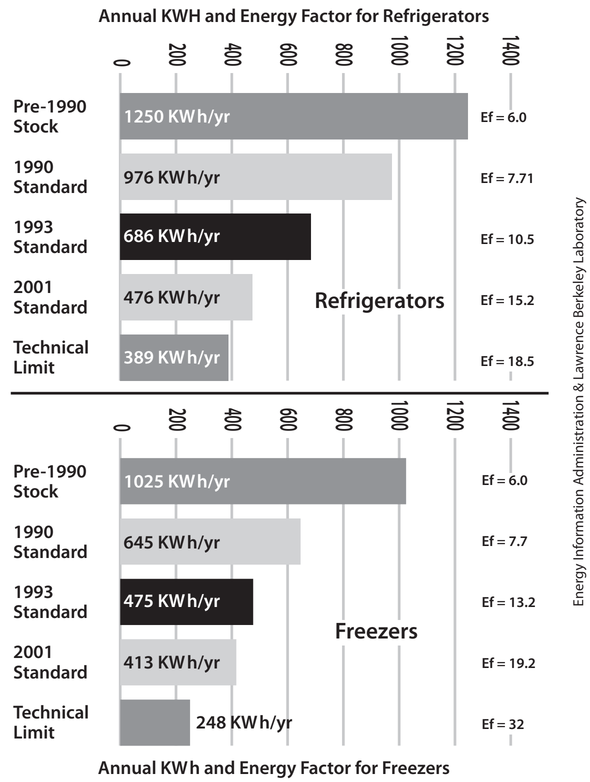
The way individuals and families use refrigerators and freezers can make a significant difference in energy consumption. Follow these recommended practices:

- Keep freezers as full as possible.
- Defrost the freezer when 1/4 inch of frost has accumulated.
- Minimize refrigerator or freezer door openings.
- Clean the coils on refrigerators and freezers with a soft brush once a year.

When selecting a new refrigerator, consider the following:

- Automatic defrost models waste energy. Choose a manual defrost model, if available in the size you want.
- Side-by-side refrigerator/freezers use more energy than units that have the freezer compartment on the top or bottom.
- Upright freezers use more energy than chest freezers.
- Operating two refrigerators uses far more energy than one larger model.

Evolution of Refrigerators and Freezers

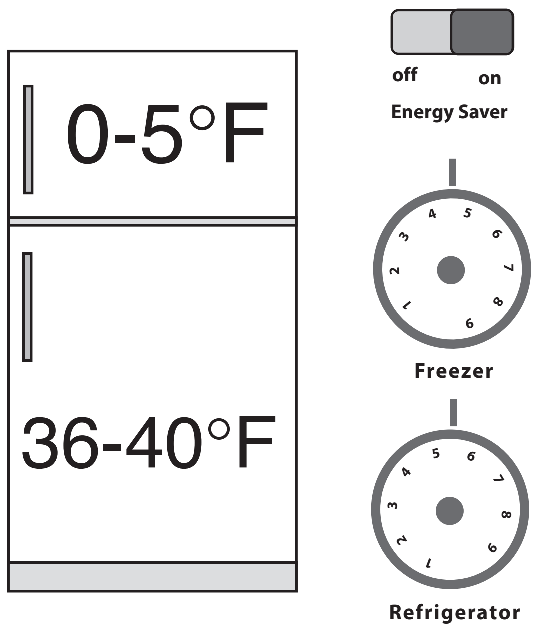


Refrigerators and freezers are evolving toward the limits of current compressor and insulation technology.

Refrigerator energy consumption — Refrigerators more than 10 years old typically consume 1000 and 2000 kilowatt-hours per year. It is now common to measure or estimate refrigerator and freezer electricity consumption during an energy audit or comprehensive energy retrofit. The most common methods are measuring a couple hours of electricity consumption or consulting a comprehensive list of refrigerators published by the Association of Home Appliance Manufacturers (AHAM).

Refrigerators have defrost controls that can interfere with accurate measurement of energy consumption. The defrost control should be reset so that it will not activate a defrost cycle while the test is underway.

Refrigerator Controls and Temperatures



Keeping refrigerator temperatures in the range illustrated above minimizes energy use while providing adequate refrigeration. The energy-saver switch should be in the on position unless frost appears around the door, in which case, switch it to the off position.

Pools and Spas

Pools and spas use energy for heating water and circulating the water through filters and chemical dispersion systems. Conservation for pools and spas focuses on making water heating more efficient, insulating the water surface to reduce evaporation, and improving pumping efficiency.

A spa's or pool's temperature setpoint is directly related to its water-heating consumption. Pools should be kept at 78°F or less, and spas or hot tubs at 102°F or less. Every degree beyond these recommended values increases pool-heating costs significantly. The efficiency of the pool's water heater is also an important factor to remember when buying a new water heater or replacing an old one. Utility customers in warm climates use up to 400 therms to heat an average-sized pool to 78° during a winter month.

Solar pool heating has become quite common. In the southern regions, solar collectors for pools tend to be less expensive than collectors for general water heating. Since they are used only in the summer, many pool-heating solar collector designs don't even use a glass covering.

For more information on solar water heating, see "Solar Water Heaters" on page 231.

More than 90% of pool heat loss occurs by evaporation from the pool's surface. Insulating pool covers can reduce pool-heating energy costs by 50–70%. Solar pool covers are designed to collect solar heat in addition to insulating the pool. Covers for spas should be at least R-12 and the tub itself should be insulated with foam insulation to R-12.

Pumping represents another large energy consumer. Water is circulated for two reasons: to mix germ-killing chemicals and to filter out particles. Many pool owners leave their pumps running 24 hours per day, which is far beyond the requirements of chemical mixing and filtering. Pump run-times of as little as 3 hours per day may be adequate to keep chemicals mixed and to remove those particulates that can be removed by filtering. Filters can't remove leaves from the top or pebbles from the bottom, nor can it scrub algae from the walls. Pool maintenance requires using a skimmer to remove large particles and using a brush to brush the pool walls, especially at the water line. Pool covers help to keep pools clean and reduce the need for filtering.

Pumps can operate more efficiently when their piping takes gradual bends instead of abrupt ones. Replacing 90° elbows with 45° elbows or flexible pipe can reduce resistance and pump horsepower. A smaller pump motor should reduce pumping energy even though the smaller pump runs longer to achieve the same daily circulation rate.

Annual Kilowatt-Hours for Pumping Options

Pumping option	Wh/gal	kWh/yr
Old bronze 1 hp	.45	4060
Standard new 1 hp	.40	3660
High efficiency 1 hp	.36	3260
High efficiency 3/4 hp	.33	3040
2-speed Hi: 1hr/day, Lo: 7 hr/day	.29	2640

Data provided by Pacific Gas & Electric, Energy Training Center. Interpreted and rounded by the author. Assumes 25,000 gallons per day and 365 days per year. First four options run 5.5 hours/day.

See "Household Appliance Electrical Usage" on page 298 for more information on appliance energy consumption.