1 Energy and Society

Adequate food, water, and shelter are basic to human survival. Closely linked to these life essentials is an adequate energy supply, for humans have always used energy to obtain food, water, shelter, and protection from parasites and predators. Over the centuries people have employed energy from many sources. First they depended on their own energy and natural energy from sunlight; later they relied on fire, draft-animal power, and water and wind power. Still later they invented engines fueled by wood, coal, petroleum, and, more recently, nuclear energy. Humans have used these various energy resources to modify and manipulate land, water, plants, and animals to fulfill their survival needs. Finding, controlling, and using energy has enabled humans to progress from an unsettled, primitive lifestyle to a more settled and sophisticated lifestyle. Among the mammals, only the humans can think creatively and develop advanced technologies.

The attainment of security and stability depends on the use of energy. For example, humans expend energy to control disease; to obtain, purify, and store water; to produce pesticides; to produce antibiotics and other drugs; and to implement public health measures. All of these have enhanced the quality of human life.

Security and stability also entail the protection of one person from another and one group of people and their resources from encroachment by rivals. Social harmony depends not only on the rules established by governments but also on the effectiveness of societal forces used to enforce the laws. Governments, police, and military forces all expend enormous amounts of energy. In the so-called civilized society of nations of the world today, governments, police, and military forces use more energy than farmers to produce food on the farm for the population being governed.

The availability of increasing energy supplies enabled humans to develop a societal structure more complex than that of the early hunter-gatherers. The present pattern of energy use contrasts sharply with that of the distant past, when finding adequate food dominated people's daily activities. White (1943) proposed that humans evolved in the following three major stages: (1) savagery—hunter-gatherers living on wild foods; (2) barbarianism—early agriculture and pastoral societies; and (3) civilization—development of engines and intensive use of fossil energy to produce food and necessities.

Each step signified major changes in both the type of energy supplies and their use by humans. In fact, White felt people would have remained on the "level of savagery indefinitely if [they] had not learned to augment the amount of energy under [their] control." The total quantity of energy controlled by humans grew to include a surplus above the amount needed for their basic needs.

DEVELOPMENT OF SOCIETIES AND ENERGY

Hunter-gathering societies were small, rarely having more than 500 individuals (Service, 1962; Lee and DeVore, 1976), and simple (Bews, 1973). As securing food and shelter consumed so much time and energy, other activities scarcely existed. With the development of agriculture, more dependable supplies of food, fiber resources, and surplus energy became available. Concurrently, a greater incentive for increased productivity and a greater interdependence among people evolved in human societies. As the stability of the food supply increased, societies that had once been seminomadic, following their food supply, gained in security and permanence.

In early agricultural societies food production still dominated human activities, and as a result the range of social interactions remained relatively narrow. Then the introduction of draft-animal power into agricultural production decreased human power expenditure and increased free personal time (see Chapters 7 and 10). People gained the freedom to participate in various activities and social systems became more complex. Over time, water and wind emerged as excellent energy resources. Instead of using draft animals that required energy for feed and care, people used waterwheels and windmills. With this change, humans had more power at their disposal and at a lower cost (calculated as human energy input) than in the past. In this way, the amount of surplus energy available to society was greatly increased.

The use of water and wind power and the subsequent reduction of dependence on animal power fostered the development of trade and transport between societal groups. Improved communications expanded the exchange of resources and ideas between groups. Technical advances spread more easily than ever before. Further developments in science and technology resulted in the invention of sailing ships, which enhanced communication, transportation, and trade. With these changes human activities diversified, and specialized disciplines such as farming, sailing, trading, and industry developed.

The invention of the steam engine was a highly significant milestone in energy use, for it signaled the beginning of the use of fossil fuels as an energy source. Later engines used coal and oil as fuels, providing humans with immense power to control their environment and to change the total economic, political, and social structure of society (Cook, 1976). Along with these changes came greater stability, even greater specialization of work, longer life spans, and improved diets.

ENERGY FROM FIRE

Since the earliest human societies, energy from fire has played a dominant role in survival. Although primitive people feared fire, they learned to control and constructively use its energy about half a million years ago. Fire enabled hunter-gatherers to ward off large animal predators and helped them clear vegetation, which provided further protection. Campfires also provided warmth in cold weather.

