

Earth's Energy Ledger

Use energy flows to explain climate changes.

HS-ESS2-4 "Use a model to describe how variations in the flow of energy into and out of Earth systems result in changes in climate.

Clarification Statement: Examples of the causes of climate change differ by timescale..."

NAME _____

DATE _____

1 READ AND MARK _____ Read it twice

YOUR JOB Underline the rule for energy imbalance. Circle the timescales and identify which energy flow each cause changes.

An energy-budget model

- ① Our simplified whole-Earth model tracks energy over equal time intervals. In its starting balance, 100 energy units arrive as sunlight, 30 are reflected to space and 70 are absorbed by Earth. Earth emits 70 units of infrared energy to space. Stored-energy change equals absorbed sunlight minus outgoing infrared. Positive change tends to warm Earth; negative change tends to cool it. These are illustrative units, not current measurements. The boundary includes the surface and atmosphere together.
- ② An increase in greenhouse gases can initially reduce infrared loss to space while sunlight stays unchanged. Energy then accumulates; as Earth warms, infrared emission increases toward a new balance. Human-caused composition changes act over decades to centuries. Large volcanic eruptions can increase reflected sunlight for a few years, reducing absorption. Ocean circulation redistributes stored heat across regions and between ocean and atmosphere; it does not create energy. Its climate effects can last from years to centuries.
- ③ Orbit and axis changes alter the seasonal and geographic distribution of sunlight over tens to hundreds of thousands of years. Long-term atmospheric composition changes can affect climate over tens to hundreds of millions of years. The same global energy total can be distributed differently, so our simple model cannot locate regional rainfall changes. More warming can reduce land ice and raise sea level; a specific local outcome needs a more detailed model. In solar-input examples below, assume the reflected fraction stays at 30 percent.

2 ANSWER WITH EVIDENCE _____ Use the passage

- 1** A volcanic scenario reflects 35 of the 100 incoming units while infrared loss is initially 70. Use the model to calculate stored-energy change and predict a temperature trend.

- 2** Why does reduced infrared loss after a greenhouse-gas increase cause initial warming? Why need the imbalance not stay the same forever?

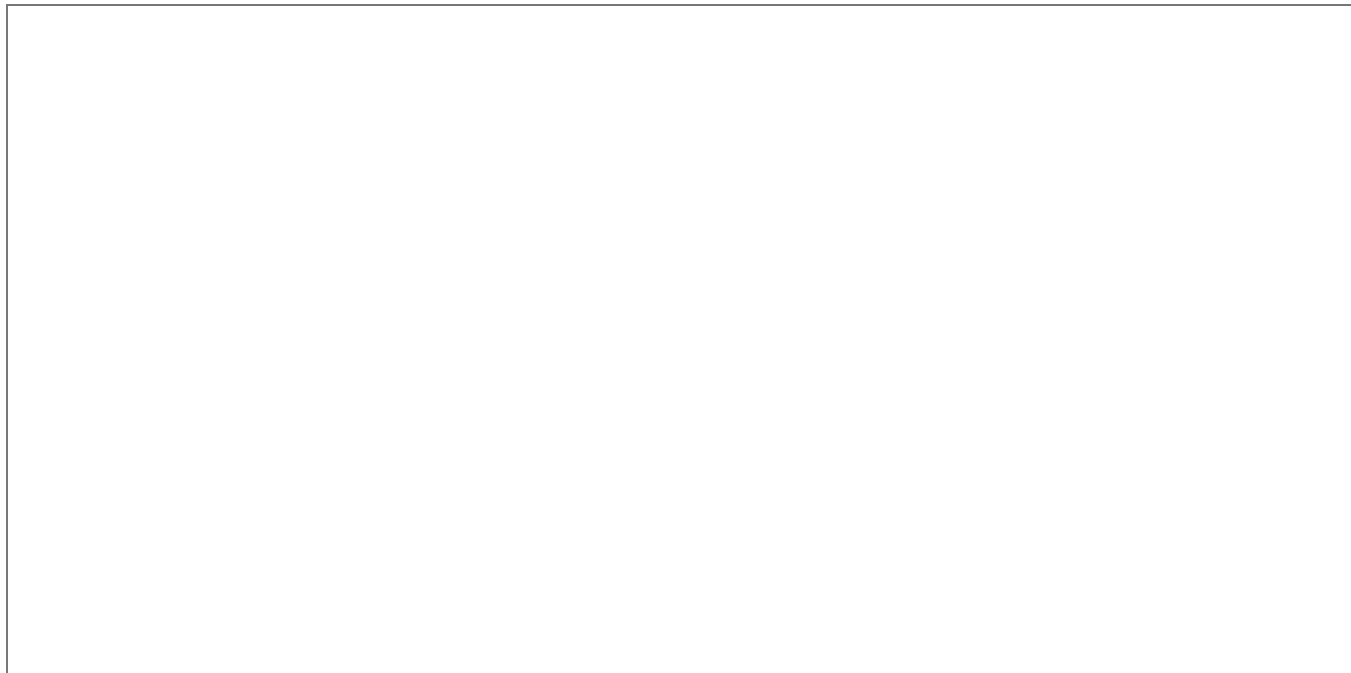
- 3** Contrast an orbit change with an ocean-circulation change: give the relevant timescale and explain why a single global total cannot predict each regional result.

