

Follow the Energy: A Twelve-Card Jigsaw Across Earth's Systems

Learning target: I can work with a team to trace the energy behind twelve real events to its source, name the chain of transfers it used, identify which Earth systems it crossed, and defend our map to another group.

Collaborative investigation

About 50 min

Jigsaw

MS-ESS2-1 · practice

MS-ESS2-6 · supports

MS-LS2-3 · supports

collaboration

discussion

visual modeling

Standards connections

MS-ESS2-1 (practice, the flow-of-energy half of the PE): Four of the cards trace energy from Earth's interior through conduction and convection to moving rock and magma; sorting and defending them builds the energy-flow side of the model this PE asks for.

MS-ESS2-6 (supports): The sea-breeze, sinking polar water and thunderstorm cards are examples of circulation driven by unequal heating, the subject of this Grade 6 PE in the California sequence. They are used here only as examples of convection, not to assess circulation patterns.

MS-LS2-3 (supports): The kelp, compost and plankton cards show sunlight entering living systems and leaving as heat, which is background for this PE's model of energy flow in ecosystems.

Purpose: practice · **Time:** about 50 minutes · **Format:** jigsaw

Answers with reasoning

Twelve event cards (all real events, described in our own words)

1 Card 1: Geyser, Iceland

Every few minutes a geyser hurls boiling water and steam many meters into the air. Rain and snowmelt seep down through cracks, meet rock that is hot from below, boil, and burst back out. Set A.

2 Card 2: Sea breeze, California coast

On a sunny afternoon the beach sand gets much hotter than the sea. Air over the land warms and rises, and cooler air from over the water slides in to replace it. Surfers feel a steady onshore wind by mid-afternoon. Set A.

3 Card 3: Kelp forest, Monterey Bay

Giant kelp grows up to tens of centimeters a day in sunlit water. Sea urchins eat the kelp, sea otters eat the urchins, and all of them lose energy as heat to the water around them. Set A.

4 Card 4: Lava flow, Hawaii

Molten rock rises through the crust and pours out onto the surface, where it cools and hardens into new rock. The magma rose because it was less dense than the solid rock around it, and it was hot because of energy from deep inside Earth. Set B.

5 Card 5: Sinking water, Southern Ocean

Near Antarctica the surface water loses energy to the cold air, and when sea ice forms it leaves its salt behind. The cold, salty water is denser than the water below it and sinks to the sea floor, then creeps slowly north. Set B.

6 Card 6: Steaming compost pile, a school garden

On a frosty morning the compost pile steams. Inside, bacteria and fungi break down leaves and scraps, and the energy they release warms the pile and the air above it. The energy in those leaves was captured from sunlight by plants last summer. Set B.

7 Card 7: Deep mine, South Africa

In the deepest gold mines, about 3 to 4 km down, the rock walls are tens of degrees hotter than the surface, and powerful cooling systems are needed so miners can work. The rock is warmed by energy moving outward from Earth's interior through solid rock. Set C.

8 Card 8: Thunderstorm, Great Plains

On a hot afternoon, warm, moist air near the ground rises in a tall column. High up the air cools, its vapor turns back into droplets that form a cloud, and gravity pulls the rain back down. Set C.

9 Card 9: Hawks on a thermal, California foothills

Hawks circle upward for hundreds of meters without flapping, riding a column of warm air. The sun heated a dark hillside, the hillside warmed the air touching it, and that air rose. Set C.

10 Card 10: Drifting continents, measured by satellites

Satellite tracking shows that continents move a few centimeters each year, about as fast as fingernails grow. They ride on slowly creeping mantle rock that is warmed from below and cooled from above. Set D.

11 Card 11: Melting glacier, Sierra Nevada

In summer, sunlight melts the surface of a mountain glacier. Meltwater runs into streams, carrying ground-up rock flour that turns the water milky, and the streams feed rivers far downhill. Set D.

12 Card 12: Spring plankton bloom, North Pacific

As days lengthen in spring, tiny floating algae near the ocean surface multiply so fast that the water turns green in satellite images. Tiny animals eat the algae, fish eat the animals, and some of the dead material sinks to the deep sea. Set D.

Part A: Expert round (one set per person)

1. Your expert set: _____. For each of your three cards, write (a) the energy source: *sun* or *Earth's interior*, (b) the chain of transfer methods in order (radiation, conduction, convection), and (c) one piece of matter that moves.

Answer: Set A: 1 geyser, interior, conduction (rock to water) → convection (boiling water rises), matter: water. 2 sea breeze, sun, radiation → conduction (sand to air) → convection, matter: air. 3 kelp, sun, radiation (captured by kelp), then energy passes through eating and leaves as heat, matter: kelp, urchins, otters. Set B: 4 lava, interior, conduction (core to mantle) → convection (less dense rock and magma rise), matter: rock and magma. 5 sinking water, sun (unequal heating) with energy lost by conduction to cold air, then convection, matter: salty water. 6 compost, sun (stored in leaves), decomposition releases heat → conduction and convection of warm air, matter: leaves, air. Set C: 7 deep mine, interior, conduction through solid rock, matter: none moving in the card (energy only). 8 thunderstorm, sun, radiation → conduction → convection, matter: moist air and rain. 9 hawks, sun, radiation → conduction → convection, matter: air. Set D: 10 continents, interior, conduction → convection (mantle creep), matter: mantle rock and continents. 11 glacier, sun, radiation, then flowing meltwater carries rock flour, matter: water and rock. 12 plankton, sun, radiation captured by algae, energy passes by eating, matter: algae, animals, sinking debris.