In addition, fires made it possible to cook foods, often making them better tasting, easier to eat, and easier to digest. Perhaps more important, cooking reduced the danger of illness from parasites and disease microbes that often contaminate raw foods. Heating also destroys some microbes responsible for food spoilage, so fire could be used to dry and preserve surplus foods for later consumption. This advance helped stabilize the availability of food supplies long after the time of harvest.

When primitive agriculture was developing, about 10,000 years ago, people set fires to clear trees and shrubs from the cropland and grazing areas. This simple procedure also helped eliminate weeds that competed with the crops. Furthermore, the ashes added nutrients to the soil and enhanced crop productivity. After cultivating crops on a certain plot for a few years, early farmers abandoned the land and cultivated other plots fertile enough to support crop growth. This form of early agriculture is termed "slash and burn" agriculture.

Wood from trees and shrubs served as the principal source of fuel for fires, although some grasses and other vegetation were also burned. When there was a relatively small human population, ample supplies of renewable energy in the form of wood were available. Today, with 6.5 billion people on Earth, firewood and other forms of biomass are in short supply in most parts of the world.

ENERGY AND THE STRUCTURE OF SOCIETIES

Early hunter-gatherer societies had minimal structure. A chief or group of elders usually led the camp or village. Most of these leaders had to hunt and gather along with the other members because the surpluses of food and other vital resources were seldom sufficient to support a full-time chief or village council.

The development of agriculture changed work patterns. Early farmers could reap 3–10 kg of grain from each 1 kg of seed planted. Part of this food/energy surplus was returned to the community and provided support for nonfarmers such as chieftains, village councils, men who practice medicine, priests, and warriors. In return, the nonfarmers provided leadership and security for the farming population, enabling it to continue to increase food/energy yields and provide ever larger surpluses.

With improved technology and favorable conditions, agriculture produced consistent surpluses of the basic necessities, and population groups grew in size. These groups concentrated in towns and cities, and human tasks specialized further. Specialists such as masons, carpenters, blacksmiths, merchants, traders, and sailors developed their skills and became more efficient in their use of time and energy. The goods and services they provided brought about an improved quality of life, a higher standard of living, and, for most societies, increased stability.

Ancient Egypt is an outstanding example of an early society that not only possessed environmental resources favorable to agriculture but also developed effective agricultural technology (Cottrell, 1955). The Nile's yearly floods deposited nutrient-rich silt on the adjacent farmland and kept it productive. The river was also a reliable source of water for irrigation. Additionally, the warm Egyptian climate was highly favorable for crop production. This productive agricultural system supported the

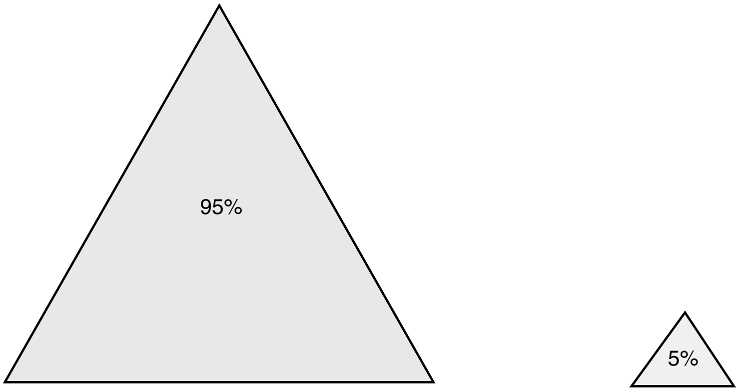

FIGURE 1.1 During the age of the Pharaohs and pyramid projects, ancient Egypt had a population of 3 million. About 95% of society was involved in agriculture. The surplus energy of about 5% was utilized for the Pharaohs and the construction of the great pyramids.

95% of the Egyptian population that was directly involved in agriculture (Figure 1.1) and provided enough surplus food to sustain the 5% of the population that did no agricultural work (Cottrell, 1955).

