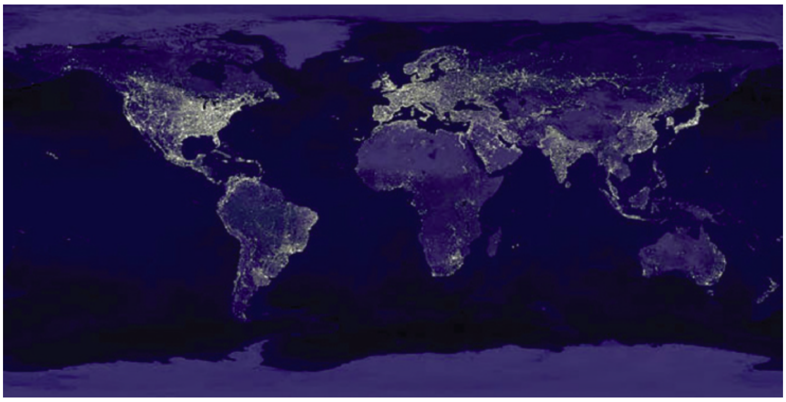
Section 5.4

Efficiency, Energy sources, and Energy conservation

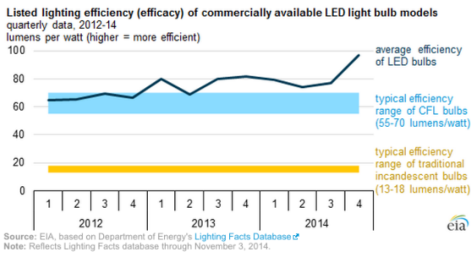


Light pollution as seen from space.

What has driven the switch from incandescent light bulbs to compact fluorescent and eventually LED light bulbs?

Efficiency

Fluorescent lamps may transform up to 25 % of the supplied electrical energy into radiant energy.



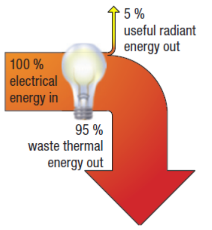
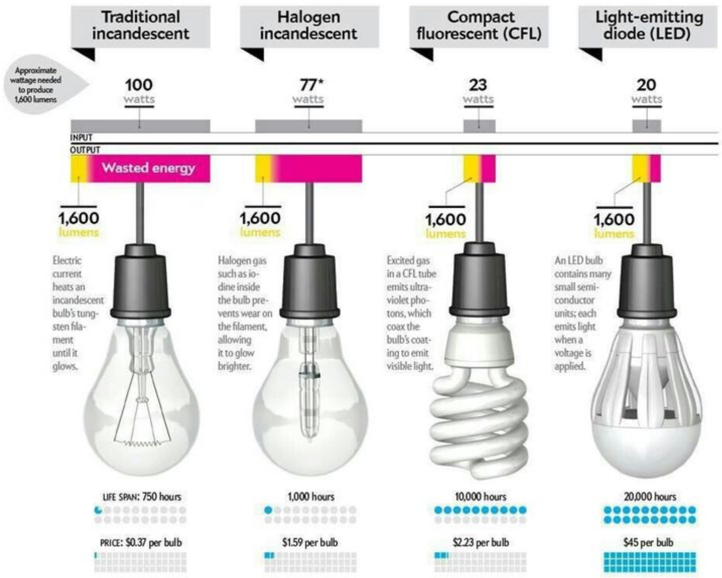


Figure 2 Incandescent light bulbs transform a very small percentage of the electrical energy supplied into radiant energy. Therefore, incandescent bulbs produce a lot of thermal energy waste.

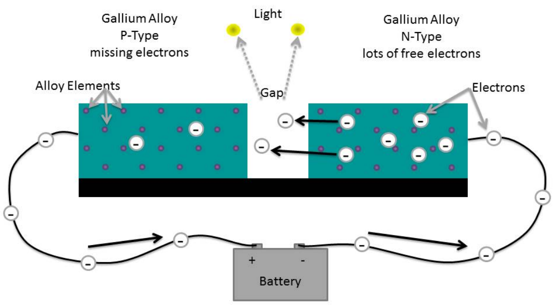


What is a Light Emitting Diode?

