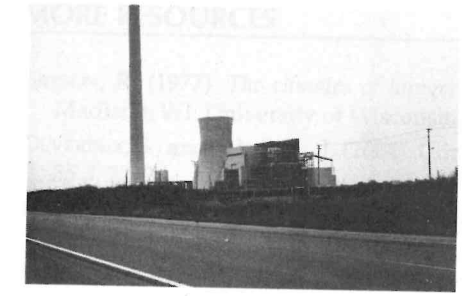
CHAPTER FOUR

Energy and Society



Coal-fired plants like this one in Indiana produce about half of America's electricity, but the exhaust from burning coal also pollute the air with mercury, sulfur dioxides, and other toxic chemicals. They also emit more greenhouse gases than other fossil fuels.

A wrecked oil tanker with crude oil visibly leaking into the ocean.

Electricity produced by wind generators constitutes a small part of the world's electricity. But it is now cost competitive, less environmentally damaging, and growing rapidly around the world.

Chapter One noted the ideas of the famous Austrian biophysicist Alfred Lotka, who proposed in the 1920s that the evolution of ecosystems is shaped by how efficiently various species of life appropriate the energy in the environment. In fact, general increases in human living standards have only been possible because of substantial increases in the amount of energy consumed. But growth in energy consumption is not only connected with human progress. The modern carbon-based energy system is connected with air pollution, oil spills, and, as Chapter Three noted, scientists are convinced that it is one of the primary human drivers of global warming. By 1990, the total energy consumption by humans around the world was 14 times larger than it was in 1890, early in the industrial era. Growth in energy consumption vastly outstripped population growth, which doubled during the same time period. But the human use of energy—its mining, refining, transportation, consumption, and polluting by-products—accounts for much of the human impact on the environment (Holdren, 1990: 159). Earlier chapters argued that human societies are "embedded" in the biophysical environment. Most fundamentally, in fact, they are embedded in systems of energy production and consumption. In other words, energy mediates between ecosystems and social systems and is a key to understanding much about the interaction between humans and environmental systems.

Energy is basically a physical variable—measured variously as calories, kilowatt-hours, horsepower, British Thermal Units, joules, and so forth. But energy is also a social variable, because it permeates and conditions almost all facets of our lives. Driving a car, buying a hamburger, turning on your computer, or going to a movie could all be described in terms of the amount of energy it took to make it possible for you to do those things. A kilowatt-hour of electricity, for instance, can light your 100-watt lamp for 10 hours, smelt enough aluminum for your six-pack of soda or beer, or heat enough water for your shower for a few minutes (Fickett et al., 1990: 65). All of social life, from the broad and profound things to the minutiae of everyday life, can be described in energetic terms.

It may well be that energy mediates between ecosystems and human systems, but that's a very abstract way of putting the human-energy–environment relationship, and its implications may not be clear to you. So before I clarify the agenda of this chapter, let me provide a concrete illustration of this statement by taking you on a historical detour, back to the 1970s.

A HISTORICAL DETOUR: RECENT ENERGY CRISES

In most of the industrial world, the winter of 1973 was an awful one, and not because of the weather. The reason was a sudden change in the availability and price of energy supplies. The world market for oil, which had become the industrial world's premier source of commercial energy, was very tight, meaning that in previous decades the global consumption of petroleum products had almost outgrown the world's capacity to produce, refine, and distribute them. U.S. domestic oil production was declining. The MDCs were increasingly dependent on the oil reserves of the LDCs such as Nigeria, Venezuela, and particularly the nations around the Persian Gulf, which possessed most of the world's known reserves. In September 1973, Japan's prime minister predicted that an oil crisis would come within 10 years. It came in more like 10 days, with the surprise attack that launched a war between Israel and her Arab neighbors that was later called the Yom Kippur War. In retaliation for the Western support of Israel, the cartel of oil-producing nations (OPEC), led by the Arab nations, declared an embargo on the export of oil to the MDCs. Nations and oil companies scrambled to buy, control, and ration existing supplies in storage and in the pipelines around the world. Oil prices zoomed from $2.50 to $10.00 a barrel, and the world economy went into rapid downturn—with price increases of almost everything, rapid inflation, plant closings, and layoffs. Rationing of energy supplies meant sudden uncertainty about the supplies of industrial, heating, and transportation fuels that Westerners had taken for granted as cheap and plentiful (Stanislaw and Yergin, 1993: 82–83). American President Richard Nixon left it to the energy departments of each state government to figure out how to allocate existing fuel. As increased costs of energy percolated through the whole economy, every facet of the American economy and lifestyle seemed threatened.

