Your ECOLOGICAL footprint

How Much Energy Do You Use?

In 2003 the average U.S. citizen used about 25 barrels (146.2 million Btu) of oil, 76,000 cubic feet (78.1 million Btu) of natural gas, 3.4 metric tons (75.6 million Btu) of coal, and 3,500 kilowatt-hours (12 million Btu) of electricity generated from nuclear or hydroelectric power plants. These quantities are much greater than the average citizen of nearly every other nation. For example, the average German citizen used about 12 barrels (68 million Btu) of oil, 39,000 cubic feet (41.3 million Btu) of natural gas, 3.0 metric tons (67.2 million Btu) of coal, and 2,200 kilowatt-hours (7.4 million Btu) of electricity generated from nuclear or hydroelectric power plants, whereas the average Japanese citizen used about 16 barrels (92.5 million Btu) of oil, 24,000 cubic feet (24.6 million Btu) of natural gas, 1.3 metric tons (22 million Btu) of coal, and 2,700 kilowatt-hours (9.1 million Btu) of electricity generated from nuclear or hydroelectric power plants.

One reason for high rates of energy use in the United States is its high income. As indicated in Figure 10.12 on page 211, average income of U.S. citizens is among the highest. But income alone cannot explain the high rates of energy use. In 2003 average per capita income in Germany and Japan was only about 25 percent less than in the United States, but German per capita energy consumption was about 41 percent lower than in the United States, and Japanese per capita energy consumption was about 51 percent lower than in the United States.

Another cause for the high rates of U.S. energy use are relatively low rates of energy efficiency. As described in the start of this chapter, SUVs are the automotive status symbol of the first decade of the twenty-first century. But these automobiles average only 15 miles per gallon. As a result, the overall energy efficiency of the U.S. automobile fleet is low compared to that of Germany or Japan. Similarly, the efficiency of insulation, lighting fixtures, and heating and cooling equipment of U.S. buildings is low, so the United States uses more energy per square meter of floor space than Germany or Japan.

Here we provide information that will let you calculate how much energy you use. One aspect of this calculation is simple: Using the information you collected for Chapter 13's Your Ecological Footprint, add up your use of coal, oil, natural gas, and electricity. Following this procedure, you will conclude that you use little or no coal—much less than the 3.4 metric tons that are used by the average U.S. citizen. There seems to be a mistake.

There is no mistake. The fact that you seem to use no coal is caused by the difference between primary energy consumption and final energy consumption. Primary energy consumption includes energy that enters the economic system from the environment. In most developed nations, primary energy consumption includes coal, oil, natural gas, and electricity generated from nuclear and hydroelectric plants. Final energy consumption includes energy that is consumed but not resold. In most developed nations, final energy consumption includes coal, oil, natural gas, and electricity, regardless of how the electricity is generated.

The important difference between these two measures concerns the energy used to generate electricity. Power companies generate electricity by burning coal, oil, and natural gas, so these fuels are included in primary energy consumption. Electricity that is generated and resold to consumers is included in final energy consumption. Because generating electricity from fossil fuels is about 40 percent efficient, final energy consumption is always less than primary energy consumption. Separating primary energy consumption from final energy consumption prevents analysts from "double-counting" energy use. When totaling your energy use, you should not count both the electricity you consume and the coal, oil, and natural gas that were used to generate it.

Calculating Your Footprint

To understand how the difference between primary and final energy consumption affects your measure of energy use, add up your direct uses of coal, oil, natural gas, and electricity. Table 1 allows you to translate physical measures of energy use, such as barrels, cubic feet, and kilowatt-hours, to energy units, such as Btus. For example, suppose you purchased 12 gallons of gasoline, 27 gallons of heating oil, 7,400 cubic feet of natural gas, and 270 kilowatt-hours of electricity. Your total energy use would be as follows:

Motor gasoline	1.5 million Btu = 12 gal × 125,000 Btu/gal
Heating oil	3.75 million Btu = 27 gal × 139,000 Btu/gal
Natural gas	7.5 million Btu = 7,400 ft^3 × 1,030 Btu/ft^3
Electricity	0.9 million Btu = 270 kilowatt-hours × 3,412 Btu/kilowatt-hour
Monthly total	13.65 million Btu

