

Does It Break Down, and Is It Worth It? Two Cup Datasets

Learning target: I can graph and calculate from data about how fast different cup materials break down and how much energy they use per use, and I can explain what the numbers do and do not tell us about which material is better.

Data and graphing

About 45 min

Individual

MS-PS1-3 · practice

MS-ETS1-3 · practice

data analysis

independent practice

Standards connections

MS-PS1-3 (practice): The datasets give students a concrete picture of how a synthetic material's end of life depends on conditions and how its benefits trade against costs. The PE is assessed with qualitative information, so this quantitative sheet builds understanding rather than serving as evidence for the PE.

MS-ETS1-3 (practice): Students analyze test data on four competing cup materials to find each one's strengths and weaknesses, which is the data-analysis step of comparing design solutions; the data are simulated and the decision is classroom-scale.

Purpose: practice · **Time:** about 45 minutes · **Format:** individual

Answers with reasoning

Part A: How fast does each cup break down?

A materials lab put identical-sized cups of three materials into an industrial composter kept at 58 °C, moist, with air moving through it. A fourth sample, a PLA cup, was buried in a sealed bin of dry soil at 20 °C with no air flow to imitate a landfill. Every 30 days a cup was removed, cleaned and weighed. The table shows the percent of the starting mass that remained.

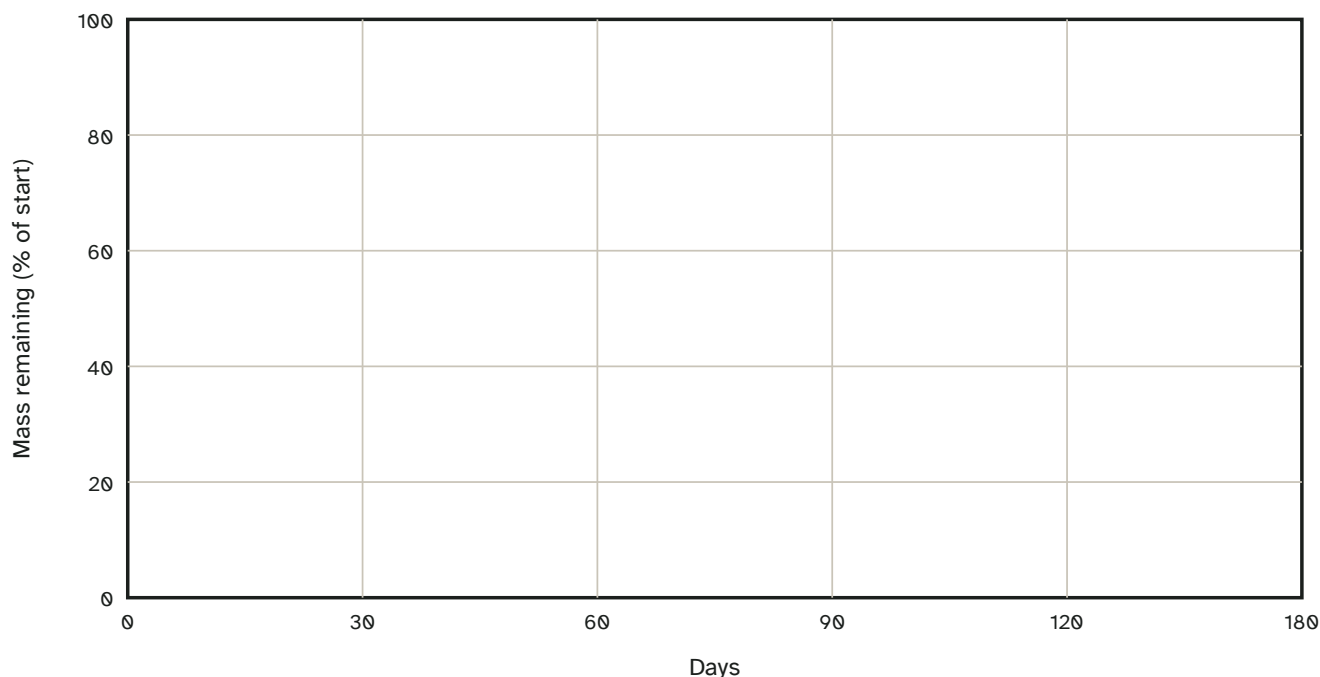
Percent of starting mass remaining (teaching dataset)

Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Day	Paper cup, composter (%)	PLA cup, composter (%)	PET cup, composter (%)	PLA cup, landfill bin (%)
0	100	100	100	100
30	62	88	100	99
60	31	61	99	99
90	12	34	99	98
120	4	15	99	98
180	1	6	99	97

Simulated data for teaching. The pattern matches published findings: paper and PLA break down in hot industrial compost over weeks to months; PET does not; PLA in a cool, dry, airless landfill barely changes.

Mass remaining versus days



1. Calculate the percent of mass the PLA cup in the composter lost by day 90 and by day 180. Show your work.

Answer: Day 90: $100\% - 34\% = 66\%$ lost. Day 180: $100\% - 6\% = 94\%$ lost.

Why: Mass lost is the starting 100 percent minus the percent remaining in the PLA composter column.

Also acceptable: Accept 66 and 94 with the subtraction shown.

2. Find the average rate of mass loss, in percent per day, for the PLA cup in the composter between day 30 and day 90. Then find the same rate for the paper cup. Which broke down faster during that interval?

Answer: PLA in composter: $(88\% - 34\%) \div (90 - 30) \text{ days} = 54\% \div 60 \text{ days} = 0.9\%$ per day. Paper: $(62\% - 12\%) \div 60 \text{ days} = 50\% \div 60 \text{ days} \approx 0.83\%$ per day. PLA lost mass slightly faster during this interval (0.9 versus 0.83 percent per day), although paper was further along because it started breaking down sooner.

Why: Change divided by time. The paper cup had already lost 38 percent by day 30, so over the whole 90 days paper is ahead; over the 30-to-90 interval PLA's rate is a little higher. Either observation shows good reading of the data.

Also acceptable: Accept 0.83 or 0.8 percent per day for paper. A student who says paper broke down faster overall because it was at 12 percent by day 90 should be credited if the interval rates are correct.

3. Describe the shape of each of the four lines on your graph in one phrase each. Which two lines are nearly flat, and what does a flat line mean here?

Answer: Paper in composter: a steep curve that drops fast at first and flattens near zero. PLA in composter: a slower S-shaped curve that starts gently, drops fastest between days 30 and 120, then flattens near zero. PET in composter: nearly flat at about 99-100 percent. PLA in landfill bin: nearly flat, drifting down only to 97 percent. The two flat lines mean almost no mass was lost: the material did not break down under those conditions.

Why: Students should read the shape as the rate of breakdown and recognize that flat means no breakdown.

Also acceptable: Accept 'curves down then levels off' for the paper and PLA composter lines.

- Each line described
- Identifies PET and PLA-in-landfill as nearly flat
- Explains flat as no breakdown

4. The PLA cup in the landfill bin lost 3 percent of its mass in 180 days. If it kept losing mass at that same rate, how many days would it take to lose all 100 percent? Convert your answer to years. Then give one reason the real answer might be even longer.

Answer: At 3 percent per 180 days, losing 100 percent would take $100 \div 3 \times 180$ days = 6,000 days. $6,000 \div 365 \approx 16.4$ years. The real answer could be even longer because the rate may slow as the easy-to-reach surface is used up, and because a landfill is sealed, cool and dry, so the microbes that could take PLA apart are mostly inactive.

Why: A linear extrapolation is a rough estimate; the point is the contrast with 180 days in the composter. Any physically sensible reason for a slower rate earns credit.

Also acceptable: Accept about 16 years (or 6,000 days). Accept 'it might never fully break down' with a reason.

5. A cup maker's advertisement says its PLA cups are 'biodegradable.' Using numbers from two different columns, explain what that word does and does not promise. Then explain what one fact about a town would decide whether switching from PET to PLA cups would reduce the cups sitting in its landfill.