The crisis continued in 1979, when a revolution in Iran disrupted world supplies and created a panic that drove oil prices from $13 to $33 a barrel. All this seemed to foretell permanent shortage and continued turmoil. Adding to the mood of crisis, a prestigious group of scholars and computer modelers (the Club of Rome) produced studies to show that among other things, the world would be visibly "running out of gas" in the future (Meadows et al., 1972). But none of the worst fears caused by the "oil shocks" of the 1970s really came true. The ability of the OPEC nations to control the world's oil supply declined as non-OPEC production increased at a rapid pace. OPEC's share of the world oil market fell from 63% in 1972 to 38% by 1985 (Stanislaw and Yergin, 1993: 82–83). People responded by changing the way they lived and worked. They insulated homes and bought more fuel efficient autos and appliances. All over the world, utility companies began switching from oil to other fuels. By 1992, the people in my home state (Nebraska) consumed 100 million fewer gallons of gasoline than they did in 1973 (Kotok, 1993: 1). Energy conservation, a consequence of both technological and behavioral changes, proved more powerful than expected, so that by the 1990s the combination of reduced demand for oil and increased supplies made its real price cheaper in 1993 than in 1973. Around the world, MDCs tried to establish security measures that would help moderate future crises. These included the creation of the International Energy Agency, an international sharing system, increased communication, the creation of a global oil futures commodity market, and the establishment of prepositioned supply reserves.[1]

BOX 4.1 WINTER IN OMAHA, 1973

In the winter of 1973, Christmas displays were turned off. The Salvation Army "Tree of Lights," a holiday tradition at the county courthouse, burned for only one hour a day. Lights in urban office buildings were turned off. Everyone worried about keeping enough gas in their cars as gas stations periodically ran out of gas. Nebraska gas stations were closed on Sundays, and every Saturday night there were long lines. The days of supercharged V-8 muscle cars were numbered, as was the 75-mph interstate speed limit. Thermostat settings in offices and homes were turned down. In the state of Iowa, individual coffeepots were banned in the statehouse, and all high school basketball games were banned after December 22 (Kotok, 1993: 1). The latter was *serious* business, if you were a high school student in the rural Midwest!

Even with these positive responses to the oil shocks of the 1970s, they were a great historical wake-up call that forever changed our understanding of energy. The 1970s marked a transition in coming to grips with the environmental and sociopolitical costs of energy. Problems of air and water pollution, many of them associated with energy consumption, came to be recognized as pervasive threats to human health, economic well-being, and environmental stability (Holdren, 1990: 158). Indeed, energy problems came—perhaps for the first time in history—to be widely recognized as an integral part of environmental concerns. In addition, consciousness of growing dependence on imported oil graphically demonstrated the growing economic and geopolitical interdependence among nations and continues to shape our foreign policy problems in, for instance, the 1992 Gulf War, and in 2006 the war in Iraq and America's tensions with Venezuela.

