

Substitute Guide: Energy Flow in Ecosystems

Course: Biology (Grades 9–12) Subject: Science Time: ~50 min standard • ~90 min block

SCIENCE

Learning goal (plain language)

Students learn how **energy flows through an ecosystem** — from the Sun to **producers**, then up through **trophic levels** of consumers — and that only about **10% of the energy passes to each next level** (the "10% rule"), which is why an **energy pyramid** is wide at the bottom and narrow at the top. Working alone with a pencil, students read a short passage, study a labeled energy-pyramid diagram and a data table, do simple 10%-rule calculations, and write an evidence-based explanation (CER). **You do not need a science background to run this.** Everything students need is printed in their packet. This is a **paper** activity — no lab, no materials, no hazards.

Standards alignment

Framework: 19 TAC §112.42 (Biology). Knowledge & skills on **energy flow, trophic levels, and ecosystem relationships**.

- **Provisional — energy flow / trophic levels:** analyze the flow of energy through trophic levels and interpret energy pyramids, including the ~10% transfer of energy between levels.
- **Provisional — ecosystem relationships:** describe the roles of producers, consumers, and decomposers and predict how changes at one trophic level affect the others.

Provisional — pending educator verification against the current official TAC source. Codes and letters are placeholders until confirmed.

(Standards are paraphrased here, not quoted. Please confirm codes and wording against your official source. This packet does not claim formal alignment to the TEKS.)

SETUP Before class (5 min)

- Count and hand out one **student packet** per student.
- Confirm each student has a **pencil**. No calculators, computers, or lab items are needed (the 10%-rule numbers are $\times 0.10$, easy to do by hand).
- Write the date on the board and remind students to fill in the name line.
- Keep the **answer key** with you — it is a separate file and is **not** in the student packet.

MATERIALS
What's needed

- Printed student packet (4–6 pages) per student.
- Pencil per student.
- This guide and the separate answer key (teacher only).
- No technology, no calculator, no lab equipment, no safety hazards.

TIMING
Suggested pacing — standard vs. block

Segment	Standard (~50 min)	Block (~90 min)	What students do
Start — Notice & Wonder	5 min	5 min	Q1–Q2 warm-up
Build — Read the science	8–12 min	12 min	Read passage, word bank, energy pyramid; Q3
Apply — Use the data	20–25 min	25 min	Table 1; Q4–Q9 (classify, 10%-rule calculations, percent transfer, predict)
Explain — CER	7–10 min	10 min	Q10 explanation (claim/evidence/reasoning)
Close — ACE	5 min	5 min	Articulate / Connect / Extend
Continue — early finishers	optional	+30 min	Design a pyramid; block adds the multi-step ocean energy-loss calculation

On a standard ~50-minute period, the core stops after the CER (Q10) and ACE; the early-finisher pyramid is optional. On a ~90-minute block, everyone also completes the block extension — a multi-step energy-loss chain that applies the 10% rule five times and computes the percent of original energy reaching the top predator.

SCRIPT**Read aloud to start**

"Today's assignment is a paper science investigation called *Energy Flow in Ecosystems*. You will work by yourself with just a pencil — no computers or calculators, and nothing to build or mix. First read the short passage and study the energy-pyramid diagram and the data table. Then answer the questions in order; if one is tricky, skip it and come back. There are a few easy math steps where you take 10% of a number — that just means multiply by 0.10, or drop a zero. Write in complete sentences where it asks you to explain. You may quietly read the passage aloud to yourself. Put your name, class period, and date at the top now. You have about 50 minutes (or the full block); raise your hand if you need help understanding a word."

SUPPORT**When students ask for help**

- **You may read any part aloud** to a student or the class.
- If they are stuck on "which trophic level," point them to the **trophic levels** box and **Figure 1** — each band is one level.
- For the 10%-rule items (Q5–Q6), remind them "10% of a number" = multiply by 0.10 (for example $10,000 \times 0.10 = 1,000$). They do not need a calculator.
- Encourage the printed **sentence stems** for the CER (Q10) and ACE sections.
- Do **not** give answers; prompt with "What does the data show?" or "Which band is above which?"
- It is fine if a student cannot finish the optional early-finisher or block task.