Why: Each set contains one interior card (1, 4, 7, 10), one physical sun card and one living-system sun card, so every expert sees the full range. The deep mine card deliberately shows energy moving by conduction without matter moving.

Also acceptable: Accept radiation as the first step for interior cards only if the student explains that heat leaving the surface is radiated; otherwise the first step is conduction.

- Correct source for all three cards
- A plausible chain in order
- A moving matter named (or 'none' for card 7)

Part B: Home group task

1. Lay out all twelve cards. First sort them into two piles by energy source: the sun, or Earth's interior. Experts must justify any card that another member doubts.
2. For each card, agree on the chain of transfers. Write it as arrows, for example 'radiation → conduction → convection.' Most cards use two or three methods, in order.
3. For each card, list every Earth system involved (geosphere, hydrosphere, atmosphere, biosphere) and the matter that moves. Mark with a star every card in which matter crosses from one system into another.
4. Record everything in the group energy map table.
5. Find the card that was the hardest to place and write one sentence explaining the group's final decision.
6. Prepare a one-minute defense of your map. Every member must be able to explain any card, not just their own set.

Group energy map (fill in)

Card	Energy source	Chain of transfers	Systems involved	Matter that moves	Crosses systems? (star)
1 Geyser					

Card	Energy source	Chain of transfers	Systems involved	Matter that moves	Crosses systems? (star)
2 Sea breeze					
3 Kelp forest					
4 Lava flow					
5 Sinking water					
6 Compost pile					
7 Deep mine					
8 Thunderstorm					
9 Hawks on a thermal					
10 Drifting continents					
11 Melting glacier					
12 Plankton bloom					

2. Group answer: Which card was hardest to place by energy source, and what settled it?

Answer: Most groups find card 6 (compost) or card 5 (sinking water) hardest. Compost: the pile is warm at night with no sunlight, but the energy was captured from the sun by plants and stored in the leaves; the decomposers are releasing stored sunlight. Sinking water: the water is losing energy, not gaining it, but the pattern exists because the sun heats the tropics more than the poles, so the source is still the sun. Card 1 (geyser) can also cause debate because the water came from rain (sun) while the heat came from below (interior); the energy that makes it erupt is the interior's.

Why: The sheet is designed so that two or three cards require backward tracing; the quality of the explanation matters more than which card is chosen.

Also acceptable: Any card with a sound explanation of what settled it earns credit.

- A specific card named
- The deciding reasoning traces energy back to a source

3. Group answer: Write the challenge the neighboring group made to your map and how you answered it with evidence from the card.

Answer: Typical challenges and good replies: 'Card 5 has no heating, so why is it the sun?' (the loop exists only because the sun heats the equator more than the poles; the polar water is the cooling half of a sun-driven loop). 'Card 1 uses rainwater, so part of it is the sun' (true for the water's journey, but the energy that boils it is from hot rock, so the eruption's source is the interior). 'Card 7 has no convection' (correct; in solid rock near a mine the energy moves by conduction, which is why it is on the card).

Why: Look for a real challenge and a reply that cites the card's wording.

Also acceptable: Any reasonable challenge and evidence-based reply.

- A specific challenge recorded
- Reply uses evidence from the card

Part C: Individual accountability (complete alone)

4. Choose one card from a set that was **not** yours. Trace its energy from the source to the end of the card's story, naming the transfer method at each step and the system the energy is in at each step.

Answer: Example for card 8 (thunderstorm): sunlight crosses space by radiation and is absorbed by the ground (geosphere); the ground warms the air touching it by conduction (atmosphere); the warm, moist air becomes less dense and rises by convection, carrying water vapor from the hydrosphere; high up the air loses energy, the vapor condenses into droplets (energy released to the air), and gravity pulls the rain down into the hydrosphere and onto the geosphere. Any card traced with correct methods and systems at each step earns full credit.

Why: The point is that the student can reproduce the reasoning for a card they did not study, not just repeat their expert set.

Also acceptable: A student who adds the heat released by condensation is going beyond the lesson accurately.

- Card is from another set
- Transfer method named at each step
- System named at each step

5. Every card powered by Earth's interior involves the geosphere, while the sun-powered cards are spread across all four systems. Explain why, using where each source's energy enters Earth's systems.

Answer: The interior's energy enters Earth's systems from below, through the rock of the geosphere, and it has to pass through rock before it can reach water, air or life; so every interior card starts in the geosphere. The sun's energy arrives from above as radiation and lands on whatever is at the surface: sea, land, air or a leaf, so it can enter any system directly.

Why: This connects the energy-source idea to the geometry of where each source's energy enters.

Also acceptable: Accept 'the interior is under the geosphere, the sun is above everything.'