After about a decade of "moderate" energy prices, in mid-1990 a rapid and significant increase in oil prices began that continues in the first decade of the twenty-first century. This led to the familiar—though episodic—process of hand-wringing by politicians and the media about rising oil prices, dependency on Middle Eastern oil, and the absence of a sustained and coherent federal energy policy. The G.H.W. Bush administration proposed federal energy policy legislation to increase the production of oil, natural gas, and nuclear power, and to open the Arctic National Wildlife Refuge (ANWR) for gas and oil exploration, as contentious then as in 2006. The Clinton-Gore administration promised a broad-based energy tax (the "BTU tax") which failed because it was unpopular with consumers and opposed by powerful industries and their congressional representatives (Joskow, 2002; Lutzenhiser et al., 2002: 222). Public complacency about energy ended quickly after 1999 as oil, gasoline, and natural gas prices increased significantly. When George W. Bush was inagurated in 2001, he proclaimed another "energy crisis." The new Bush administration proposed another "supply side" policy to open up public lands (including ANWR) for drilling and exploitation. This policy proposal contained large subsidies for the fossil fuel and mining industries, with precious little to develop alternative energy sources. After 9–11, energy fears became enmeshed with the expensive, unpopular War in Iraq, which lasted longer than World War II. Even with Republican congressional majorities, the controversial energy bill failed regularly in Congress, faced with opposition for many reasons. Energy was again a contentious and highly visible part of America's political controversies. In 2005 a version of the energy bill became law (but without drilling rights in ANWR or funds for alternative energy development). After dominating the auto market for a decade, the sales of large autos (particularly SUVs) slumped and smaller, fuel-efficient autos were again becoming popular—though not a significant part of America's vehicle fleet.

This historical detour frames some of the ways that energy mediates between human societies and the environment. As you can see, energy "crisis" moods come and go, as do political and media attention to energy problems. If there is no energy crisis, there certainly is an *energy predicament*. A *crisis* is a rapidly deteriorating situation that, if left unattended, can lead to disaster in the near future. But there is an energy *predicament*, that is, an ongoing chronic problem that, if left unattended, can result in a crisis (Rosa et al., 1988:168). This predicament has a number of dimensions to which this chapter turns, including (1) sources of energy problems; (2) studies about the relationship between energy and society, or what some scholars have termed *energetics;* (3) the current energy system and some possibilities for alternative methods of producing energy; and (4) some policy issues about transforming existing energy systems.

ENERGY PROBLEMS: ENVIRONMENTAL AND SOCIAL

Our energy predicament has four interacting dimensions, or problems: (1) source problems, having to do with energy resource supplies; (2) problems related to population growth and economic growth and development; (3) global policy and geopolitical problems; and (4) sink problems, having to do with energy by-products, health hazards, and greenhouse gas emissions.

Source Problems: Energy Resource Supplies

As the twenty-first century began, three nonrenewable fossil fuels (oil, natural gas, and coal) supplied about 75% of the world's commercial energy needs. Nuclear power supplied 6%, and renewable sources, such as hydropower and wind, solar, and geothermal power, together supplied another 7%. In the less developed countries (LDCs) an important source of renewable energy is

biomass (mostly fuelwood and charcoal made from wood). It is still the main source of heating and cooking for about half of the world's population (U.S. Department of Energy, British Petroleum Institute, Worldwatch Institute, and the International Energy Association, cited in Miller, 2005: 351–352).

Since the pessimistic estimates of world oil reserves in the 1970s, estimates of known reserves doubled (Stanislaw and Yergin, 1993: 88), and energy analysts agree that in the near term the earth's supply of fossil fuels will not be a problem. At present consumption rates, known reserves of crude oil and natural gas will last many years, and there is an awful lot of coal in the world, but its use carries extraordinary risks compared to those of oil and natural gas.