ACCESS**Accommodations & language support**

- **Read-aloud** of any passage or question is allowed for all students.
- Point students to the **sentence stems** and the **Word Bank** (definitions provided).
- Extended time is fine; the core can stop after Q10 if time runs short.
- Students may answer in phrases if writing full sentences is a barrier, as long as the idea is clear. Showing the $\times 0.10$ step is enough for Q5–Q6.
- The packet is grayscale-safe — it prints and reads clearly in black and white; the pyramid uses patterns and labels, not color.

TOOLS Allowed & not allowed

Allowed: pencil, the printed packet, quiet self-read-aloud. **Not needed / not allowed:** calculator (the math is taking 10% of a number), phones, computers, lab materials.

Collect at the end:

Collect every packet, whether finished or not, with names on them. Stack them for the teacher. Note on a sticky how far most students got and any questions that caused confusion.

Answer key:

The **answer key is a separate file** (answerkey.html) and is for the teacher only. Please do not hand it to students.

Teacher follow-up (for the returning teacher)

Watch for two high-value misconceptions: students thinking *energy is recycled like matter*, and thinking *bigger animals have more energy available*. A quick next-day discussion contrasting the one-way flow of energy with the cycling of matter, and tying the pyramid shape to the 10% rule, would reinforce this well. The 10%-rule calculations (Q5–Q6) and the "remove a trophic level" prediction (Q9) show who can reason with the data; the CER (Q10) responses show who can cite specific energy values as evidence.

Energy Flow in Ecosystems

Course: Biology (Grades 9–12) Subject: Science Time: ~50 min standard · ~90 min block

Work mode: Independent · pencil only **SCIENCE**

Name

Class period

Date

Start Here

This is a **paper investigation**. You will study a diagram of an energy pyramid, read a short passage, and analyze a data table using a pencil. You do **not** need a computer, a lab, or any materials besides this packet and a pencil. There are **no hazards** — nothing is measured, mixed, or built. Work by yourself and do your best thinking. You will do some arithmetic with the "10% rule"; the numbers are chosen so you can do them by hand. Write in complete sentences where you are asked to explain. If a question is hard, skip it, keep going, and come back. Reading the passage quietly aloud to yourself is allowed and encouraged.

START

Notice & Wonder

5 min

Think about how many of each kind of living thing you would find in a field: grasses, insects that eat the grass, and hawks that eat other animals.

1 In almost every ecosystem there are a huge number of plants, far fewer plant-eaters, and only a small number of top predators such as hawks or wolves. Write one thing you notice and one thing you wonder about why there are so few top predators compared with plants.

2 Where do you think the energy in a grassland originally comes from, and what do you think happens to most of it as it moves from grass, to grasshoppers, to the animals that eat grasshoppers? Give your best first idea.

Trophic levels, energy pyramids, and the ~10% rule

Energy enters most ecosystems as sunlight. **Producers** (green plants, algae, and some bacteria) capture that energy through **photosynthesis** and store it as chemical energy in food. Every other organism gets its energy by eating. A **trophic level** is a feeding position in a food chain — a step that describes where an organism gets its energy.

- **Producers (1st trophic level)** — make their own food from sunlight. Also called autotrophs.
- **Primary consumers (2nd level)** — **herbivores** that eat producers (for example, a grasshopper eating grass).
- **Secondary consumers (3rd level)** — **carnivores** (or omnivores) that eat primary consumers (a shrew eating a grasshopper).
- **Tertiary consumers (4th level)** — carnivores that eat secondary consumers (a snake eating a shrew). Higher levels (quaternary, etc.) may follow.
- **Decomposers** — bacteria and fungi that break down dead organisms and wastes at every level, returning **matter** (nutrients) to the soil so producers can reuse it.

An **energy pyramid** is a diagram that shows the amount of energy (in kilocalories, kcal) available at each trophic level. It is widest at the bottom (producers) and narrows toward the top, because **energy is lost at every step**.

The ~10% rule: when energy passes from one trophic level to the next, only about 10% is stored in the next level and becomes available to the organisms above it. The other ~90% is lost — used for the organism's own life processes (movement, growth, keeping warm) and released to the surroundings as heat. That lost energy is *not* recycled back up the pyramid. Because so little energy reaches the top, top-level consumers must be few in number.

Matter vs. energy: matter (atoms and nutrients) *cycles* and is reused thanks to decomposers, but energy flows one way — in as sunlight, out as heat — and must be constantly resupplied by the Sun.