- Interior energy enters through rock from below
- Solar energy lands on the surface of any system

6. The compost pile (card 6) was warm on a frosty morning with no sunlight on it. Explain why its energy source is still the sun, and what happened to that energy between last summer and this morning.

Answer: Last summer plants captured sunlight and stored its energy in the leaves (in the plants' food). The leaves died and were added to the pile. Bacteria and fungi are now breaking down that stored food to get energy, and some of that energy leaves them as heat, warming the pile. So the pile's energy is sunlight that spent months stored in plant matter; the sun is still the source even though no sunlight is hitting the pile this morning.

Why: Tracing energy backward through storage is the key skill; it also previews the idea that energy flows through living things and leaves as heat.

Also acceptable: Accept 'the decomposers are eating old sunlight.'

- Energy was captured by plants from sunlight
- Stored in plant matter
- Released as heat by decomposers

7. A thirteenth card arrives: 'Tides: twice a day the sea rises and falls along the whole California coast, and the moving water stirs the deep ocean.' Decide whether it belongs in the sun pile, the interior pile, or neither, and explain your reasoning. What does this card tell you about the lesson's statement that all of Earth's energy comes from the sun or Earth's interior?

Answer: Model response: Neither pile. The tides are raised by the Moon's gravity (and the sun's, to a lesser extent) pulling on the oceans as Earth turns; the energy that stirs the deep ocean comes from Earth's rotation and the Moon's pull, not from sunlight or from Earth's hot interior. This shows that the lesson's statement is a simplification: the sun and the interior are by far the two main sources, but tidal energy is a real third source, much smaller than the sun but important for mixing the deep ocean. A careful scientist would say 'almost all' rather than 'all.'

Why: Students should recognize a case the two-bin model cannot hold and conclude that the statement is nearly, not completely, true. The Moon's role in tides is prior knowledge for most students; if not, the card's wording ('twice a day,' 'the whole coast') should prompt it.

Also acceptable: A student who puts it in the sun pile because 'the sun also pulls on the oceans' has part of the truth; award credit if the Moon is named as the main cause.

- Places the card in neither pile
- Names the Moon's gravity (or Earth's rotation) as the source
- Concludes the lesson's statement is a simplification

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Expert round (Part A)	All three cards have the correct source, an ordered chain of transfers and a moving matter; the expert can explain each to the home group without notes.	Three correct sources; one chain out of order or missing a step.	One source wrong, or chains listed as a single method.	Part A incomplete or copied from another expert without understanding.
Energy map (Part B)	All twelve cards correctly sourced; chains and systems accurate; every card where matter crosses systems is starred; the hardest card has a written decision.	Ten or eleven cards correct; one or two chains incomplete; stars mostly right.	Several cards sourced by surface features (hot means interior, cold means sun) rather than by tracing energy; stars missing.	Map mostly blank or sorted without reasons.
Defense (Step 3 and q3)	Any member can defend any card; the challenge is recorded and answered with the card's own evidence.	Defense given by one or two members; the reply is correct but does not cite the card.	Defense restates the map without reasons.	No defense or challenge recorded.
Individual accountability (Part C)	All four Part C answers accurate, trace energy step by step, and recognize the tides as a third source.	Three of four accurate; one thin or partly incorrect.	Two accurate; others restate the group map without reasoning.	Part C mostly blank or inaccurate.

Teacher notes

All twelve events are real and described in our own words: Iceland's geysers erupt every few minutes; sea breezes form on sunny California afternoons; Monterey Bay's giant kelp can grow tens of centimeters a day; Hawaiian lava rises because magma is less dense than surrounding rock; Antarctic Bottom Water forms as cold, salty water sinks; compost piles heat up from microbial decomposition; the deepest South African gold mines (about 3 to 4 km) need cooling because rock temperature rises with depth; thunderstorms are convection; hawks ride thermals; satellites measure plate motion of a few centimeters per year; Sierra glaciers release rock flour into streams; the North Pacific has spring plankton blooms. Shuffle each deck before handing it out. The tides card (q7) is the lesson's hedge: tidal energy from the Moon is a real third, smaller source, so the Key Science Concept's 'all the energy' is a simplification; record this in accuracyNotes. Card 7 is the only card in which no matter moves, which makes it the cleanest example of conduction.

Scaffold offered to students: Trace backward, not forward

To find a card's energy source, start at the end of the story and ask 'where did that energy come from?' until you reach either sunlight or Earth's hot interior. For the kelp card: otters got energy from urchins, urchins from kelp, kelp from sunlight; source: sun. For the geyser: the water got energy from the rock, the rock from the rock below it, and so on down to the interior; source: Earth's interior. Then read the story forward to list the transfer methods in order.

Extension: The card that crosses twice

Card 11 (the melting glacier) carries matter from the hydrosphere into the geosphere and back: ice melts, the water picks up rock flour, and the rock flour settles in a lake downstream. Write a fourteenth card about one real California event in which matter crosses between at least three Earth systems in a single story, powered by one source. Then explain which transfer method appears in the most cards on the table and why that method shows up in so many different systems.