Consider oil. There is a rough consensus among energy analysts that at current rates of consumption, about 80% of known oil reserves will last for between between 40 and 90 years (Miller, 2005: 353). But world oil discovery peaked in the 1960s and has been declining ever since, and experts currently estimate that world oil production will peak sometime between 2010 and 2020 and will decline thereafter (Alkett, 2006; McKenzie, 1992; Podobnik, 1999; Prugh, 2006). The discovery, production, and consumption of energy resources is said to "peak" because they follow a bell-shaped curve, beginning small, rising steadily, and declining unexpectedly to near exhaustion, a pattern first described by Shell Oil geologist oil expert M. King Hubbert in 1956. Like global warming, the concept of an "oil peak" is accepted, but the particulars of timing are controversial (Motavalli, 2006; Roberts, 2004: 171–173; Yeomans, 2004: 106–108). But if you think that new oil discoveries will forever push back resource depletion, consider some stubborn facts. At present (not future) rates of consumption, (1) the estimated crude oil reserves under Alaska's North Slope—the largest ever found in North America—would meet world demand for only six months, or the U.S. demand for three years. (2) With the world's largest oil reserves, Saudi Arabia alone could supply the world's oil needs for only 10 years (Miller, 2005:229). Hardly anyone thinks that in the future, this much oil will be discovered every 10 years. Oil company executives have known this for some time. Two decades ago Robert Hirsch, then vice president and manager of research services for Atlantic Richfield Oil Company, urged beginning an orderly transition to alternate energy technologies in the early to middle twenty-first century (1987: 1471).

Like projections about other scientific questions like global warming, how long it will take to deplete fuel and mineral reserves are expert guesstimates, notoriously dependent on assumptions and contingencies. To mention a few in particular, if trends toward greater MDC energy efficiency resumes with full force, declining demand could stretch out supplies many years beyond current estimates. On the other hand, depletion–time estimates could shorten because of lack of success in exploring likely geological sources, or unexpected growth in either the world market economy or economic development in the LDCs. My point is that even if constraints are not as strong as thought in the 1970s, supply concerns continue.

Population Growth, Economic Development, and Distribution Problems

In 2000, the world's 6 billion people consumed almost 14 terawatts of energy (a terawatt is equal to the energy in 5 billion barrels of oil). But that world consumption statistic hid very unequal consumption among nations. MDCs have about one-fifth of the world's people but consume almost three-fourths of the world's energy. Even among MDCs, North Americans consume more energy per capita or per dollar of GDP than do other MDC people. Americans drive bigger cars and drive them farther, live in bigger houses and heat, cool, and light them more, and work in buildings that use substantially more energy per square meter than do Europeans (Joskow, 2002: 107). Comparisons with LDCs are more stark: One American consumes as much per capita energy as do 3 Japanese, 6 Mexicans, 14 Chinese, 38 Indians, 168 Bangladeshis, 280 Nepalis, or 531 Ethiopians (Goodland et al., 1993: 5)

If projections for future energy demands and population growth hold true—and we keep our current disregard for energy efficiency—by the year 2100 by most estimates the world's 10 billion people will need about 50 terawatts of electricity, or around 4 times what we produce today. That is a staggering amount of power. Generating it would require an energy infrastructure far larger and costlier than any that exists today (Roberts, 2004: 223). Furthermore, if the large numbers of Chinese, Indians, and others in LDCs were to become energy consumers living even remotely close to the present living standards of MDC people, that would place enormous strains on the supply of global energy resources, and the resulting environmental degradation, toxic wastes, and heat-trapping greenhouse gases would be intolerable.

Policy and Geopolitical Problems

As noted earlier, the momentum toward greater energy efficiency stalled by 1990. Even though some of it lasted, there were disturbing signs of increasing per capita energy consumption (Klare, 2002: 101). The rebound in energy consumption was partly a consequence of the marketing of gas-guzzling sport utility vehicles and pickup trucks that made up about half of all U.S. new car sales. At a deeper level, the rebound in consumption was a consequence of public policy. Recent U.S. energy policy has been *supply-side policies* promoting an increased supply of energy resources and ensuring a low price for energy. Such policies undercut much of the potential for conservation to have an effect on energy markets. Chapter One discussed "economic externalities," and energy markets have some significant costs—ones not directly paid for by either energy producers or consumers. Here are some important ones, emphasizing oil markets:

- Government subsidies and tax breaks for oil companies and road builders
- Pollution cleanup

- Military protection of oil supplies in the Middle East (at least $30 billion a year not including the Iraq war)
- Environmnental, health, and social costs such as increased medical bills and insurance premiums, time wasted in traffic jams, noise pollution, increased mortality from air and water pollution, urban sprawl, and harmful effects on wildlife species and habitats (Miller, 2005 : 384)
- Various costs in U.S. deficit balance of payments between exports and imports (more than one-third of which are due to energy imports) (Kingsley, 1992: 119)

If you really want to get a sense of some of these, imagine factoring into the price of each gallon of gasoline you buy *a share* of other costs. Think about your share of the total and cumulative costs of U.S. military and foreign aid in the Middle East to maintain relations with oil suppliers—including the war in Iraq. Indeed, if all of the health, geopolitical, and environmental costs of oil were internalized in its market price and if government subsidies from production were removed, oil would be so expensive that much of it would immediately be replaced by improved efficiency or other fuels (Miller, 1998: 434).

Demand-side policies that evolved during the 1990s had similar problems. Although by eschewing price controls, rationing, and energy-allocation policies of the 1970s, it viewed the proper role of government to respond to market imperfections and breaking down regulatory barriers. They did moderate prices, which fell steadily by about 20% during the decade even though they were very volatile. But energy consumption grew steadily—17% from 1991 to 2000—and net imports grew by more than 50% during the 1990s. Canada became the major supplier of U.S. natural gas, while the Persian Gulf continued to provide about 30% of world oil production. Although the United States imports only about 18% of its oil from the Gulf, it has a significant strategic interest in the region because its major allies (Japan and Western Europe) rely mainly on the Middle East (Stanislaw and Yergin, 1993: 86–87).

The International Energy Agency, in its *World Energy Outlook 2000*, expects fossil fuel consumption to grow by 57% (2% annually) between 1997 and 2020 (Dunn, 2001: 40). In the world economy, geopolitical conflicts of interest are likely between the commodity-producing nations and the consuming nations for both fuel and nonfuel minerals. Most disadvantaged will be nations that have neither the money to buy much fuel nor the resources to sell. Abstractly, energy is an important part of the patterns of world trade and politics that will determine who is poor and who is affluent, and who is well fed and who is hungry. It is unthinkable to try to understand either current world tensions or environmental problems without considering the importance of the production and distribution of energy around the world.

The important point is not that fossil fuels are becoming absolutely exhausted, but that the era of relatively cheap fuels is coming to an end. It is easily available oil that is scarce, not all oil. Meeting energy needs in the future will require much greater investments than in the recent past. It means extracting fuels from increasingly difficult and marginal sources, accommodating the needs of a growing human population, and paying the geopolitical overhead costs of an orderly energy market in a world system of nations. These costs don't even include the costs of increased environmental damage (Hirsch, 1987; Holdren, 1990: 158; Klare, 2002; Mazur, 1991: 156; Motavalli, 2006: 29).

Sink Problems: Energy and Environment

Though energy supplies are thought to be less constraining now than in the 1970s, environmental problems caused by the present energy system are thought to be more severe and getting worse (Flavin and Dunn, 1999: 24; Motavalli, 2006; Roberts, 2004; Stanislaw and Yergin, 1993: 88). Stated abstractly, the most pressing problems may not be source problems, but sink problems.

Burning fossil fuels is a major source of anthropogenic CO_2, a major heat-trapping greenhouse gas. Burning oil products also produces nitrous and sulfur oxides that damage people, crops, trees, fish, and other species. Urban vehicles that run almost exclusively on petroleum products cause much urban pollution and smog. *Oil spills* and leakage from pipelines, storage, transportation, and drilling sites leave the world literally splattered with toxic petroleum wastes and by-products. The ecosystem disruption from oil spills can last as long as 20 years, especially in cold climates. Oil slicks coat the feathers and fur of marine animals, causing them to lose their natural insulation and buoyancy, and many die. Heavy oil components sink to the ocean's floor or wash into estuaries and can kill bottom-dwelling organisms (e.g., crabs, oysters, and clams), making them unfit for human consumption. Such accidents have serious economic costs for coastal property and industries (such as tourism and fishing).

