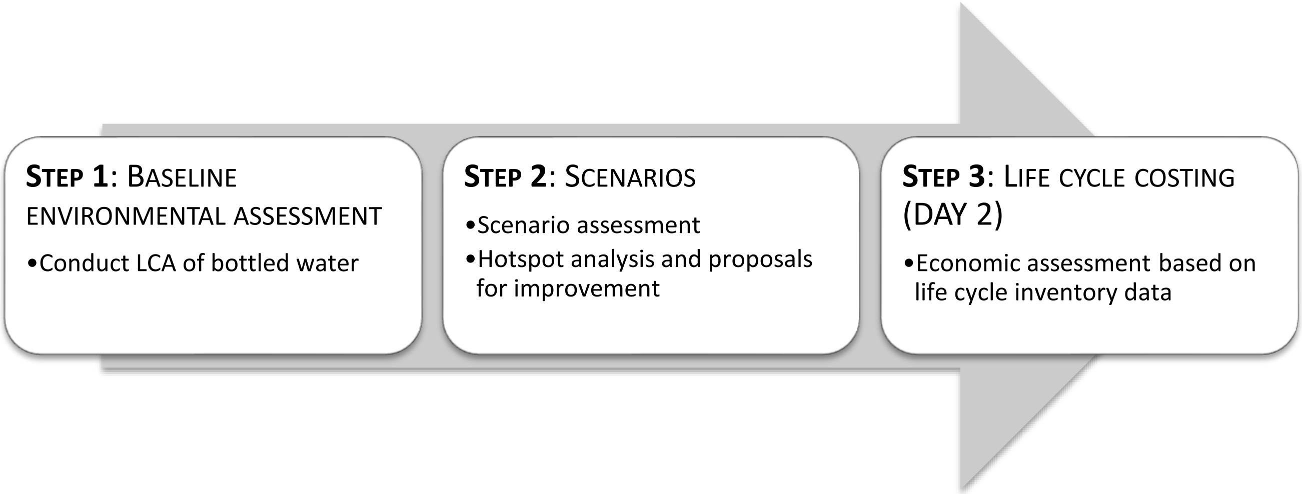
The University of Manchester

CCaLC2 practical session

Carbon Footprinting and Sustainability: Bottled Water

This practical requires three steps, as follows:



How to begin

Download CCaLC2 from this link or from the website. (For the latter you will need to fill in a form.)

STEP 1 — Baseline environmental assessment

TASK — Estimate the carbon footprint of a PET water bottle using CCaLC, based on the data below.

1. Description of PET bottle

The components and contents of the PET bottle are listed in Table 1.

Table 1: Components of PET bottle (0.5 l)

Component	Material	Quantity (g/0.5 litre container)
Bottle	PET resin (bottle grade)	24
Top	Polypropylene (PP) resin	2
Label	Kraft paper, bleached, at plant, Europe	0.2
Water	Drinking water – from ground water	500

2. Functional unit

The functional unit is defined as “1000 litres of bottled water”. The volume of the PET bottle is 0.5 litres.

3. System boundary

A simplified life cycle of PET bottled water is shown in Figure 1.

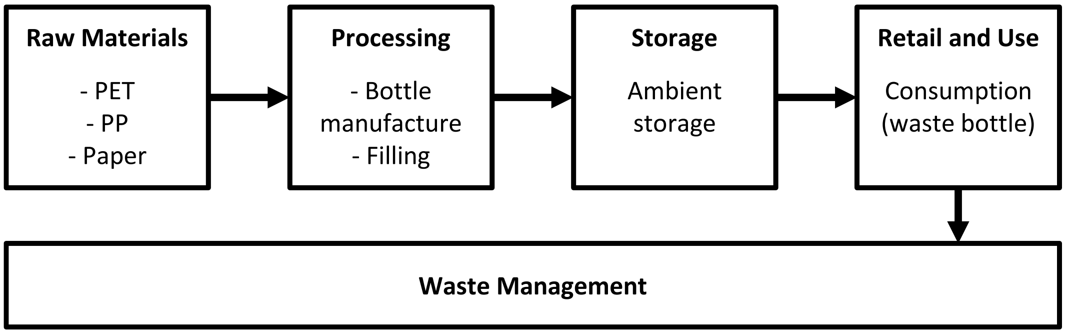


Figure 1: The life cycle of a PET bottle

The following life cycle stages are considered:

a) Raw materials: PET and PP resins, Kraft paper, and water;
b) Processing: Bottle manufacture; bottle filling;
c) Storage: Ambient storage of the product at a distribution centre;
d) Retail and use: Consumption of the drink and discarding of waste bottles (it is assumed that the drink is consumed at retailer);
e) Waste management: Disposal of waste bottles in landfill; and
f) Transport: Transport of raw materials, bottles and waste along the life cycle of the bottle.