A light-emitting diode (LED) is a semiconductor light source that emits light when current flows through it. Electrons in the semiconductor recombine with electron holes, releasing energy in the form of photons. ... Modern LEDs are available across the visible, ultraviolet, and infrared wavelengths, with high light output. (A semi conductor, conducts electricity under certain conditions.)

L.E.D.

Electricity -> Light



Important Facts	 Light Emitting Diodes (LEDs)	 Incandescent Light Bulbs	 Compact Fluorescents (CFLs)
Sensitivity to low temperatures	None	Some	Yes - may not work under negative 10 degrees Fahrenheit or over 120 degrees Fahrenheit
Sensitive to humidity	No	Some	Yes
On/off Cycling Switching a CFL on/off quickly, in a closet for instance, may decrease the lifespan of the bulb.	No Effect	Some	Yes - can reduce lifespan drastically
Turns on instantly	Yes	Yes	No - takes time to warm up
Durability	Very Durable - LEDs can handle jarring and bumping	Not Very Durable - glass or filament can break easily	Not Very Durable - glass can break easily
Heat Emitted	3.4 btu's/hour	85 btu's/hour	30 btu's/hour
Failure Modes	Not typical	Some	Yes - may catch on fire, smoke, or omit an odor

Efficiency

Efficiency is the ratio of the amount of useful energy produced (energy output, or E_{out}) to the amount of energy used (energy input, or E_{in}), expressed as a percentage. Efficiency is calculated as follows:

$$\text{efficiency} = \frac{E_{out}}{E_{in}} \times 100\ \%$$

It is currently impossible to have more energy come out of a system than goes in to a system.

Sample Problem 1

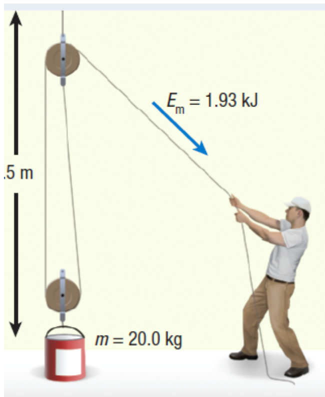
A firefly's body transforms chemical energy in food into radiant energy that appears as a greenish glow in its abdomen.

Fireflies use this glow to attract mates or prey. What is a firefly's efficiency if its body transforms 4.13 J of chemical energy into 3.63 J of radiant energy?

Figure 3 A firefly can transform chemical energy into radiant energy.

Sample Problem 2

What is the efficiency of a rope-and-pulley system if a painter uses 1.93 kJ of mechanical energy to pull on the rope and lift a 20.0 kg paint barrel at constant speed to a height of 7.5 m above the ground



Practice

1. A forklift uses 5200 J of energy to lift a 50.0 kg mass to a height of 4.0 m at a constant speed. What is the efficiency of the forklift? T/I [redacted]
2. A tow truck attaches a cable to a car stuck in a muddy ditch. The 1250 kg car is pulled up an embankment to a height of 1.8 m at a constant speed. The cable exerts a force of 5500 N over a distance of 12.6 m to pull the car out of the ditch. K/U T/I
   (a) What is the amount of useful energy produced? [redacted]
   (b) What amount of energy is used to pull the car from the ditch? [redacted]
   (c) Calculate the percent efficiency. Why is the efficiency less than 100 %? [redacted]