Word Bank

producer	an organism that makes its own food from sunlight (autotroph); the 1st trophic level.
consumer	an organism that gets energy by eating other organisms (heterotroph).
decomposer	bacteria/fungi that break down dead matter and return nutrients to the soil.
trophic level	a feeding step in a food chain that shows where an organism gets its energy.
energy pyramid	a diagram of the energy (kcal) available at each trophic level.
10% rule	about 10% of the energy at one level is passed to the next; ~90% is lost as heat.

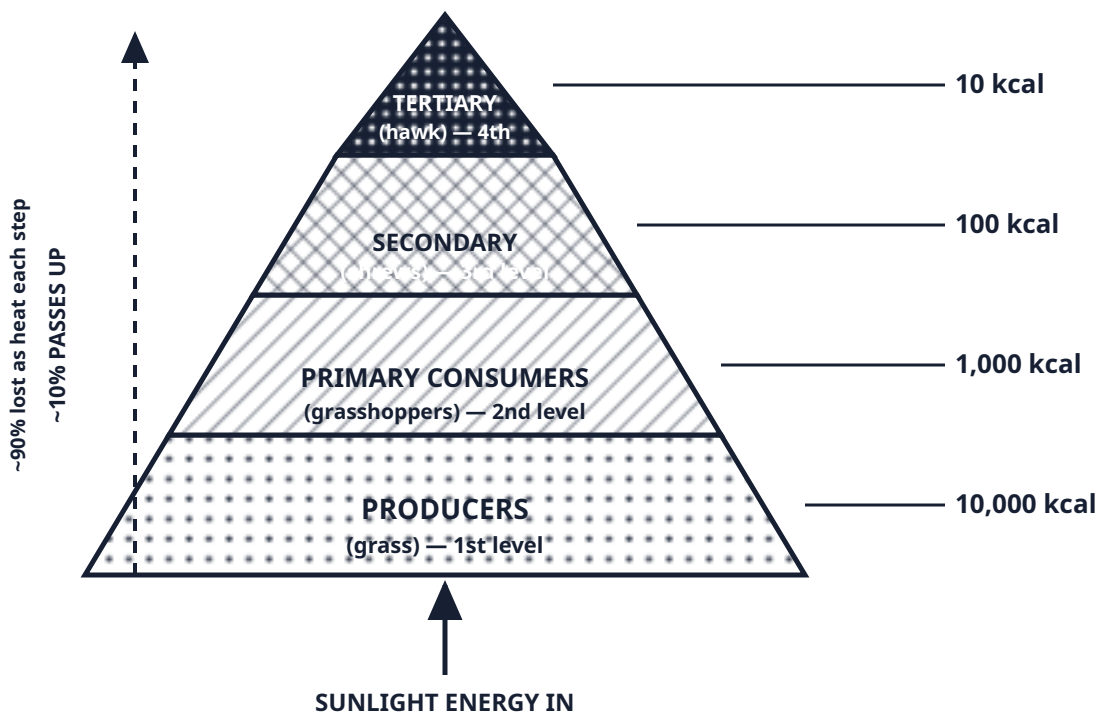


Figure 1. Energy pyramid for a grassland ecosystem. Each band is a trophic level; its width and the value on the right show the energy (kcal) available there. Moving up, each level holds about one tenth of the level below it (the ~10% rule); the dashed arrow marks the ~90% lost as heat at each step. Patterns and labels — not color — carry the meaning, so the figure reads clearly in grayscale.

3 Using Figure 1, name the trophic level that has the most energy available and the one that has the least. In one sentence, explain why the pyramid narrows as you go up.

Table 1 gives the energy measured at each trophic level of the same grassland, plus a list of organisms to classify. Study it, then answer. (These are original numbers for this packet.)

Table 1. Energy available at each trophic level of a grassland ecosystem, in kilocalories per square meter per year (original data).

Trophic level	Example organism	Energy available (kcal/m ² /yr)
1 — Producers	Grass	10,000
2 — Primary consumers	Grasshoppers	1,000
3 — Secondary consumers	Shrews	100
4 — Tertiary consumers	Hawk	10

4 Classify the organisms. For each organism below, write its trophic level number and its role (producer, primary consumer, secondary consumer, tertiary consumer, or decomposer). Use the grassland food chain grass → grasshopper → shrew → hawk, plus soil fungi.

a) Grass _____

b) Grasshopper _____

c) Hawk _____

d) Soil fungi _____

5 Calculate energy passed with the 10% rule. Show your work. Using the 10% rule, about 10% of the energy at one level is passed to the next.