Answer: Biodegradable promises that living things can break the material down under the right conditions: in the hot, moist, aerated composter the PLA cup was 94 percent gone by day 180 (6 percent remaining). It does not promise that the cup will break down wherever it is thrown: in the landfill bin the same material was 97 percent still there after 180 days. The deciding fact about a town is whether its waste actually goes to an industrial composter that runs hot and accepts PLA; if the festival or cafeteria cups go to a landfill, PLA cups will sit there almost like PET cups and the switch will not shrink the pile.

Why: Full credit requires numbers from the composter column and the landfill column, and the town fact about where waste goes. This is the accurate version of 'biodegradable' that the textbook's 'several days' and the opener's unconditional 'biodegradable cups' both miss.

Also acceptable: Accept 'whether the town collects the cups separately and sends them to a composter' as the deciding fact.

- Uses a number from the PLA composter column
- Uses a number from the PLA landfill column
- Names access to industrial composting (or where the waste goes) as the deciding fact

Part B: Single-use or reusable? Counting energy per use

The same lab estimated how much energy it takes to make one cup of each kind, from the natural resource to the finished cup, and how much energy one wash in a dishwasher uses. A single-use cup is used once. A

reusable cup is used many times and washed after each use. Energy is given in megajoules (MJ); one megajoule is roughly the energy in a small snack bar.

Energy to make and to wash one cup (teaching dataset)

Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Cup	Natural resource	Energy to make one cup (MJ)	Energy per wash (MJ)
Single-use PET	petroleum	0.5	not washed
Single-use PLA	corn	0.6	not washed
Reusable polypropylene (plastic)	petroleum	15	0.1
Reusable stainless steel	iron and chromium ores	30	0.1

Simulated values chosen to be realistic in size and order; a real life-cycle study would also count water, transport and what happens at the end.

6. Complete the table with the total energy, in MJ, for each number of uses. For single-use cups, every use is a new cup. For reusable cups, count the cup once plus one wash per use. Show one full calculation below the table.

Answer: Single-use PET: 10 uses = $10 \times 0.5 = 5$ MJ; 50 uses = 25 MJ; 100 uses = 50 MJ. Reusable polypropylene: 10 uses = $15 + 10 \times 0.1 = 16$ MJ; 50 uses = $15 + 5 = 20$ MJ; 100 uses = $15 + 10 = 25$ MJ. Reusable steel: 10 uses = $30 + 1 = 31$ MJ; 50 uses = $30 + 5 = 35$ MJ; 100 uses = $30 + 10 = 40$ MJ.

Why: Single-use total is the per-cup energy times the number of uses; reusable total is the one-time making energy plus 0.1 MJ per wash. At 10 uses both reusable cups have used more energy than single-use; at 50 uses polypropylene is ahead and steel is not; at 100 uses both reusable cups are ahead.

Also acceptable: Accept totals written with units; the most common error is forgetting the one-time making energy or charging it for every use.

7. The break-even point is the number of uses at which a reusable cup has used the same total energy as the same number of single-use PET cups. Calculate the break-even number of uses for the polypropylene cup and for the steel cup. Show your work. (Hint: each use of a reusable cup saves 0.5 MJ on a new PET cup but costs 0.1 MJ for a wash.)

Answer: Each use of a reusable cup gains $0.5 \text{ MJ} - 0.1 \text{ MJ} = 0.4 \text{ MJ}$ compared with a new PET cup. Polypropylene: $15 \text{ MJ} \div 0.4 \text{ MJ per use} = 37.5$, so the cup breaks even at about 38 uses. Steel: $30 \text{ MJ} \div 0.4 \text{ MJ per use} = 75$ uses.

Why: Setting $0.5n = 15 + 0.1n$ gives $0.4n = 15$, $n = 37.5$; for steel $0.4n = 30$, $n = 75$. A student can also check against the q6 table: polypropylene is behind at 10, ahead at 50; steel is behind at 50, ahead at 100.

Also acceptable: Accept 37.5, 38 or 'about 40' for polypropylene with the work shown, and 75 for steel.

8. A student buys a reusable polypropylene cup, uses it 20 times, and loses it. Calculate the energy used by that cup and by 20 single-use PET cups. Which choice used less energy, and what does that say about when 'reusable' is actually better?

