INTERLUDE

Social Issues and the Energy Crisis

Our discussion of energy has been scientific. We have defined energy, its many forms, and the laws that summarize the transformation of one form of energy into another. We can do all this without mentioning gas lines, nuclear accidents, thermal pollution, windfall profits, or international oil cartels. Yet these problems face us daily. We pause here to examine briefly the social issues that arise from our use of energy.

Life itself is an entropy-increasing process. The remarkable order demonstrated in the evolution and maintenance of living organisms is accomplished at the expense of order elsewhere in the universe. We are not talking just about the refuse, the sewage, and the pollutants so abundantly obvious today. Entropy increases as plants transform radiant energy from the sun into the energy needed for their growth. Entropy increases as we transform the plants we eat into the thermal energy needed to sustain our lives. As we live and breathe, we have no choice but to increase the entropy of our environment. Our only choice lies in how quickly we make that increase occur.

Two variables—population and per capita energy consumption—dominate the rate at which we increase entropy. During the early 1970s, population in the United States was increasing at an average of about 1.5% per year. The amount of energy consumed per person during this same time interval was also increasing, roughly at a rate of 2.0% per year. Combining these two variables, we find that the total energy consumed in the United States was increasing at a rate of about 3.5% per year. While such a growth rate may sound modest, it can have disastrous results.

Exponential Growth

We commonly use a mathematical function, called the *exponential function,* to describe quantities that grow steadily at a fixed rate. Frequently the rates are stated as percentages for annual growth, like 3.5% per year. Another way to describe this rate of increase is the doubling time, the length of time for the quantity to double in value. For example, a growth rate of 3.5% per year corresponds to a doubling time of roughly 20 years. Given a fixed growth rate of total energy consumption, by the year 2005 we will be consuming twice as much energy as now; by 2025, four times as much; by 2045, eight times as much, and so forth. While the doubling time remains constant, the total energy consumed each year will soar out of sight. The impact of even modest growth on the consumption of a limited resource can be devastating.

To see how devastating, let's consider an analogy taken from biology. We begin with a single yeast cell in a petri dish filled with agar, a growing medium. The agar can supply enough food for a single cell to live a million days—a seemingly infinite food supply. Suppose the yeast cells divide, doubling in number every 72 minutes (min). We begin with one cell; 72 min later we have two cells; in another 72 min, four cells; and so forth. One day later we have more than a million cells. One cell could have lived a million days on the food supply. With a doubling time of 72 min, we have less than a day's supply of food in the second day. As the food supply is exhausted, exponential decay replaces exponential growth. Yeast cells begin to die. Instead of doubling time, we now describe the half-life of the cells—the time it takes half the remaining cells to die.

Our energy consumption can be compared to the growth of the yeast cells who doubled while gobbling their food. Unlike the yeast cells, however, we gobble more energy per person as the number of people grow. A doubling time of 20 years means that in 400 years we will have less than "a day's food" left from a resource people once thought would last 400 million years. One day our energy appetite will exceed available resources and exponential decay will replace exponential growth.

Limited Resources and a Limited Environment

Many argue that energy is not a limited resource—the only limitation we currently face is the technological development of new energy sources. Our knowledge of the heat engine tells us otherwise. Heat engines require some lower-entropy form of energy to operate and must exhaust waste energy. The current exponential growth in energy consumption poses two problems: (1) adequate supplies of lower-entropy sources of energy and (2) the ability of the environment to absorb thermal waste energy.

Our current crisis in lower-entropy sources of energy focuses on fossil fuels, which now provide nearly 97% of our energy needs. The exponential growth in energy consumption and the convenience of fossil fuels have conspired to consume in a matter of decades an energy resource that accumulated over hundreds of millions of years. History reports similar crises—water-power shortages in England and periods of wood scarcity in Europe. Each time, a shortage of existing energy resources stimulated the discovery and development of new sources. The current crisis is stimulating the use of coal and nuclear fuels and the recovery of smaller fields of natural gas and oil. Those who have learned the lesson of history now argue for the development of renewable rather than nonrenewable sources. Coal, natural gas, and oil are energy sources that cannot be replaced within a relatively short time interval, once consumed. Hence, they are called *nonrenewable energy sources*. Other energy sources, like the sun, the wind, and flowing water used in hydroelectric plants replace themselves, so to speak. As long as the sun continues to supply thermal energy to our planet, most of these sources will continue to exist. Consequently, they are called *renewable energy sources*. Solar energy, the recovery of methane from vegetable and animal wastes, and the use of wind and geothermal forms of energy head the lists of renewable sources. Regardless of the renewable sources developed or the new sources found, exponential growth will someday cause the demand for energy to exceed the supply.

Long before the energy sources diminish, the earth's environment will severely limit us because of its inability to absorb the thermal energy exhausted by the heat engines we run. Seventy percent of the thermal energy derived from fossil fuels is dumped into the lakes, the streams, and the atmosphere that surrounds us. Combined with pollutants, this thermal waste energy poses a serious environmental threat. Rather than starving to death like the yeast cells, we may well poison ourselves with pollution.

Energy and Societal Values

Our ultimate energy source, the sun, will one day dim, taking with it all the energy sources we now gobble so eagerly. We have no choice but to flow with the inevitable increase in entropy. The choice we have is in how long we allow ourselves to watch.

Exponential growth stands as a spectre against unlimited consumption of energy. Like the yeast cells in the petri dish of agar, we grow and multiply in a limited environment. Unlike the yeast cells, we can vary our energy consumption according to our wisdom or our greed. Whether we last another century or thousands of centuries depends largely on our willingness to impose limitations on our own consumption of energy.

The willingness to impose limits is largely a matter of values, not science. Science describes the limitations imposed by the environment; our choice of values describes the limitations we impose on ourselves. Consciously or unconsciously, our actions reflect our values. Do we value the present more than the future—our own comfort more than that of our children or grandchildren? Is the convenience provided by automobiles more valuable than the cleaner air that once surrounded us? Is the time saved by driving worth the obesity found in an increasingly sedentary society? Is our throw-away economy worth the cost to our environment and its resources? Is profit more valuable than the thermal energy lost by inefficient machines? Energy is like a candle in a dark night. The way in which we, individually and collectively, choose to burn that candle will determine how long and with how many the light may be shared.