5a. The producers hold 10,000 kcal. About how much energy is passed up to the primary consumers (grasshoppers)? Show $10,000 \times 0.10$.

5b. About how much energy is passed from the primary consumers up to the secondary consumers (shrews)? Show your work.

5c. Compare your answers with the "Energy available" column in Table 1. Do your calculated values match the table? What does that tell you about this ecosystem?

6 Percent transfer. The hawk (tertiary consumer) has 10 kcal available and the shrews (secondary consumers) below it have 100 kcal. Calculate the percent of energy transferred from the shrews to the hawk. Show the formula (energy passed $\div$ energy in lower level $\times$ 100) and your work.

7 Observation vs. inference. Write O if the statement is an observation (a value read directly from Table 1 or Figure 1) or I if it is an inference (a conclusion you reason out).

- ___ a) The producers have 10,000 kcal available.
- ___ b) There can only be a few hawks in this grassland because so little energy reaches the top.
- ___ c) The hawk level has 10 kcal available.
- ___ d) Most of the energy at each level was lost as heat before reaching the next level.

8 Interpret the pyramid shape. In 2–3 sentences, explain what the shape of the energy pyramid (wide bottom, narrow top) tells you about how energy moves through the ecosystem. Use the words trophic level and 10% rule.

9 Predict the effect of removing a trophic level. Suppose a disease kills off almost all the grasshoppers (the primary consumers). Predict what would happen to (a) the grass and (b) the hawks, and explain why using energy flow.

Question 10. A student claims, "Top-level consumers such as hawks are limited in number because of how energy flows through the ecosystem." Using the energy data in Table 1 and Figure 1, write a **claim** answering *why top-level consumers are limited*, support it with **two pieces of evidence** (specific numbers from Table 1 or Figure 1), then explain your **reasoning** using trophic levels and the 10% rule.

Sentence stems you may use: "Top-level consumers are limited because..." · "One piece of evidence is... (from Table 1 / Figure 1)." · "A second piece of evidence is..." · "This limits top consumers because the 10% rule says..."

CLAIM

EVIDENCE (TWO PIECES, WITH NUMBERS)

REASONING

ARTICULATE

Explain the **10% rule** in your own words, as if teaching a friend.

CONNECT

Point to one row of Table 1 or one band of Figure 1 that shows the 10% rule in action. Name the numbers.

EXTEND

Give a **new** example of a food chain (not grassland) and label at least three of its trophic levels.

CONTINUE Early Finisher & Block Extension

optional • block ~+30 min

If you finish early (no new materials needed):

Design a pyramid for a new ecosystem. On the back of this page, invent a food chain for a different ecosystem (for example an ocean, a desert, or a pond). Draw a four-level energy pyramid, label each trophic level with a real organism, and — starting from a producer level of your choice — use the **10% rule** to fill in a reasonable energy value (kcal) for each level. Then write one sentence about what would happen if the top level disappeared.

Block-period extension — multi-step energy-loss chain:

A separate ocean food chain starts with **phytoplankton producers holding 50,000 kcal**. Using the 10% rule at every step, calculate the energy available at each level up the chain: **phytoplankton** → **zooplankton** → **small fish** → **tuna** → **shark** (five levels). Show your work for each step. Then answer: what percent of the *original* producer energy reaches the shark? Explain, using the 10% rule, why very large top predators like sharks need such an enormous area of ocean to survive.

Turn in:

Hand in this whole packet with your name, class period, and date filled in. Make sure questions 1–10 and the ACE box are answered. The early-finisher pyramid and the block-period energy chain are optional but turn them in too if you did them.



TEACHER ANSWER KEY FOLLOWS

Do not copy the pages after this divider for students.

Answer Key: Energy Flow in Ecosystems

Course: Biology (Grades 9–12) Subject: Science For teacher use only

SCIENCE

How to use this key

Answers are grouped by section and question number. Many items are open-ended; accept any response that shows correct reasoning even if the wording differs. The energy calculations are worked out in full. Notes flag where more than one answer is defensible and list common misconceptions to watch for. Estimated grading time: ~6–8 min per packet.