Answer: Lost polypropylene cup: $15 \text{ MJ} + 20 \times 0.1 \text{ MJ} = 17 \text{ MJ}$. Twenty PET cups: $20 \times 0.5 \text{ MJ} = 10 \text{ MJ}$. The single-use cups used less energy. 'Reusable' is only better if the cup is actually reused past its break-even point (about 38 uses here); a reusable cup that is lost, broken or left in a drawer can cost more energy than the single-use cups it replaced.

Why: The calculation is straightforward; the interpretation is the point. This is a fair-minded result: reusables are not automatically better.

Also acceptable: Accept 'reusable is better only if you keep using it' as the conclusion.

- 17 MJ and 10 MJ with work
- States that single-use used less energy in this case
- Connects the result to reaching the break-even number of uses

9. Suppose a school has to choose between the PLA cup and the steel cup for its cafeteria. List two things the energy dataset tells you and two important things it does not tell you. Then explain why someone who only looked at Part A, or only at Part B, could reach the wrong decision.

Answer: The energy dataset tells you: a PLA cup costs 0.6 MJ every time, and a steel cup costs 30 MJ once plus 0.1 MJ per wash, so compared with PLA the steel cup saves energy only after $30 \div (0.6 - 0.1) = 60$ uses (75 uses compared with PET). It does not tell you: how much water the dishwasher uses; whether the school's waste goes to a composter where PLA would actually break down or to a landfill where it would not; how many steel cups will be lost or stolen; what mining ore or growing corn does to land and water; or what the cups cost in money. Someone using only Part A might pick PLA because it breaks down in a composter without asking whether the school has one; someone using only Part B might pick steel without asking whether students will keep the cups long enough to reach the break-even point.

Why: Full credit needs two accurate things the data show and two specific things they do not, plus the one-sided-decision explanation. The 60-use figure against PLA is a bonus, not required.

Also acceptable: Accept 'where the cups go at the end' and 'cost in dollars' as missing information.

- Two things the energy data show, with numbers
- Two specific gaps in the data
- Explains how each part alone could mislead

Teacher notes

Both datasets are simulated and labeled as such. The breakdown pattern is faithful to published results: PLA composts in industrial conditions (about 58 °C, moist, aerated) over weeks to months, with a common standard of 90 percent of its carbon converted to carbon dioxide within 180 days; it does not break down on any useful timescale in a landfill, a backyard pile or the ocean; PET does not biodegrade in compost. The energy figures are illustrative in size and order (single-use cups well under 1 MJ; a reusable plastic cup tens of MJ; steel more), and the break-even logic (dozens of uses) matches real life-cycle findings. Expect the common error in q6 of charging the making energy at every use. In the q9 debrief, keep both sides honest: reusables usually win when reused enough; single-use cups win when reusables are lost early. The extension uses real rounded energy densities (gasoline about 32 MJ per liter, ethanol about 21 MJ per liter): one liter of E10 carries $0.9 \times 32 + 0.1 \times 21 = 28.8 + 2.1 = 30.9 \text{ MJ}$, about 3.4 percent less than gasoline.

Scaffold offered to students: Rates and break-even, step by step

A rate is a change divided by the time it took. For q2, subtract the later percent from the earlier percent, then divide by the number of days between them; the unit is percent per day. For q7, think of each use as a small contest: the reusable cup saves the 0.5 MJ that a new PET cup would have cost, but spends 0.1 MJ on a wash, so each use gains 0.4 MJ on the single-use option. Divide the energy it took to make the reusable cup by 0.4 MJ per use to find how many uses pay it back.

Extension: The fuel in the tank

Nearly all gasoline sold in the United States is E10, about one tenth ethanol by volume. Real reference values, rounded: a liter of gasoline releases about 32 MJ when burned; a liter of ethanol releases about 21 MJ. Calculate the energy in one liter of E10 (0.9 L gasoline plus 0.1 L ethanol) and the percent less energy it carries than pure gasoline. Then write three sentences: what this means for how far a car goes on a tank, why that is not by itself a reason to reject ethanol, and what other information (land, water, the energy to grow and distill the corn) you would want before judging corn ethanol fairly.