# Stuff

Physics and Mathematics of Sustainable Energy

College of the Atlantic.

| Material | Energy | Carbon |
|---|---|---|
| Stainless Steel | 56.7 | 6.15 |
| Steel | 20.1 | 1.37 |
| Polyurethane insulation (rigid foam) | 101.5 | 3.48 |
| Aluminum (general & incl 33% recycled) | 155 | 8.24 |
| Plywood | 15 | 1.07 |
| PVC | 77.2 | 2.41 |
| Iron | 25 | 1.91 |
| Glass | 15 | 0.85 |

Table 18.1: Embodied energies and carbon for different materials. Energies are in units of MJ/kg. Carbon is in units of kg of $CO_2$ per kg. From the Circular ecology database, http://www.circularecology.com/embodied-energy-and-carbon-footprint-database.html, cited on https://en.wikipedia.org/wiki/Embodied_energy.

Figure 1: Embodied energy and carbon for a few materials.

1. Calculate the embodied energy and $CO_2$ of a 15 gram aluminum can.
2. Calculate the embodied energy and $CO_2$ of a 192 gram glass bottle.
3. A 2MW turbine requires around 80 tons of steel.
   (a) How much energy would such a turbine produce every month?
   (b) How much $CO_2$ is saved by the turbine, assuming that its electricity displaces electricity generated from natural gas, which has a carbon intensity of around 470 g/kWh? (The carbon intensity of electricity from wind is around 12 g/kWh.)
   (c) What is the embodied emissions in the steel in the turbine?
   (d) What is its carbon payback time?
   (e) Suppose that turbine is made in Aarhus, Denmark and then travels via container ship to New York City. How much $CO_2$ is emitted by the boat that transports the turbine. Use an emissions rate of 25 g per ton-km, which is a typical[1] value for a modern freight ship.
   (f) How do the emissions associated with making the steel compare with the emissions associated with transporting it?
4. Mike Berners-Lee[2] cites an estimate that the carbon cost of building a new, two-bedroom house is 80 tons. Let's round this up to 100 tons.

[1] http://timeforchange.org/co2-emissions-for-shipping-of-goods/

[2] Berners-Lee, Mike. How bad are bananas?: the carbon footprint of everything. Greystone Books, 2011.

(a) Assume the house lasts for 100 years. How much carbon dioxide is this per year?

(b) How much fuel oil, per year, would generate the same amount of carbon dioxide?

(c) Discuss the relative merits of insulating a very leaky house or tearing it down and building a new one.

5. Estimates vary, but the energy associated with making a car is roughly 100 GJ.

   (a) If you own the car for ten years, what is this energy cost in kWh/day? What is the carbon cost in tons of $CO_2$ per year?

   (b) If you burn a gallon of gasoline, how much $CO_2$ is emitted?

   (c) Burning how much gasoline would release as much $CO_2$ as was released in the making of the car?

   (d) How far could you drive with this amount of gasoline?

6. Vaclav Smil[3] estimates that the embodied energy in a smartphone is 0.25 GJ.

   (a) If you own the phone for two years, what is this energy use in kWh/day?

   (b) Smil estimates that a smartphone annually consumes 4 kWh of electricity. How much would this electricity cost in Maine? How does the yearly energy use of the phone compare to the yearly energy consumption of the phone?

[3]Smil, Vaclav. "Embodied energy: Mobile devices and cars [Numbers Don't Lie]." *IEEE Spectrum* 53.5 (2016): 26-26.