START Notice & Wonder

grade for effort • ~2 min

- 1 Why are there so few top predators compared with plants?

Full credit for any reasonable notice + wonder. Ideal: Notice — "there are way more plants than hawks." Wonder — "why can't the land support as many hawks as grasshoppers?" Accept any on-topic wonder. *Science note (not required from students):* so little energy reaches the top trophic level (the 10% rule) that only a few top predators can be supported.

- 2 Where the energy comes from; what happens as it moves up.

Accept any reasonable prior idea. Target ideas: the energy originally comes from the Sun (captured by producers in photosynthesis); as it moves up, most of it is lost (as heat / used for life processes), so less is available at each higher level. Do not penalize incomplete prior knowledge here — this is a warm-up.

BUILD Read the Science

~1 min

- 3 Most/least energy; why the pyramid narrows.

Most energy: producers (grass), 10,000 kcal — the bottom level. **Least energy:** tertiary consumers (hawk), 10 kcal — the top level. **Why it narrows:** only about 10% of the energy at each trophic level is passed to the next; the rest (~90%) is lost as heat, so less energy is available at each step upward.

4 Classify the organisms.

- a) Grass — trophic level 1, producer (autotroph).
- b) Grasshopper — trophic level 2, primary consumer (herbivore).
- c) Hawk — trophic level 4, tertiary consumer (top carnivore).
- d) Soil fungi — decomposer (breaks down dead matter; acts on every level, so no single trophic-level number is required — accept "decomposer, not a numbered feeding level").

5 Calculate energy passed with the 10% rule (worked).

- 5a. $10,000 \text{ kcal} \times 0.10 = 1,000 \text{ kcal}$ passed to the primary consumers.
- 5b. $1,000 \text{ kcal} \times 0.10 = 100 \text{ kcal}$ passed to the secondary consumers.
- 5c. Yes — the calculated values (1,000 and 100 kcal) match Table 1. This tells students that this ecosystem follows the ~10% rule closely: each level holds about one tenth of the level below it. (Accept any answer noting the match and that ~90% is lost at each step.)

6 Percent transfer, shrews → hawk (worked).

Formula: percent transfer = (energy in higher level ÷ energy in lower level) × 100.
 $= (10 \text{ kcal} \div 100 \text{ kcal}) \times 100 = 0.10 \times 100 = 10\%$. This is consistent with the 10% rule. (Full credit for correct setup and 10%; accept "about 10%.")

7 Observation (O) vs. Inference (I).

- a) O — a value read directly (10,000 kcal).
 - b) I — a reasoned conclusion ("can only be a few hawks because...").
 - c) O — a value read directly (10 kcal).
 - d) I — a conclusion reasoned from the pattern (energy lost as heat is not shown as a single measured value; it is inferred from the drop between levels).
- Observation = measured/read directly; inference = a conclusion reasoned from evidence.*

8 Interpret the pyramid shape.

Full credit if the student ties the wide-bottom, narrow-top shape to energy loss between trophic levels via the 10% rule. Model: "The pyramid is wide at the bottom and narrow at the top because each trophic level only passes about 10% of its energy to the next (the 10% rule). Since ~90% is lost as heat at each step, far less energy is available higher up, so the top levels are small." Accept equivalent wording.

9 Predict the effect of removing a trophic level (grasshoppers).

(a) Grass: would likely increase / grow more at first, because far fewer grasshoppers are eating it.

(b) Hawks: would decline — with fewer grasshoppers, the shrews (secondary consumers) lose their food and decrease, so the energy reaching the hawks drops and their numbers fall.

Why: energy flows upward through the food chain; removing the primary consumers cuts the pathway that carries energy from producers to the higher levels. *Defensible alternate:* a student may note shrews could switch to other prey if available; accept if reasoned. Direction (grass up, hawks down) plus an energy-flow justification earns full credit.

10 Why are top-level consumers limited?

Model answer. Claim: Top-level consumers such as hawks are limited in number because only a tiny fraction of the ecosystem's energy reaches the top trophic level. **Evidence:** (1) In Table 1, producers have 10,000 kcal but the hawk level has only 10 kcal — 1,000 times less. (2) In Figure 1, each band holds about one tenth of the level below it (10,000 → 1,000 → 100 → 10 kcal). **Reasoning:** By the 10% rule, only ~10% of the energy at each trophic level passes to the next; the other ~90% is lost as heat. After three transfers only about 0.1% of the producers' energy remains, so there is enough energy to support only a few top consumers.

