For many of the systems we will be studying in this class, we will be analyzing the flow of energy.

There is a useful analogy with the flow of water. If we consider two of these streams, we can find find the flow after they combine by simply adding up the flow of the two streams. This assumes that the water is conserved, neglecting evaporation, and assuming that there is no accumulation of water in the system.

The First Law of Thermodynamics tells us that energy is *conserved*. This can be hard to observe in your every day life because when energy changes form, we often switch to different units of measurement.

Standard International Unit	Joules
Energy in food	Calories
Electrical energy	kWh = $(10^3\ \mathrm{J/s})(3.6 \times 10^3\ \mathrm{s})$
Battery capacity	Ah which depends on voltage
Chemistry	kJ/mol
Natural gas energy	Therm = 10^5 BTU
Gasoline energy	gallon
Crude oil	barrel
particle or nanoscale physics	eV
astrophysics	erg

This is a lot of different units, which can complicate the process of figuring out where energy goes. In this class, we are going to standardize on Joules, and for energy rates we will write Joules/second. The latter is the same as a Watt, but it can be helpful to be reminded that it is just a Joule per second.

MacKay shows (in "Sustainable Energy Without the Hot Air") that

On a per capita basis, each person in England is using about 8000 J/s (averaged rate).

He then shows that

It is realistic for England to produce this energy using wind, solar, bioass, tides and hydro.

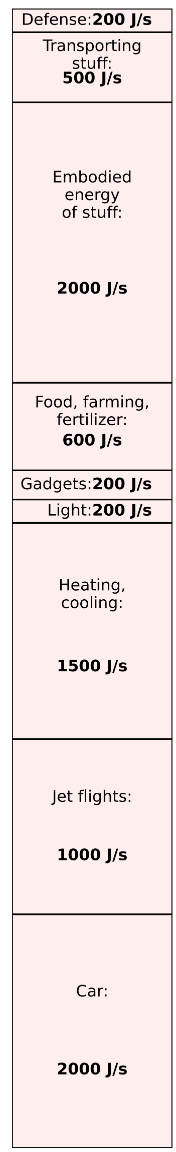

Figure 1:

1 "Time-averaged rate of energy use"

Consider, for example, the time-averaged rate of energy use by a car.

morning commute

$$\begin{aligned} \text{energy used} &= [8 \times 10^4\ \mathrm{J/s}][15\ \text{minutes}] \qquad (1)\\ &\approx [10^5\ \mathrm{J/s}][10^3\ \mathrm{s}] \\ &= 10^8\ \mathrm{J} \qquad (2)\end{aligned}$$

evening commute

$$\text{energy used} = 10^8\ \mathrm{J} \qquad (3)$$

daily total

$$\text{energy used} = 2 \times 10^8 \text{ J} \tag{4}$$

$$\begin{aligned} \text{24 hours} &= 8.6 \times 10^4 \text{ s} \quad (5) \\ &\approx 10^5 \text{ s} \quad (6) \end{aligned}$$

$$\begin{aligned} \text{time-averaged rate of energy use} &= \frac{2 \times 10^8 \text{ J}}{10^5 \text{ s}} \quad (7) \\ &\approx 2000 \text{ J/s} \quad (8) \end{aligned}$$