4. Raw materials

The raw materials for the PET bottle are PET and PP resins for the bottle and the top, respectively. Kraft paper is used for the label. All materials are assumed to be virgin. The bottle is filled with drinking water extracted from a groundwater source. The carbon footprint data for these materials are available in the CCaLC database.

5. Energy

Table 2 summarises energy use in different life cycle stages. Note that the energy for bottle manufacture is the combined amount for the manufacture of the bottle and the cap.

Table 2: Energy use in the life cycle of the PET bottle

Process	Energy type	Amount (MJ/functional unit)
Bottle manufacture	Heat, natural gas, at industrial furnace low-NOx >100kW	500
Filling	Electricity, medium voltage, production, UK, at grid	306
Filling	Steam - natural gas, UK	340

6. Transport

Table 3 summarises the distances travelled and the transportation modes. Assume that the water is sourced on-site and therefore does not require transportation to the filling plant.

Table 3: The transportation modes and distances travelled in the life cycle of the PET bottle

Raw material	Distance travelled by road (km)	Packing density (kg/m^3)	Empty on return?
PET resin (to manufacture & filling)	100 (40t truck)	50.0	Yes
PP resin (to manufacture & filling)	100 (40t truck)	5.2	Yes
Kraft paper (to manufacture & filling)	100 (22t truck)	0.5	Yes
Filled bottles to storage	100 (40t truck)	1000.0	Yes
Bottles from storage to retailer/use	100 (22t truck)	1000.0	Yes
Waste bottles to landfill	20 (40t truck)	9.0	Yes

7. Waste management
It is assumed that all PET bottles are landfilled (‘Landfill – plastic’ in CCaLC).

8. Results
Once you have finished the CCaLC model, review your results and consider the hotspots.

STEP 2 — Scenarios

TASK — First, you will **choose at least one** of the alternative scenarios given below, then use CCaLC and the information provided to estimate the carbon footprint of that scenario.

1. Scenarios

<u>Scenario 1: Light weighting</u>

Modelling: The bottles are made thinner to save material. Reduce the mass of PET and PP by 10% each and update any other parts of the life cycle affected by the new mass.

<u>Scenario 2: Bio-based materials</u>

Modelling: Petrochemical PET is replaced. Replace PET with ‘Bio-based Polyethylene terephthalate (PET) (amorphous grade, sugarcane-based)’.

<u>Scenario 3: More recycling</u>

Modelling: Recycled material and end-of-life recycling are prioritised. Replace 40% of your PET feedstock with ‘Polyethylene terephthalate (PET), 100% recycled’ (same transport assumptions). Reduce the amount of waste going to landfill by 35% on the assumption that people recycle more.

<u>Scenario 4: Cogeneration</u>

Modelling: A combined heat and power plant is installed at the factory. Replace electricity with ‘Electricity-CHP-1’. Replace heat and steam with ‘Heat-CHP-1’.

2. Results
Enter the carbon footprints that you have calculated into the table to compare the different scenarios.

Table 4: Carbon footprint of the different scenarios

Scenario	Carbon footprint (kg CO_2-eq./f.u.)
Baseline scenario: Standard bottle	
New scenario:	

3. Decision-making and ideas for improvements
Use the results of your two models to decide which one is best and how your final solution might be improved.

STEP 3 — LCC

TASK — Modify your LCA models (baseline and new scenario) to include costs. You can do this in CCaLC2 but it may be easier and more flexible in Excel!

1. Cost information for all scenarios

- Costs of materials:
    - PET 0.29 £/kg
    - PP 0.44 £/kg
    - paper (Kraft) 0.45 £/kg
    - BioPET: 0.10 £/kg
    - Recycled PET: 30% cheaper than virgin PET
- In the baseline production process, material costs make up 45% of the total cost of manufacture. The other 55% is utilities (electricity, gas, etc.).
- The CHP system in Scenario 4 reduces energy bills by 40%.
- You may wish to assume an annual production volume during your analysis, in which case you can find suitable examples of bottling plants online to justify your assumption.

2. Results

Enter the costs that you have calculated into the table to compare the different scenarios.

Table 5: Costs of the different scenarios

Scenario	Cost (£/f.u.)
Baseline scenario: Standard bottle	
New scenario:	