Defensible alternates: A student may cite the percent-transfer calculation from Q6 (10%) or the shape of the pyramid as evidence. Accept any claim supported by two correct numeric pieces of evidence and sound 10%-rule reasoning.

CER scoring rubric (3 points)

Score	Claim	Evidence	Reasoning
3	Clear claim: top consumers are limited by energy available at the top level.	Two accurate numeric pieces from Table 1 and/or Figure 1 (e.g., 10,000 vs. 10 kcal).	Correctly uses the 10% rule / trophic levels to explain why so little energy reaches the top.
2	Claim stated, mostly clear.	One solid numeric piece, or two with a minor error.	Some correct linkage but incomplete or a small misconception.
1	Vague or partly correct claim.	Evidence weak, non-numeric, or not from the sources.	Little or flawed reasoning; 10% rule not correctly applied.
0	No/incorrect claim.	No evidence.	No reasoning.

ACE Articulate / Connect / Extend.

Articulate: accept any accurate plain-language statement (e.g., "only about a tenth of the energy at one level gets to the next; the rest is lost as heat").

Connect: the cited pair must show a 10× drop, e.g., producers 10,000 → primary consumers 1,000 kcal, or 100 → 10 kcal.

Extend: any correct non-grassland food chain with ≥ 3 labeled trophic levels (e.g., algae → minnow → bass → osprey; or leaves → caterpillar → songbird → hawk). More than one answer is defensible.

EXTEND Early finisher & block extension (optional)

EF Design a pyramid for a new ecosystem.

Reward a coherent four-level pyramid with a real producer at the base, plausible organisms at each level, and energy values that drop by $\sim 10\times$ per step (any reasonable producer starting value). The "what if the top disappeared" sentence should note the level below would increase and/or the chain above collapses.

Block Multi-step ocean energy-loss chain (worked).

Starting producers (phytoplankton) = 50,000 kcal. Apply $\times 0.10$ each step:

- Phytoplankton (producer): 50,000 kcal
- Zooplankton (primary consumer): $50,000 \times 0.10 = 5,000$ kcal
- Small fish (secondary consumer): $5,000 \times 0.10 = 500$ kcal
- Tuna (tertiary consumer): $500 \times 0.10 = 50$ kcal
- Shark (quaternary consumer): $50 \times 0.10 = 5$ kcal

Percent of original energy reaching the shark = $5 \div 50,000 \times 100 = 0.01\%$. Why sharks need a huge area: only one ten-thousandth of the producers' energy survives four transfers, so an enormous amount of phytoplankton (and ocean area) is needed to supply enough energy for even a small number of large top predators. (Full credit for correct chained multiplications and 0.01%.)

- **"Energy is recycled like matter."** *Matter* (nutrients/atoms) cycles and is reused by decomposers, but **energy flows one way** — in as sunlight, out as heat. Lost energy is not passed back up the pyramid.
- **"100% (or most) of the energy transfers to the next level."** Only about **10%** is passed on; ~90% is lost as heat and to life processes. Watch for students who multiply by the wrong factor in Q5–Q6.
- **"Bigger animals have more energy available to them."** The opposite is true: top predators sit at the *highest* trophic level, where the *least* energy is available. Their large size does not increase the energy reaching them — it is why so few can be supported.
- **"Decomposers are the top of the pyramid."** Decomposers act on every level and return matter to the soil; they are not a higher feeding step above the top predator.
- **Observation vs. inference (Q7).** Students often mark a reasoned cause or consequence ("can only be a few hawks because...") as an "observation." A "because..." or "would be..." statement is usually an inference.

Teacher follow-up based on likely errors

If many students say energy is recycled (misconception), contrast the one-way energy arrow with the matter cycle in a quick 5-minute discussion. If the 10% calculations in Q5–Q6 are shaky, model $\times 0.10$ (or $\div 10$) aloud with units. If Q9 (removing a level) is thin, re-anchor to the upward energy arrows in Figure 1. If CER (Q10) evidence is non-numeric, model citing the 10,000-vs-10-kcal contrast. The "energy is recycled" and "bigger = more energy" misconceptions are the highest-value items to address next class.