Prelab: Energy and Lighting

Energy and Light

The United States consume a **lot** of energy. The power consumed, averaged over the year 2017, is about 1.1 Tera-Watts, that is:

$$1{,}100{,}000{,}000{,}000 \text{ W.}$$

(Remember that power is energy lost per unit of time.) Remember how you produced about 100 W by riding your bike when you tried hard enough? If every poson in the world rode a bike like this all the time, we would live in a *Black-Mirror*-esque nightmare, but **still** be 30% short of meeting the US' needs.

As much as 1/3 of all the energy used in the USA is for lighting – much of it in commercial buildings, factories, etc. These are produced by:

- **incandescent lights**: uses the resistance within a filament to convert electricity to heat, about 2% of which is then converted to light when the heated filament begins to glow.

- **fluorescent lights**: electrons in the gas filling the bulb are excited into higher energy orbitals by electric currents flowing through the gas. As the electrons are "de-excited", they emit light, which is not visible to humans. Therefore, fluorescent bulbs have **mercury** (unfortunately) to convert the invisible UV light into visible light resembling that is fairly comfortable.

- **light-emitting diodes** (**LED**): a technology that is rapidly taking over. They produce light by a complicated process called electroluminescence, which means electrons transitioning among energy levels of the bulk material.

These technologies differ mainly in the efficiency of converting **electric power** to **luminous power** (i.e., stength of visible light emitted). The SI unit of luminous power is the **Lumen** (**L**). Both are units of power, so the Lumen and Watt are closely related:

$$1 \text{ W} = 683 \text{ L},$$

i.e., 1 Watt of luminous power is equal to 683 Lumen. Recent laws in the US designed to reduce wasted energy have led to labeling in the unit of luminous power.

However, the conversion between electric and luminous power is not perfect, some of it is lost to heat or other processes. The **efficiency** ϵ is the amount of luminous power P_L we get for the electric power P:

$$\text{efficiency} = \frac{\text{luminous power}}{\text{electric power}}$$

$$\epsilon = \frac{P_L}{P}$$

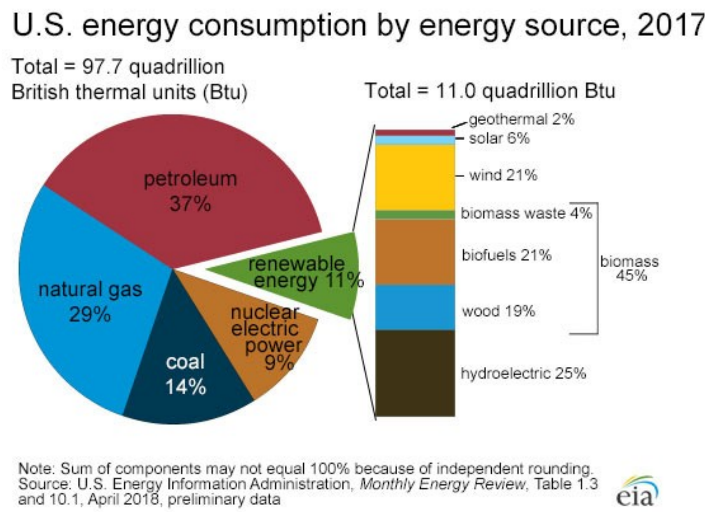
Suppose we have a incandescent bulb shown in the picture above labelled as 60 W and 780 L. That means the light bulb consumes P = 60 W of electric power. The luminous power is 780 L, which is the same as 1.14 W. This means from 60 W of electrical power we put in, we only get 1.14 W of visible light out, an meager **efficiency of 1.9 %**.

Other light bulbs are more efficient than that:

Bulb	Lumens	Electrical Power (W)	Efficiency	Lifetime	Cost
Incandescent	860	60	1.9 %	1000 hours	$ 0.40
Halogen	750	43	2.6 %	1000 h	$ 1.00
CFL (Hg!)	840	13	9.4 %	12,000 h	$ 2.00
LED	1180	15	11.5 %	25,000 h	$16.00

Solar power

Most of the energy we use on Earth comes directly or indirectly from the Sun. In the last decade there has been a realization that fossil fuels (coal, gas, oil) are detrimental to the environment because they are a source of greenhouse gases such as carbon dioxide (CO_2), which is the primary driver for man-made climate change.



Clean renewables, like solar power and wind turbines, have become a growing component of the energy supply. Direct conversion of sunlight into electrical power is gaining much attention and Michigan is emerging as a major supplier of devices that can perform this conversion: **photovoltaic panels**.

Conversion of solar energy into electricity is based on semiconductor materials like silicon or cadmium telluride (CdTe) in which photons (quanta of light) cause the electrons inside the semiconductor to be raised into higher energy states. Typical band gaps (energy difference between states) are about 1 electron-volt in the case of silicon. Thus most photovoltaic cells have a maximum output voltage of about 1 volt (similar to that of a battery).

The charge produced by the photocell can be used directly to power devices and appliances or, more typically, is stored in a battery or a capacitor for later use.

This storage step is necessary because the places where solar energy is abundant (e.g., Arizona, New Mexico) are not necessarily the same locations where most of the energy is going to be used.