

1 · Carbon footprint kg CO₂e

Footprint = $\Sigma \text{ amount} \times \text{emission factor}$

amount in the factor's unit: kWh · litres · kg · tonne-km

1 kg = 1,000 g · 1 t = 1,000 kg

Frito-Lay chips, 34.5 g bag: 33 + 22.5 + 11.25 + 6.75 + 1.5 = 75 g CO₂e (farming, manufacture, packaging, shipping, disposal)

2 · Per unit, share, hotspot

Per unit = $\text{total footprint} \div \text{number of units}$

Share = $\text{stage} \div \text{total} \times 100 \%$

Hotspot = stage with the biggest share → work on it first

Chips: farming 33 ÷ 75 = 44 % → hotspot; per gram 75 ÷ 34.5 = 2.17 g CO₂e per g

3 · Transport tonne-km

Tonne-km = tonnes moved × km

Transport footprint = tonne-km × factor per tonne-km

Fuel route = litres × kg CO₂e per litre

1 t flour × 150 km = 150 tkm × 0.058 kg = 8.7 kg CO₂e by truck

4 · Life cycle cost and crossover (S5-2)

Life cycle cost = price + (energy € per km + other € per km) × km per year × years

Crossover km = $(\text{price B} - \text{price A}) \div (\text{variable € per km A} - \text{variable € per km B})$

Crossover years = $\text{crossover km} \div \text{km per year}$

A 30,000 € + 0.25 €/km, B 40,000 € + 0.15 €/km, 20,000 km × 6 years: A 60,000 €, B 58,000 €; crossover 100,000 km = 5 years < 6 → B cheaper over its life

5 · Break-even and end of life

Reuse break-even = extra footprint to make ÷ footprint saved per use → **round up**

Revenue retrieval (S5-1) = resale + recycling revenue – processing – disposal cost

Hard cup 167 g vs single-use 27 g, washing 10 g per use: 167 ÷ (27 – 10) = 9.8 → 10 uses. Harmonizer: 35.49 + 11.94 – 22.33 – 2.97 = 22.13 \$

6 · € per tonne and the plan

€ per tonne = extra cost per year ÷ t CO₂e saved per year (*negative = saves money*)

Cheapest-first plan: sort by € per tonne, add measures until the target is reached

Plan cost = sum of € per year of the chosen measures

A +300 € ÷ 2 t = 150 €/t; B –100 € ÷ 0.5 t = –200 €/t → B first, even though A is bigger

Before you hand in

① "x [unit] per [unit]"

② trips, crates, people rounded **up**

③ decision in words, matching your numbers

Heizer, Render & Munson (2023), Pearson, Suppl. 5 · examples: own and Suppl. 5 · compiled with Claude, reviewed by R. Bartnik