To calculate your primary energy consumption, use the information in Table 2 to translate your use of electricity back to the quantities of coal, oil, or natural gas that are used to generate it. Add these indirect uses to your direct uses of coal, oil, and natural gas to calculate your primary energy consumption. Continuing with the previous example, suppose you go to school in the Boston area. You would calculate the quantity of fossil fuels used to generate the 270 kilowatt-hours of electricity as follows:

Coal	1.6 million Btu = 270 kilowatt-hours × 5,990 Btu/kilowatt-hour
Oil	0.8 million Btu = 270 kilowatt-hours × 2,803 Btu/kilowatt-hour
Natural gas	0.05 million Btu = 270 kilowatt-hours × 184 Btu/kilowatt-hour
Monthly total	2.45 million Btu

TABLE 1 Energy Content of Fuels

Fuel	Units	Multiply to Convert to Thousand Btu
Coal	Pounds	11,474 Btu per pound
Motor gasoline	Gallons	125,000 Btu per gallon
Heating oil	Gallons	139,000 Btu per gallon
Natural gas	Cubic feet	1,030 Btu per cubic foot
Electricity	Kilowatt-hours	3,412 Btu per kilowatt-hour

But not all of your electricity is generated from fossil fuels, so you also have to determine the amount of electricity generated from fuels other than coal, oil, and natural gas. In the United States most of this other electricity is generated by nuclear or hydroelectric plants. Use the fractions in Table 3 on page 424 to calculate the quantity of electricity that you use generated by nuclear and hydroelectric sources. Continuing with our example, you would calculate these quantities as follows:

Electricity from nuclear power 0.2 million Btu = 270 kilowatt-hours × 3,412 Btu/kilowatt hour × 0.252 Nuclear power

Electricity from hydroelectricity 0.05 million Btu = 270 kilowatt-hours × 3,412 Btu/kilowatt-hour × 0.054 Hydroelectric power

To calculate your direct use of primary energy, you need to sum the quantity of coal, oil, and natural gas you use directly; the quantity of coal, oil, and natural gas used to generate the electricity you consume; and the electricity generated from nuclear and hydroelectric power plants. Finishing our example, this sum would be 15.45 million Btu (1.5 million Btu + 3.75 million Btu + 7.5 million Btu + 1.6 million Btu + 0.8 million Btu + 0.05 million Btu + 0.2 million Btu + 0.05 million Btu). Notice that this total is greater than the final consumption of energy, 13.65 million Btu.

Finally, your energy intake includes the energy used to produce the nonenergy goods and services you purchase. To estimate this quantity, refer to your purchases of goods and services that you used in Chapter 13's Your Ecological Footprint to calculate the quantity of carbon dioxide that you emit. Multiply the dollar values of your purchases by the energy intensities for those categories.

To illustrate, suppose you purchased a $30 pair of pants. Pants fall within the nondurable manufactures category. According to Table 4 on page 424, each dollar spent on goods from this category represents 4,970 Btu of coal, 6,110 Btu of oil, 2,520 Btu of natural gas, and 5,650 Btu of electricity. Based on these values, a $30 pair of pants requires 149,100 Btu of coal, 183,300 Btu of oil, 75,600 Btu of natural gas, and 169,500 Btu of electricity.

Interpreting Your Footprint

Now calculate your primary energy consumption over the year. To do so, sum your direct and indirect uses of primary energy. If you have calculated monthly or weekly values, be sure to increase them so they represent annual values.

Compare your total to the values in the opening paragraph. Is your total greater than or less than the national average? What is the reason for this difference? Try to answer using the relevant portion of the IPAT equation. In other words, is your income higher than or less than the national average? Similarly, do you tend to use technologies that have a high or low energy efficiency?

Finally, let's compare your energy use to that elsewhere. The opening paragraph has information about energy use in Japan and Germany. How could you change your energy use to match these nations?

Now let's compare your energy use to that in a developing nation, China. In 2003 the average Chinese citizen used about 1.5 barrels (9.0 million Btu) of oil, 933 cubic feet (0.9 million Btu) of natural gas, 1.0 metric tons (23.7 million Btu) of coal, and 244 kilowatt-hours (0.8 million Btu) of electricity generated from nuclear or hydroelectric power plants. Could you reduce your use of energy to this level? What if you consumed no energy directly and purchased only goods and services with a low energy intensity?

