

# Stuff

## Physics and Mathematics of Sustainable Energy

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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<sub>2</sub> per kg. From the Circular ecology database, <http://www.circular.ecology.com/embodied-energy-and-carbon-footprint-database.html>, cited on [https://en.wikipedia.org/wiki/Embodied\\_energy](https://en.wikipedia.org/wiki/Embodied_energy).

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

1. Calculate the embodied energy and CO<sub>2</sub> of a 15 gram aluminum can.
2. Calculate the embodied energy and CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> is emitted by the boat that transports the turbine. Use an emissions rate of 25 g per ton-km, which is a typical<sup>1</sup> value for a modern freight ship.
  - (f) How do the emissions associated with making the steel compare with the emissions associated with transporting it?

<sup>1</sup><http://timeforchange.org/co2-emissions-for-shipping-of-goods/>