Table 1 Energy Transformation Efficiencies of Various Devices and Processes

Device or process	Energy transformation	Major waste output energy	Transformation efficiency	Considerations
gasoline-powered vehicle	chemical (in gasoline) → kinetic (vehicle motion)	thermal	8–15 %	• produces carbon dioxide, which contributes to climate change • creates air pollution
electric vehicle	electrical → kinetic (vehicle motion)	thermal	24–45 %	• currently more expensive to purchase than gasoline-powered vehicles • more efficient than a gasoline vehicle but uses heavy batteries that must be constructed and discarded in special ways to help limit environmental contamination
bicycle	kinetic (pedal) → kinetic (bicycle motion)	thermal	90 %	• most efficient self-powered vehicle • limited to transporting one or two individuals • use is weather dependent • road safety issues
loudspeakers	electrical → sound	thermal	1 %	• efficiency appears to be low, but useful output energy is more than enough to produce audible sound • most of the electrical input is transformed into thermal energy
electric heater	electrical → thermal	radiant	98 %	• very efficient transformer of electrical energy into thermal energy
hydroelectric power plant	kinetic (moving water) → electrical	thermal	80 %	• efficient method of generating electricity • damming rivers may flood land and disrupt ecosystems
nuclear power plant	nuclear → electrical	thermal	30–40 %	• relatively efficient for generating electricity • produces radioactive waste
solar cell	radiant → electrical	thermal	20–40 %	• relatively efficient for generating electricity
photosynthesis	radiant → chemical	thermal	5 %	• although it appears inefficient, it is the only process that transforms radiant energy into chemical energy in organisms • directly or indirectly responsible for maintaining virtually all life on Earth
animal muscles (including human muscles)	chemical (in food) → kinetic (muscle movement)	thermal	20 %	• although it appears to be relatively inefficient, this energy-transforming process provides all the energy animals use to perform work

Sources of Energy

Renewable Energy sources are sources of energy that are considered limitless or can replenish themselves over time. Wind, solar, tidal, geothermal, biomass are considered renewable.

Non-renewable Energy sources are sources of energy that once consumed are gone forever. The fossil fuels industry (oil, natural gas) and nuclear power are considered non-renewable energy sources.

Generating Electricity

Electricity is Generated by Spinning Turbines that are attached to a generator. The spinning can be accomplished by passing water or pressurized steam over the blades of the turbine to make it spin.

Hydroelectric power is generated by having large volumes of water pass over the turbine blades to make them spin.

Nuclear power is generated by using the energy released in nuclear decay (fission) to super heat water, that is used to create steam to spin the turbine blades.

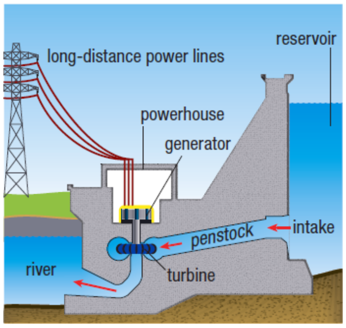
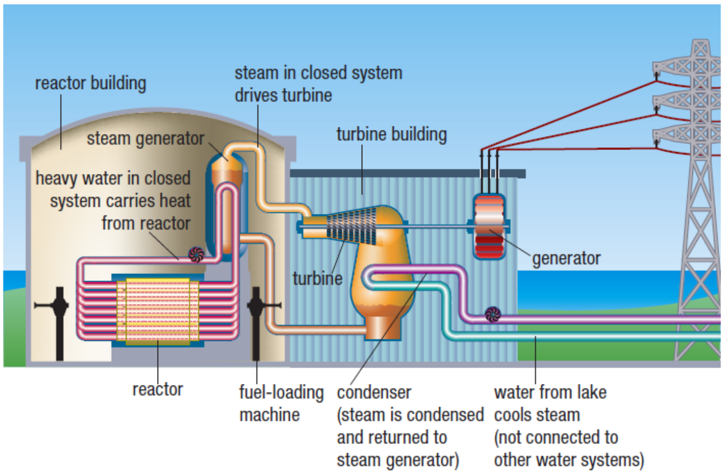


Figure 12 Operations of a typical hydroelectric power plant

nuclear fission the decomposition of large, unstable nuclei into smaller, more stable nuclei

nuclear fusion a nuclear reaction in which the nuclei of two atoms fuse together to form a larger nucleus

Nuclear Power Plant Basics



Solar Energy

Solar energy can be used to generate heat or electricity.

