Your ECOLOGICAL footprint

How Much Sunlight Do You Use?

The physical systems of planet Earth use solar energy to generate the natural resources and environmental services you consume. This box provides information that allows you to calculate the quantity of solar energy that is used to provide the food you eat, the clean water you drink, and the paper you use.

The link between solar energy and food supply is fairly direct. Plants use solar energy to combine molecules that contain a single atom of carbon (carbon dioxide, CO_2) into molecules that contain six molecules of carbon (glucose, $C_6H_{12}O_6$). Glucose stores some of this solar energy in a form you can use.

How much solar energy is stored in your food? Only about 0.3 percent of the solar energy that hits a leaf is stored in glucose (photosynthesis has an efficiency of about 0.3 percent). This efficiency implies that a plant must capture about 300 kcal of solar energy to store 1 kcal of energy. Of this 1 kcal, about 0.4 kcal are converted to plant material (40 percent efficient). And only about 10 percent of a plant is edible (10 percent efficient). Because all these conversions are relatively inefficient, the average kcal of plant foods such as red peppers or tomatoes represents about 7,500 kcal of solar energy. This energy total increases by a factor of 10, to 75,000 kcal of solar energy, for a kcal of meat. For reasons described in the next chapter, animals convert only about 10 percent of plant food to edible meat.

Solar energy also is required to produce drinkable (potable) water. Due to the forces of gravity, water eventually makes its way to the ocean. There it mixes with sodium (and other minerals), and the high concentration of these minerals makes seawater undrinkable. Seawater is made drinkable via the work done by solar energy. This energy separates water from the minerals and moves the water over land and to a reservoir near you.

Evaporation is a very energy-intensive process: As described on page 64 of this chapter, 540 kilocalories are required to convert a kilogram of liquid water to a kilogram of water vapor, which is a gas. In addition, great amounts of solar energy are required to lift the water so it forms a cloud and to move the cloud horizontally (paths 1 and 2 of the convection cell in Figure 4.3).

The solar energy used to provide potable water can be calculated by dividing the amount of solar energy used to drive the hydrological cycle over a year by the annual rate of precipitation globally. This quotient implies that 750 kcal of solar energy are required to generate a kilogram of precipitation.

Solar energy also is used to produce paper. Paper is made from wood created by trees. This woody material is generated by the same process that generates edible energy. As with plants, only about 0.3 percent of the solar energy that hits a tree's leaf is stored in glucose (0.3 percent efficient). Most of this energy (50–70 percent) is used to produce roots. Only about 5 percent is used to make plant material that can be used to make paper. This implies that about 6,000 kcal of solar energy are needed to make about 1 kcal of plant material. On average, dry wood contains about 4,500 kcal per kilogram. This implies that about 27 million kcal of solar energy are required to make a kilogram of material that can be converted to paper.

The papermaking process also is relatively inefficient. The Kraft process is used to make most (about 80 percent) of the paper in the United States. In this process dry wood is soaked and heated in a liquid that consists mainly of sodium. Between 40 and 65 percent of the dry wood becomes usable pulp. These efficiencies imply that about 2 kilograms of dry wood are needed to make 1 kilogram of paper. All together, these inefficiencies imply that about 54 million kilocalories of solar energy are required to produce a kilogram of paper.

Calculating Your Footprint

How many kilocalories do you eat per day? Most dieticians suggest that people eat about 2,500 kcal per day. (On food containers, Calories with a capital C is equivalent to a kilocalorie.) The Food and Agriculture Organization (part of the United Nations) reports that the average U.S. citizen used 4,821 kcal per day in 2003 (this included food that was wasted). In the next chapter you will determine the energy content of your food. Multiply this sum by 7,500. This represents the amount of solar energy used to grow your food.

______ kcal sunlight = 4,821 food kcal/day × 7,500 kcal/kcal

How much water do you drink? The British Dietetic Association suggests that a healthy adult should drink about 2.5 liters of water per day. If you assume that 750 kcal of solar energy are required to generate a kilogram of precipitation (1 liter of water weighs 1 kilogram), how much solar energy is required to generate 2.5 liters of drinking water?

______ kcal sunlight = 2.5 liters/day × 750 kcal/liter

The average U.S. citizen used 314 kilograms of paper per year in 2004. This translates to about 0.86 kg/day. If you assume that 54 million kilocalories of solar energy are required to generate a kilogram of paper, how much solar energy is required to grow the paper you use every day?

______ kcal sunlight = 0.86 kg/day × 5.4×10^7 kcal/kg

The total amount of solar energy you use for food, water, and paper is the sum of these three uses (your total should be about 101.3 million kcal per day).

Interpreting Your Footprint

What area of Earth's surface is required to capture the sunlight used to grow your food, generate your drinking water, and grow the trees used to make your paper? If we assume that the solar constant at the equator is 28,320 kcal/m^2/day and that Earth's albedo is about 31 percent, you can use the following formula to calculate the area used:

______ m^2/day = [1.01×10^8 kcal/day/28,320 kcal/m^2/day] × 1/0.69

As will be described in Chapter 11, the average person living in the United States uses more energy and materials than the average person on the planet. The Food and Agriculture Organization reports that the average person on Earth uses 3,272 kcal per day and uses 0.15 kilograms of paper per day. How much more sunlight do you use than the average person on Earth? How much more land is required to capture this sunlight?

STUDENT LEARNING OUTCOME

- Students will be able to explain why the land they use extends well beyond the house or apartment they live in.