Packaging and Recycling

This worksheet contains

- Average amount of packaging thrown away daily
- Energy and CO_2 that goes into a PET bottle and an aluminium can
- Energy and CO_2 recoverable through recycling the bottle and can
- Calculating how many bottles/cans need to be recycled to save the UK average daily carbon footprint
- Comparison of environmental impact of PET bottle and Al can

We see packaging around us every day; the necessity of much of it can be contested, and once the product it contained has been removed, most of it gets thrown away.

It is estimated that the average resident of Britain throws away 400g of packaging every day, producing an average energy demand of 4kWh/person/day for packaging. This is around 3% of our annual energy consumption.

Here we will calculate the energy demand for a couple of different drinks containers and the impact of recycling them. We will also calculate the carbon footprints of these containers.

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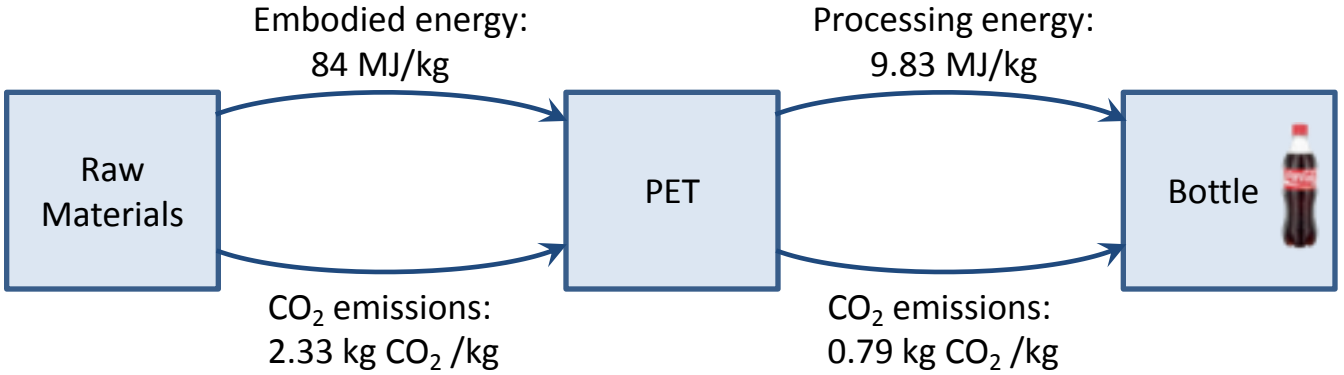
Plastic Bottles

Bottles for soft drinks are mostly made from a plastic called PET. Life cycle analysis allows us to estimate the energy that goes into making the bottle, or the corresponding emissions of CO_2.

Raw materials (ores and hydrocarbons) are converted into usable engineering materials such as PET – the energy used, per kg of output material, is known as the *embodied energy*.

Manufacturing products such as bottles uses more energy per kg of material – this is the *processing energy*.

The figure shows energy data from the *Materials Databank* for PET, and equivalent CO_2 emissions (kg CO_2 /kg material) .



Energy per bottle

First we need a conversion factor for energy from MJ to the more familiar kWh: 1 kWh = 3.6 MJ

The mass of an empty single 500ml coca-cola bottle is **25g**.

So the embodied energy in one bottle is: 0.025 kg x 84 MJ / 3.6 = 0.58 kWh.
Processing adds : 0.025 kg x 9.83 MJ / 3.6 = 0.07 kWh, giving a total energy input of 0.65 kWh per bottle.

This doesn't sound much from a daily personal consumption of energy of around 125 kWh – but this is just one bottle! Taking 400g of mixed packaging as a whole, the figure is estimated to be 4 kWh/person/day (3% of the typical total).

How much of this can be recovered by recycling?

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Bottle Re-use and Recycling

Empty bottles may be re-used – e.g. as a water-bottle, provided they are cleaned properly. This immediately saves the energy required to make and transport bottled water (UK tap water is just as good to drink!).

But most people will have far more plastic bottles to dispose of than they need as water bottles. What do we achieve by recycling them, instead of putting them in a bin?

If we recycle a bottle, we need to spend more energy on the recycling process – the key question is just how much is this *recycling energy*, compared to the original embodied energy?

From the *Materials Databank*:

PET recycling uses **35 MJ/kg of energy** and the associated CO_2 emissions is **0.98 kg CO_2 /kg**

Compare this with the embodied energy of new PET: 84 MJ/kg, so recycled PET "embodies" roughly 40% as much energy as new PET. Put another way, recycling saves 60% of the energy needed to provide PET for future products.

Energy and CO_2 savings

First converting energy units: PET recycling energy is 35 MJ/kg / 3.6 = 9.7 kWh/kg.