3 YOUR TURN _____ Your own words

Build and use your own energy-flow model for a sustained solar-input increase. Use the blank canvas for the arrows and the ruled space for your explanation.

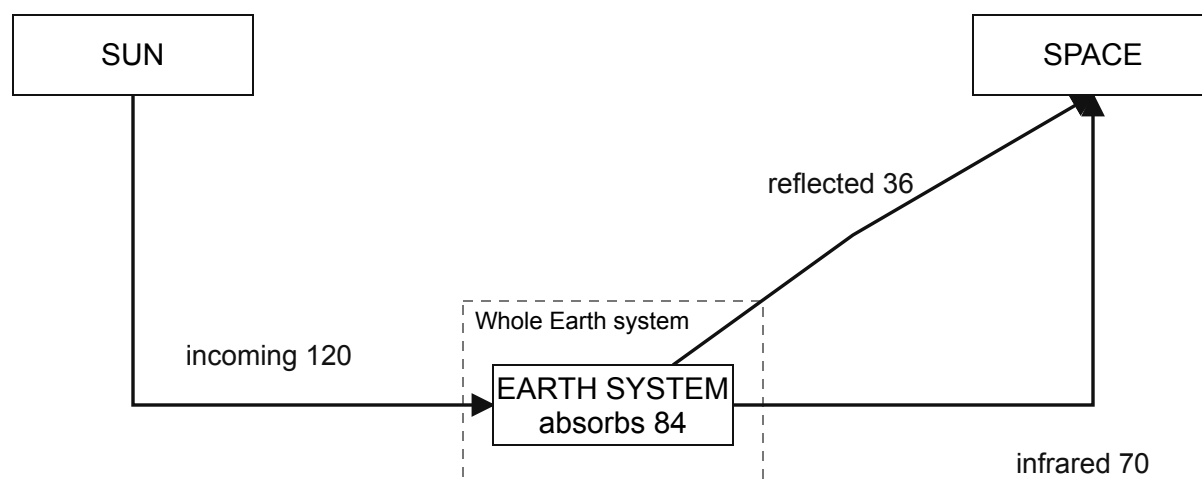
Solar input: 120 units per interval

Draw the Sun, an Earth-plus-atmosphere system boundary, and space. Show incoming sunlight of 120 units, the reflected amount, the absorbed amount inside Earth and initially outgoing infrared of 70 units. Label every arrow and state the common time interval. Then calculate the stored-energy change.



Explain the temperature trend and the outgoing infrared needed for a new balance. Name one climate result the model cannot locate or quantify.

Solar input: 120 units per interval · example model



Arrows show the initial changed state. Of 120 incoming units, 36 return as reflected sunlight and 84 are absorbed. Infrared loss initially stays at 70, leaving +14 units per interval in the Earth system. Warming increases emission; a new balance would require 84 outgoing units if absorption stays 84. The dashed boundary encloses Earth and its atmosphere; Sun and space are outside.

1. Absorption is $100 - 35 = 65$. Change is $65 - 70 = -5$ units per interval, so Earth tends to cool.
2. Absorption initially exceeds infrared loss, so energy accumulates. As Earth warms it emits more infrared energy; it can approach a new balance at a higher temperature.
3. Orbit/axis changes act over tens to hundreds of thousands of years and redistribute sunlight. Ocean circulation acts over years to centuries and redistributes stored heat. Regional and seasonal distribution is missing from a single global energy total.

PART 3 · YOUR TURN (SAMPLE ANSWER)

With 120 incoming units, 36 are reflected and 84 absorbed. Initially $84 - 70 = 14$ units accumulate each interval, so warming is expected. With the reflected fraction unchanged, outgoing infrared would have to reach 84 units per interval for a new balance; the simple model does not specify how many degrees of warming this requires.

Assess the model, calculation and explanation together. Incoming sunlight partitions into reflected and absorbed energy; do not add absorbed energy as a second external input. A new balance does not mean a return to the old temperature. This is a whole-Earth model, so internal surface-atmosphere exchanges are omitted. The illustrative solar change is a hypothetical scenario, not an estimate of recent solar variability. Scientific reference: NASA Climate and Earth's Energy Budget, science.nasa.gov/earth/earth-observatory/climate-and-earths-energy-budget/.