In 1989 the large tanker *Exxon Valdez* went off course, hit rocks, and spilled 11 million gallons of oil in Alaska's Prince William sound, resulting in unthinkable damage to ecosystems and local human communities. It wound up costing $7 billion (including cleanup costs and fines for damage).[2] By 1998, virtually all merchant marine ships had double hulls, but only 15 percent of oil supertankers did, even though in theory the Oil Protection Act of 1990 regulated supertankers to reduce the danger of such oil spills. To get around the law, many oil carriers shifted their oil transport operations to lightly regulated barges pulled by tugboats, a reduction reduction in oil-spill safety that led to several barge spills. In 2002 the oil tanker *Prestige* sank off the coast of Spain and leaked twice as much oil as did the *Exxon Valdez.* Because they are such graphic media topics, oil tanker accidents, pipeline accidents, and drilling blowouts get the most publicity. But experts estimate that between 50 and 90% of the oil reaching the oceans comes from the land, when waste oil dumped on the land by cities, individuals, and industries ends up in streams that flow into the ocean (Miller, 1998: 527–529; 2004: 507).

Coal is hazardous to mine and the dirtiest, most toxic fuel to burn. Mining often devastates the land, and miners habitually suffer and often die from black lung disease. Burning coal produces larger amounts of particulate matter and CO_2 than burning other fossil fuels, and electric power generation (mostly from coal) is the second largest producer of toxic emissions in the United States. Burning coal alone accounts for more than 80% of the SO_2 and NO_x injected into the atmosphere by human activity. In the United States alone, air pollutants from coal burning kill thousands of people each year (estimates range from 65,000 to 200,000), contribute to at least 50,000 cases of respiratory disease, and result in several billion dollars in property damage. The most threatening product of coal-burning power plants are particles of toxic mercury.

In 2000, the National Academy of Science estimated that 60,000 babies a year might be born with neurological damage from mercury exposure in pregnant women who have consumed mercury-laden fish. Also, burning coal releases thousands of times more radioactive particles into the atmosphere per unit of energy produced than does a normally operating nuclear power plant. Damage to the forests of Appalachia, the northeast United States, eastern Canada, and Eastern Europe can largely be attributed to coal-fired industrial plants. Reclaiming the land damaged by coal mining and installing state-of-the-art pollution control equipment in plants substantially increases the costs of using coal. As with petroleum, if all of coal's health and environmental costs were internalized in its market cost and if government subsidies from mining were removed, coal would be so expensive that it would be replaced by other fuels (Fulkerson et al., 1990: 129; Miller, 2005: 365).

Summarizing, our energy predicament includes future source constraints and the ways in which the present energy system is intimately connected with environmental degradation, population and economic growth, climate change, and the global equity and geopolitical tensions that plague the world. Later in this chapter I will turn to some of the possibilities, and options for transforming the present system to address our energy predicament. But there are some clues about these from the relationship between energy to society, and studies of that relationship by scholars, to which I now turn.

THE ENERGETICS OF HUMAN SOCIETIES

The ultimate source of *all* the world's energy is radiant energy from the sun. Fundamental to understanding the energy flows of both ecosystems and human social systems, autotrophic (green) plants transform solar radiant energy into stored complex carbohydrates by the process of photosynthesis. These are then consumed and converted into kinetic energy through the respiration processes of other species. Energy filters through the ecosystem as a second species consumes the first, a third the second, and so on. Unlike matter, energy is not recycled but tends to degenerate through the process of *entropy* to disorganized forms such as heat, which cannot be used as fuel for further production of kinetic energy or to sustain respiration. Such inefficiency means that only a portion of stored potential energy becomes actual kinetic energy.

