Earth's Energy Budget (1 of 4)

Energy that Earth receives from sunlight is balanced by an equal amount of energy radiating into space. **(Slide 1)**

Earth's Energy Budget: Part 1 - Sunlight (Slide 2)

A "parcel" is one percent of the total amount of energy that the sun sends to the earth on a typical day. (100 parcels are equal to 1.97 calories per square centimeter per day, or 342 watts per square meter every second, or 1231 kilowatts per square meter. It's easier to remember a nice round number like a hundred. **(Slide 3)**

Start with 100 parcels (100% of the solar energy) coming toward the earth from the sun.

Arrow already has 100 written on the diagram. **(Slide 4)**

1. The sunlight hits the atmosphere first before it can get to the ground. About 23 parcels bounce off the clouds and back to outer space. IMPORTANT: That's an average for the whole world – obviously, some places are cloudier than others. **(Slide 5)**

   Arrow B represents reflection from clouds. Write 23 on the line for that arrow.

2. More than half of the sunlight goes right through the air and down to the earth's surface. That's good; otherwise the earth where we live would be dark and cold! **(Slide 6)**

   What arrow on the diagram represents sunlight that reaches the ground? C
   Write 55 on that line.

3. That leaves about 22 parcels (100-23-55). That energy stays in the air – it makes the air warmer.

   Write +22 on the line inside the air symbol on the diagram. **(Slide 7)**

4. Some sunlight just bounces off the surface of the earth and goes back out to outer space. That is called reflection and it is not the same everywhere. More energy is reflected off a snowy surface; less from dark soil or dark-green trees. Measurements from satellites tell us that the average for the whole world is about 7 parcels. **(Slide 8)**

   What arrow on the diagram represents reflection from the earth surface? D
   Write 7 on the line next to that arrow.

   Dark soil and water reflect less energy than white clouds do. The arrow for reflection from the earth is therefore thinner than the arrow for reflection from clouds.

5. The rest of the sun's energy (after all this reflection) goes into the ground. Subtract 7 (for reflection) from the 55 parcels that came from the sun to the ground.

   What do you have left? 48 *Write that number on the line inside the earth symbol.*
   (Slide 9)

This is the energy that heats the surface of the earth (the ground and the water in oceans and lakes). **(Slide 10)** Some of this energy also makes plants grow. It's a very small amount, but it is important for life! (But over millions of years decaying plants and animals have produced fossil fuels, essentially storing that solar energy.)

Earth's Energy Budget: Part 2 – Surface Heat

Where does the solar energy absorbed by Earth and its atmosphere go? Exchanges go on in the system. When we move to the other side of the diagram, parcels are the same quantity of energy, but are heat, not light.

6. Now, let's look at the earth. Remember (from Part 1) the earth gets 48 parcels from the sun and 20 parcels from the air.
   Write 48 on line E. **(Slide 11)**

7. About 25 of those parcels are used to evaporate water – from oceans, lakes, rivers, soil, trees, grass, and even from your skin when you sweat. This energy then moves with the evaporated water up into the air, where it eventually becomes clouds.
   Write a 25 on arrow G to represent energy moving in evaporated water. **(Slide 12)**

8. 6 parcels heat the air near the ground. It's a small number, but it's important. Some of that air moves upward (because hot air rises). Some goes sideways, creating wind.
   What arrow represents energy moving from ground to the air? _F_
   Write a 6 on that arrow. (It should be the thinnest arrow you have labeled so far) **(Slide 13)**

9. The rest of the energy can't just stay in the earth. Every object that has heat must radiate some of it away. The earth radiates about 117 parcels. About 105 of those are absorbed by the air or clouds. The other 12 go on through the air to outer space.
   What arrow on the diagram represents radiation from the earth to the air? _H_
   Write a 105 on the line for that arrow. (The thickest arrow on the diagram)
   What arrow represents radiation from earth to outer space? _I_
   Write a 12 on that arrow. **(Slide 14)**

Questions 6-9 were about all the ways the earth sends energy away from the surface. If you add up these numbers, you might see a big problem. Every day, the earth gets 48 parcels from the sun, but it "sends away" a total of 148 parcels (25 by evaporation, 6 to the air, and 117 by radiation). In short, it sends away 100 parcels more than it gets from the sun. **(Slide 15)**

The atmosphere is the solution to the puzzle. If there were no atmosphere, the energy budget would be easy to calculate. The earth's surface would be colder. As a result, it would not have to radiate so much energy away. It would also not use any energy to evaporate water or heat air.