Relatively little food energy was needed to support the small ruling class. Furthermore, Egypt's naturally isolated location provided protection from invasion, so the society did not have to expend large amounts of energy to maintain a military class. As a result, the Pharaohs could and did use the 5% of the population not involved in agriculture as slave laborers to build pyramids and stock them with goods and materials for a life that, Egyptians believed, would come after life on Earth.

During this early period the Egyptian population remained relatively constant because of rulers' demands for slaves. As soon as surplus men were mature enough for work, they were assigned to pyramid construction and literally worked to death during the few years of slave labor. When they died, they were replaced with new surplus labor. This system was sustained without jeopardizing the fundamental agricultural system that involved the efforts of almost all the Egyptian people.

During the age of the Pharaohs, which spanned the years from 2780 to 1625 B.C. (Fakhry, 1969), Egypt had a population of about 3 million, much less than the 74 million of today. A 5% food/energy surplus from about 3 million people is not much; on a per capita basis, this ranges from 100 to 150 kcal per day (Cottrell, 1955), or the equivalent of 10–15 kg of surplus wheat per person per year. Based on 3 million people, this totals 30–45 million kg of surplus wheat per year.

The construction of the Cheops pyramid over a 20-year span used an amount of energy equal to the surplus energy produced in the lifetime of about 3 million Egyptian people (Cottrell, 1955). During the construction period the pyramid work force was about 100,000 slaves per year. Assuming that each slave received 300–400 kg of grain per year, the total cost would be 30–40 million kg of grain, or the entire food/energy surplus produced by the Egyptian agricultural community.

Later in its history, Egypt used surplus resources to support large military forces and conquer some of its neighbors. These military operations not only secured additional land and food but also brought many conquered people back to Egypt to be slaves. But the vast deserts over which the Egyptian forces had to travel and transport supplies naturally limited the military operations. Ever-increasing quantities of energy had to be expended simply to protect the supply routes and transport military provisions.

At other times, when the population became large relative to the land and the agricultural resources, agricultural surpluses were not available in Egypt. In these relatively overpopulated conditions and with shortages instead of surpluses, the Egyptian society was just able to maintain itself. Sometimes civil strife and social problems developed. These conditions often led to a decline in population because these unstable societies were unproductive in agriculture or any other essential activity.

Thus, Egypt's early history provides a prime example of the role that energy, as measured by food surpluses, played in the structure and activities of a society. Although the structures of today's societies are far more complex than that of ancient Egypt, energy availability and use continue to be major factors in the standard of living.

FOOD AS A FOCAL POINT OF SOCIETIES

In natural communities, the entire structure and function of the population revolves around food as an energy source (Elton, 1927). This situation is also true of human societies. Primitive societies used food as the medium of exchange long before money was used. They traded surpluses of crops and in this way not only improved their own diets but also had the opportunity to interact with other groups.

The populations of all species are influenced by the relation between food supplies and demand. As with human societies, stability has advantages for a biotic community's survival and therefore is an important evolutionary trend (Pimentel, 1961, 1988). Evolved balance in supply–demand economies of natural populations contributes to the relative stability that is observed in these dynamic community systems.

The major reason why food and energy are considered critical resources for all natural communities, including humans, is that living plants can convert relatively limited amounts of solar energy—only about 0.1% of the sunlight reaching the Earth—into biomass. Before fossil fuels were discovered and used, humans shared with other animals that portion of the sun's energy captured by plants and subsequently converted to food/energy.

In prehistoric times, humans acknowledged the importance of food in their lives, as revealed in the many pictures of animals and food plants they painted in caves and on tools (Figure 1.2). Egyptian artwork pictures various food crops and livestock, and grains and other food items were customarily buried with the dead. The Mayan civilization of Central America depended on corn (maize) as its staple food and produced numerous sculptures and paintings of corn.

