Stuff

Physics and Mathematics of Sustainable Energy

November 7, 2023. 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?

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

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.

   (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. The energy associated with making a car in the US is 119,000 MJ. The CO_2 cost is 10,480 kg[3].

   (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. Estimates vary, but the emissions associated with the production of a medium-sized standard gasoline car is aroung 6 tons of CO_2e. Let's assume the car gets 25 miles to the gallon and is driven for 100,000 miles in the car's lifetime.

   (a) What are the emissions associated with driving the car?

   (b) The emissions associated with driving the car are what percent of the car's total emissions (production plus use)?

7. Vaclav Smil[4] 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?

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

[3]`Yan,Xiaoyu."Energydemandandgreenhousegasemissionsduringtheproductionofapassengercarin China. "EnergyConversionandManagement50.12(2009):2964-2966..`

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