Unfortunately, a cold, waterless, airless planet would not have any life. You wouldn't be here!

In Part 3, we look at the atmosphere part of the system. That's the part that makes life possible on earth. Unfortunately, it is also the part that humans are altering, causing climate change.

Earth's Energy Budget: Part 3 – The Atmosphere

10. Now let's look at the atmosphere. This is the most complicated part of the environment. Remember (from Part 1) the atmosphere gets 22 parcels of energy from the sun.
    Write that 22 on line J. **(Slide 16)**

11. It also gets energy from the earth:
    6 parcels by heating the air (Line F)
    25 by evaporating water (Line G)
    105 by longwave radiation (Line H)
    *Write that total here _136_*
    *Add the 22 coming from the sun _158_* **(Slides 17-18)**

12. This total is the amount of energy coming into the atmosphere. Satellites record about 58 parcels of radiation going out from the atmosphere to outer space. (Clouds are colder than the ground. For that reason, the upper air does not have to radiate as much energy per day as the ground.)
    *What arrow represents the radiation from the air to outer space? _L_*
    Write 58 on that arrow? **(Slide 19)**

13. The lower air is warm. Therefore, it radiates nearly 99 parcels down toward the ground. (That's actually the total downward radiation from all levels of the air.)
    *What arrow represents downward radiation from the air? _K_*
    Write 99 on that arrow. **(Slide 20)**

14. There is just one tiny arrow left. Rain might feel cold when it lands on your skin, but it actually carries some heat down from the air to the earth. It just feels cold on your skin because your skin is warmer than the average temperature of the earth.
    *What arrow represents the movement of heat in rain and snow? _M_*
    Write 1 on that line. **(Slide 21)**

15. Now let's review by working out the energy balance for the atmosphere. **(Slide 22)**

INCOMING		OUTGOING	
Short wave radiation from the sun:	22	Longwave radiation to outer space:	_58_
Heating of air by the warm ground:	6	Longwave radiation down to the ground:	_99_
Evaporation of water:	25	Precipitation down to the ground:	_1_
Longwave radiation from the earth:	105		
Total	_158_	Total	_158_

Please remember, these are all average figures. On any given day at any given place, the numbers will be different, and usually they do add up. In June, the sun is higher in the sky in Michigan and lower in Australia – so Michigan gets warmer and Australia gets cooler. In January, the reverse is true. There are also some day-to-day differences. One day may be cloudy, for example, or windy. As a result, temperatures go up or down from day to day, as well as from season to season.

Earth's Energy Budget: Part 4 – Human Activity

Note: Slide 25 is the whole diagram without the numbers. Slide 26 has all the numbers filled in. These slides could be displayed for students to use to complete the final worksheet:

Remind students of the following before starting.

Now let's put the whole diagram together. Remember that every number is a global average and is likely to be different in different places. That is one reason why it is hard to measure the importance of human activity in causing changes in this huge and complicated system. Nevertheless, it is clear that human activity can alter some parts of the system.

16. For example, jet airplanes flying high above the ground can make clouds that reflect some of the incoming sunlight.
    Circle the arrow(s) that might change: A B (C)

17. What human activities might change the amount of reflection from the ground (arrow D)?
    _x_ cutting rainforest _x_ plowing soil and planting wheat
    _x_ setting dry grass on fire _x_ removing snow from streets and driveways
    _x_ doing something that might cause the polar icecaps to melt

18. If you marked "all of the above" for question 18, you are right. The big questions, however are "How much?" and "Which of these is the most important?" What do you think?
    Answers will vary. Icecaps are probably the best answer, but use students' answers to assess whether students need more review of the science.

19. What human activities might change the amount of energy that goes up by evaporation? What effect could that have on the amount of cloud in the sky?
    Answers will vary. Possible human activity: cutting trees. Effects: more clouds, more rain, fog

20. Many scientists think that the biggest impact is from burning fossil fuels like coal and oil. Burning puts carbon dioxide into the air, and carbon dioxide traps more of the radiation that goes up from the ground surface.
    Circle the arrow(s) that get bigger: (H) I J

21. The changes described in questions #20 and #21 tend to make the lower air warmer.
    Circle the arrow(s) that might get bigger as a result J (K) L M
    What effects might that have on other parts of the system?