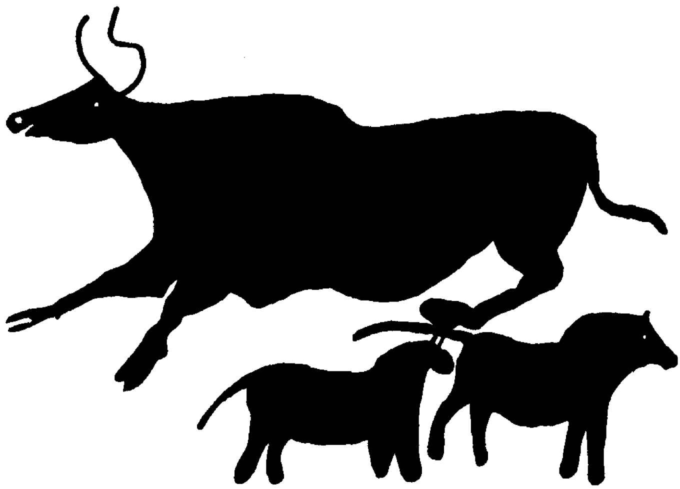

FIGURE 1.2 Drawing of a cow and several small horses in the painted cave of Lascaux, France.

Many religious and cultural groups celebrated successful harvests with ceremony and pageantry.

USE OF ENERGY IN FOOD SYSTEMS

One measure of the relative importance of food in society as a whole is the amount of energy and labor devoted to producing it. In prehistoric times, about 95% of the total energy expended by the family was used for food. This included hunting and gathering, transporting the food back to camp, and preparing it for consumption.

Even today in some developing countries, the energy expended on food systems represents 60–80% of the total expended energy (RSAS, 1975). By contrast, in many developed countries the proportion of energy devoted to food production ranges from 15% to 30%, and little of this is human energy. For example, in the United States, the amount of energy expended on food production represents about 19% of the total energy used. In the developing countries, this percentage includes energy used for production, processing, packaging, distribution, and preparation of food.

Although the United States spends but 19% of its total energy on food, the overall quantity of energy it uses is several times that used in the less complex societies of developing countries (Figure 1.3). The United States expends three times as much energy per capita for food production as the developing countries for all energy-consuming activities including food production. This comparison emphasizes once again the energy-intensive lifestyle that has developed in such countries as the United States following the ready availability and low cost of fossil-fuel energy resources.

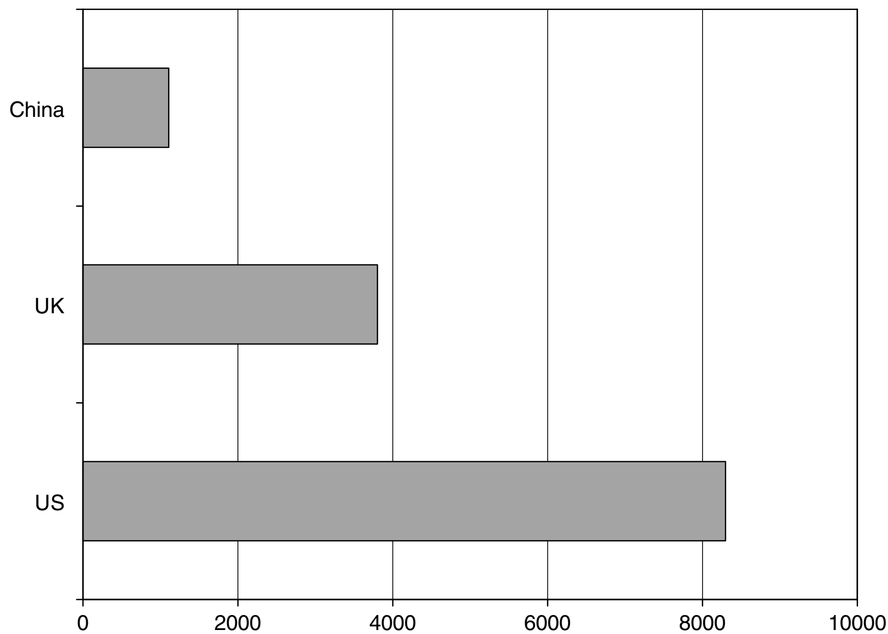

FIGURE 1.3 Energy consumption rates per capita per year in gallons of oil equivalents in the United States, the United Kingdom, and China (1 gal = 3.78 L).

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