When solar energy interacts with certain solids, such as modified forms of silicon, the radiant energy may be transformed into electrical energy in the form of an electric current. This is the energy transformation that occurs in a photo voltaic cell. When the source of radiant energy is the Sun, the photo voltaic cell is sometimes called a solar cell.

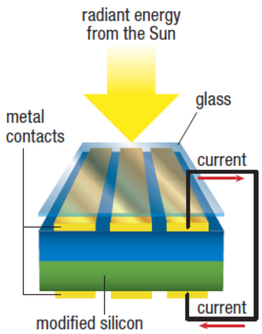


Figure 10 Radiant energy is transformed into electrical energy (electric current) in a photovoltaic cell.

Figure 11 A parking meter uses electrical energy produced by a solar cell.

Renewable energy resource	Description	Considerations
geothermal	• Earth possesses a virtually unlimited supply of thermal energy deep underground. • Geothermal energy may be used directly for heating and cooling or be transformed into electrical energy.	• accessible only in certain areas • in some locations, deep holes need to be drilled into the ground to reach pockets of thermal energy
wind	• Wind strikes the blades of a fan-like turbine, which turns an electricity generator that generates electrical energy.	• can be used only in windy locations • turbines generate electricity only when wind is blowing • turbines are noisy, and the blades may strike birds and other wildlife
tidal	• As tides rise and fall, the moving water strikes the blades of a turbine, which turns a generator. The generator generates electrical energy. • Tidal turbines are similar to wind turbines and are placed in bodies of water where significant tidal movements occur.	• turbines only work during tidal movements • may disrupt aquatic ecosystems
biofuels	• Biofuels are solid, liquid, and gaseous fuels derived from the bodies of living or dead plants and animals. • Biofuels can include wood, biological waste, and gases such as methane produced during the decomposition of plant matter. • Solid biofuel may be called biomass and gaseous biofuel may be called biogas.	• burning the fuels may produce air pollutants, including carbon dioxide, which is linked to climate change

Conserving Energy

Energy may be conserved by designing, producing, and using machines, appliances, and devices that transform energy more efficiently. Energy may also be conserved by

- turning lights off when not required
- switching off electrical devices instead of leaving them on standby mode
- taking short showers instead of baths if possible
- running dishwashers and clothes washers only when they are full
- hanging clothes to dry
- using fans to reduce the need for air conditioning
- using public transit and carpooling when possible

5.4 Questions

1. In a race, a 54 kg athlete runs from rest to a speed of 11 m/s on a flat surface. The athlete's body has an efficiency of 85 % during the run. How much input energy did the athlete provide? T/I
2. Athletes who compete in downhill skiing try to lose as little energy as possible. A skier starts from rest at the top of a 65 m hill and skis to the bottom as fast as possible. When she arrives at the bottom, she has a speed of 23 m/s. T/I
   (a) Calculate the efficiency of the skier.
   (b) Explain why the mass of the skier is not required when calculating the efficiency.
3. A golf club with 65 J of kinetic energy strikes a stationary golf ball with a mass of 46 g. The energy transfer is only 20 % efficient. Calculate the initial speed of the golf ball. T/I
4. Describe one advantage and one disadvantage in using
   (a) non-renewable energy resources
   (b) renewable energy resources K/U A
5. Compare nuclear power plants with hydroelectric power plants in terms of efficiency, method of generating electricity, energy transformations, and environmental impact. K/U C A
6. An article on the Internet claims, "Fossil fuels are actually a renewable energy resource since decaying plant and animal matter is making new oil, natural gas, and coal all the time." Discuss the validity of this statement. C A
7. In this section, two different methods of using solar energy were described: passive solar design and photovoltaic cells. Explain the difference between passive solar design and photovoltaic cells. K/U

Section 5.4 #1,2,3