For a 25g bottle, the recycling energy = 0.24 kWh

So recycling one bottle saves: (embodied energy per bottle – recycling energy per bottle) = 0.58 – 0.24 = **0.34 kWh**

In terms of CO_2 emissions:

(CO_2 emissions for new PET – CO_2 emissions to recycle PET) = 2.33 – 0.98 = **1.35 kg CO_2 /kg**

For a 25g bottle, recycling the bottle potentially saves emissions of 0.025 x 1.35 = **0.034 kg CO_2**

This is only 0.11% of one person's daily carbon footprint (30 kg CO_2), so recycling **880 small bottles** will make one person carbon neutral for a day! It sounds a lot – but routine bottle collection in schools is so easy to implement, it is a simple first step towards a lower carbon footprint.

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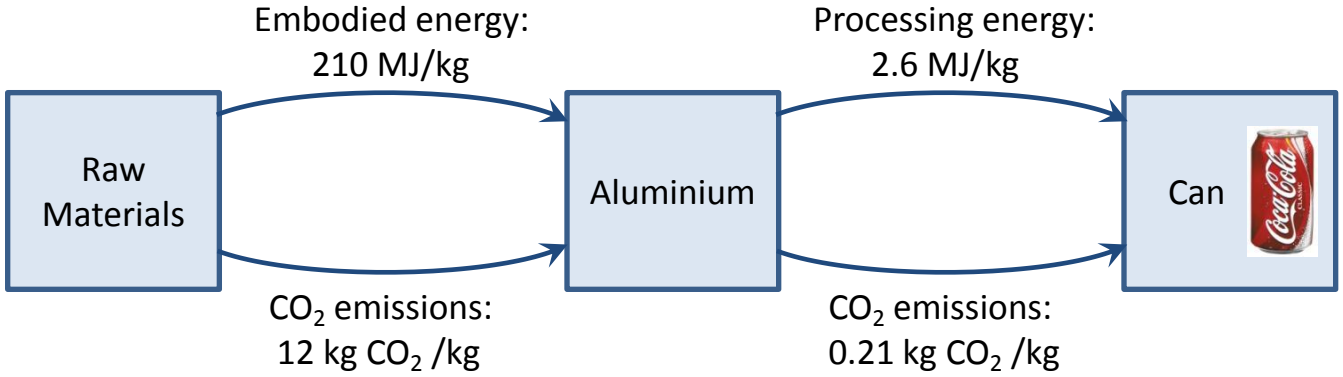
What about Aluminium Cans?

The mass of an empty 330ml aluminium drinks can is **20g**. The figure shows the energy and CO_2 data for aluminium.



Recycling Al cans – energy and CO_2 savings?

A can can't be re-used, but can readily be recycled. This is an example of *closed loop recycling* – sorted Al cans are remelted to make new aluminium sheet for can bodies.

The energy and CO_2 results for recycling aluminium cans are summarised below, as calculated for a PET bottle. See if you can calculate these values for yourself (using additional data from the *Materials Databank*).

- recycling aluminium uses only **9%** of the embodied energy of new aluminium produced from ore
- recycling one aluminium can saves **0.96 kWh** of energy, and saves **0.22 kg CO_2**
- recycling one aluminium can saves **0.7%** of one person's daily carbon footprint (30 kg CO_2), so recycling **136 small cans** will make one person carbon neutral for a day!

136 cans is surprisingly few – for half litre cans it is closer to 100. This really emphasises the energy value of aluminium: once we have made it, we really should use it again and again. Looking at the number of cans in street litter, we clearly have a long way to in using our resources wisely. *Does your school/town recycle cans?*

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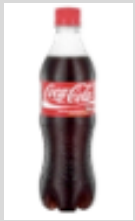
Are PET bottles or Al cans more environmentally friendly?

This comparison needs a bit of careful thought. We could compare one bottle with one can – but is this fair, when they contain different volumes of drink? To compare the materials at an equivalent usage, we will consider 100 PET bottles (i.e. 50 litres of drink), and the number of cans that contains the same volume, i.e. 150 x 330ml cans.

	50 litres in PET bottles (100 x 500ml bottles) 	**50 litres in Al cans (150 x 330ml cans)** 
Embodied energy, using new material (kWh)	58	175
Recycling energy, using old containers (kWh)	24	16
CO_2 footprint, using new material (kg CO_2)	5.8	36
CO_2 footprint, recycling old containers (kg CO_2)	2.4	3.3

On energy grounds, recycled aluminium is the best option, with an equivalent large saving of CO_2. Using recycled PET offers smaller savings in proportion, but the energy and CO_2 impacts are similar to recycled Al. But note that closed-loop recycling of PET bottles is not currently possible – recovered bottles are *downcycled* into other products (e.g. fleece jackets).

Plastic bottles have other benefits of course – the screw-top means the drink does not have to be consumed all at once, and the bottle can be re-used to carry water many times before it is recycled.

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Sources

Ashby MF, 2009. Materials and the Environment, Butterworth-Heinemann.

Granta Design Ltd, 2011. Cambridge Engineering Selector (CES) Database.

Images from http://yoursay.footprintfriends.com