Of course, this inefficiency is a great benefit, because we are now living off the stored energy capital of millions of years ago, but it is also true that the second law of thermodynamics (entropy) means that the relatively plentiful supplies of these fuels are ultimately exhaustible. More precisely, we will never absolutely use them up, but they can become so scarce and low grade that the costs of the energy and investment necessary to extract, refine, and transport them exceed the value of their use. We will have to squeeze the sponge harder and harder to get the same amount of energy, and the damage to the environment will increase as we do so.

Low- and High-Energy Societies

All human societies modify natural ecosystems and their energy flows, but they vary greatly in the extent to which they do so. Human respiration alone requires enough food to produce about 2,000–2,500 calories a day, but people in all human societies use vastly more energy than this minimum biological requirement to provide energy necessary for their shelter, clothing, tools, and other needs.[3]

Table 4.1 illustrates the prodigious growth of world energy consumption since the beginning of the industrial era and the increasing human dependence on petrochemicals. By contrast, the traditional fuels of preindustrial societies (e.g., wood, dung, plant wastes, and charcoal) are still the energy mainstays of many people in poorer LDCs. While the aggregate energy consumption of the world has grown, it is also important to note that most of that growth is accounted for by the MDCs as high-energy societies. Indeed, a typical suburban household of an upper-middle-class American family consumes as much energy as does a whole village in many LDCs!

Table 4.1 Per Capita Energy Consumption in Different Types of Societies

Society	*Kilocalories per day per person*
MDC (U.S.A.)	260,000
MDC (other nations)	130,000
Early industrial	60,000
Advanced agricultural	20,000
Early agricultural	12,000
Hunter-gatherer	5,000
Prehistoric	2,000

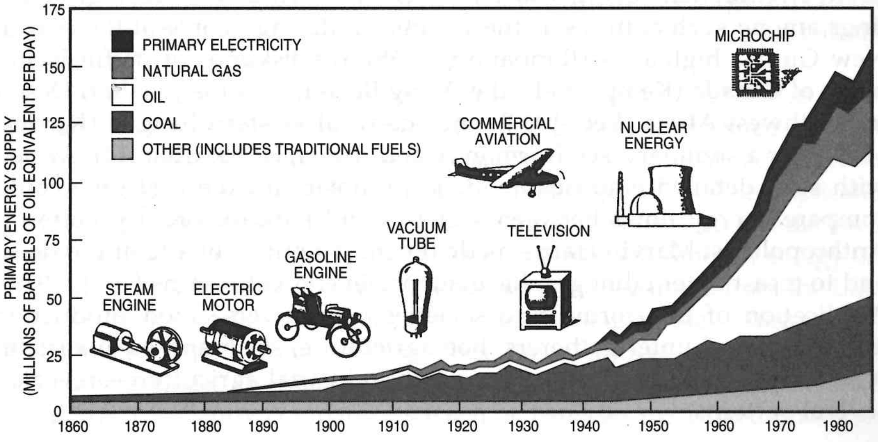
Source: Adapted from Miller, 2002: 333.

Industrialization and Energy

Industrialization was possible because new technologies of energy conversion were more efficient than traditional fuels. During the first phase in the early nineteenth century, the dominant technology depended upon coal mining, the smelting and casting of iron, and steam-driven rail and marine transport. The system's components were closely intertwined, and the creation of integrated mining, smelting, manufacturing, and transportation infrastructures made industrialization possible. By the beginning of the twentieth century, the system was being radically transformed again—by electric power, internal-combustion engines, automobiles, airplanes, and the chemical and metallurgical industries. Petroleum emerged as the dominant fuel and "feedstock" for the petrochemical industry. See Figure 4.1.