STUDENT LEARNING OUTCOME

- Students will be able to describe the differences between primary and final energy consumption.

TABLE 2 Btu's of Fuel Used to Generate a Kilowatt-hour of Electricity

Regions (States)	Coal	Oil	Natural Gas
New England (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont)	5,990	2,803	184
Middle Atlantic (New Jersey, New York, Pennsylvania)	2,741	1,306	935
East North Central (Illinois, Indiana, Michigan, Ohio, Wisconsin)	8,631	37	77
West North Central (Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota)	8,471	47	170
South Atlantic (Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia)	5,239	557	953
East South Central (Alabama, Kentucky, Mississippi, Tennessee)	6,730	99	419
West South Central (Arkansas, Louisiana, Oklahoma, Texas)	5,895	98	2,520
Mountain (Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming)	7,509	11	658
Pacific Contiguous (California, Oregon, Washington)	177	5	702
Pacific Noncontiguous (Alaska, Hawaii)	358	6,111	2,747

Source: Calculations based on data from Electric Power Monthly, Energy Information Administration, U.S. Department of Energy.

Your Ecological Footprint (*continued*)

TABLE 3 Regional Share of Electricity Generated by Nuclear and Hydroelectric Plants

Regions (States)	Nuclear	Hydroelectric
New England (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont)	.252	.054
Middle Atlantic (New Jersey, New York, Pennsylvania)	.349	.062
East North Central (Illinois, Indiana, Michigan, Ohio, Wisconsin)	.226	.007
West North Central (Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota)	.0	.027
South Atlantic (Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia)	.238	.020
East South Central (Alabama, Kentucky, Mississippi, Tennessee)	.184	.060
West South Central (Arkansas, Louisiana, Oklahoma, Texas)	.111	.014
Mountain (Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming)	.075	.084
Pacific Contiguous (California, Oregon, Washington)	.127	.409
Pacific Noncontiguous (Alaska, Hawaii)	.0	.086

Source: Calculations based on data from Electric Power Monthly, Energy Information Administration, U.S. Department of Energy.

TABLE 4 Energy Intensities of Nonenergy Goods and Services Measured in Thousand Btu per Dollar

	Coal	Oil	Natural Gas	Electricity
Biological Resources	2.24	6.77	1.40	1.83
Mineral Resources	16.63	8.47	7.77	10.50
Durable Manufacturers and Construction	3.65	3.61	1.68	2.85
Nondurable Manufacturers	4.97	6.11	2.52	5.65
Transportation Services	1.66	25.06	1.07	1.58
Other Services	2.05	3.10	1.35	1.68

Source: Data from R.W. England and S.D. Casler, "Fossil Fuel and Sustainable Development: Evidence from U.S. Input–Output Data, 1972–1985," *Advances in the Economics of Energy and Resources* 9: 21–44. Adjusted for the effects of inflation and gains in energy efficiency.

THE FORMATION OF FOSSIL FUELS

Fossil fuels are grouped together because they are derived from the net primary production of autotrophs that lived millions of years ago. This biological material did not follow the usual path in the global carbon cycle in which organic material decays back to carbon dioxide and flows back to the atmosphere (Figure 6.6 on page 105). Instead the organic material decayed partially and remained buried.

The geological processes that short-circuited the global carbon cycle had to satisfy several conditions. First large amounts of organic matter had to be available in a relatively small area. This implies that the organic precursors of fossil fuels originated in highly productive ecosystems. Next the organic matter had to be cut off from oxygen so that it would not decay aerobically according to Equation 5.3 on page 89. This partially decayed organic matter then had to be rearranged in a way that concentrated its energy content. Finally, all these processes had to occur close to Earth's surface so that people could recover the energy in an economically feasible manner.

All of these conditions occurred together only rarely. Indeed, fossil fuel can be thought of as a geological accident. In sum, the fossil fuel resource base represents a bit more than a century of net primary production by terrestrial ecosystems (at current rates). (You can approximate this value by looking at the flows and storages in Figure 6.6 on page 105.) As a result, the supply of fossil fuels is limited.

Coal

Measuring the supply of fossil fuels relative to the net primary production of terrestrial ecosystems does not imply that all fossil fuels are derived from plants. But this comparison is relevant for coal. Coal is derived from terrestrial plants that lived millions of years ago. Originally people