Withdrawals of so much energy from nature in the United States and other MDCs required substantial modifications of natural energy flows. Industrial cities alter ecosystems radically, requiring enormous amounts of energy from remote reserves of fossil fuels to power industry, heating, lighting, cooling, commerce, transportation, waste disposal, and other services. Cities become inert and relatively abiotic. Wastes are no longer naturally absorbed but must be transported to waste treatment plants (Humphrey and Buttel, 1982: 139). In addition, industrial farmers use machinery, fertilizer, and fuel manufactured by urban industries, and food is no longer consumed mainly on farms. MDCs thus have integrated agricultural-industrial consumption systems that use enormous amounts of fossil fuels and vastly modify natural ecosystems and energy flows. Since energy plays such a powerful role in connecting and

Figure 4.1 Growth in Energy Consumption in the Industrial Era
Source: Adapted from G.B. Davis, *Energy for Planet Earth,* 1990. Copyright by Scientific American Inc. Used with permission.



modifying both ecosystems and social systems, it is therefore an important topic for the social science understanding of human–environment relationships.

Social Science and Energetics

Remarkably, in spite of how obvious the last sentence in the preceding paragraph is, in early social science there were only fragmentary attempts to understand the energy–society relationship (Carver, 1924; Geddes, 1890; Ostwald, 1909; Soddy, 1926; Spencer, 1880).[4] Beyond the notion that energy is the crucial linkage between societies and their biophysical environments, about the only generalization that remains from these early analyses is that increases in energy production and efficiency are related to increases in the structural complexity and the scale of human societies (Lutzenhiser et al., 2002: 223). That represents very little in terms of cumulative development of understanding the environment–energy–society relationship!

After World War II, prominent anthropologist Leslie White (1949) rekindled interest in energetics by describing the resource and technological bases for social evolution, and sociologist Fred Cottrell developed the notion that available energy limits the range of human activity. He tried to demonstrate the pervasive social, economic, political, and even psychological change that accompanied the transition from a low-energy society (preindustrial) to a high-energy society (industrial), and argued that the vast social change to modernity could ultimately be traced to energy conversion (Cottrell, 1955; Rosa et al., 1988: 153).

Macrolevel Studies of Low-Energy Societies

In the 1960s anthropologists conducted meticulous empirical studies about environment–energy–society interactions in diverse ecological settings among such cultures as the Tsembaga Maring people of the central New Guinea highlands (Rappaport, 1968), the Eskimos of Baffin Island north of Canada (Kemp, 1971), the !Kung Bushmen of the Kalahari Desert in Southwest Africa (Lee, 1969), and the rural Western Bengali (Parrick, 1969). For a summary, see Kormondy and Brown (1998: Chap.14). Armed with such detailed empirical evidence, scholars for the first time could compare energy flows between societies and look for orderly patterns. Anthropologist Marvin Harris made the most significant attempt to do so and to recast older ethnographic evidence in energetic terms (1971, 1979). Application of this formula to societies with diverse food production technologies—hunter-gatherers, hoe agriculture, slash-and-burn agriculture, irrigation agriculture, and modern industrial agriculture—revealed several patterns.

First, while confirming the central insight of historic energetic theories (about the relationship between energy efficiency and societal size and social complexity), these studies cast doubt on the argument of early analysts that increased technological efficiency led to increased available energy, which in turn led to larger populations and greater social complexity. The newer anthropological evidence suggested that population pressure was often the driving force of this process, promoting increased technological efficiency of energy conversion to meet rising demands (for a recent confirmation of this, see Boserup, 1981). *Second,* anthropological studies suggested that high-energy societies would typically replace or assimilate low-energy societies whenever they came into contact. The most obvious example for Americans is the outcome of contact between Europeans and Native Americans, but evidence of this replacement around the world is compelling.[5] *Third,* these studies questioned the long-term outcomes of the process of energy intensification. The recurrent response to population pressures was an upgrading of consumption, and preindustrial societies often overburdened their environments, depleting essential resources faster than they could be regenerated, and disrupting ecological cycles—and their own long-term sustainability. Anthropological literature is replete with evidence in preindustrial societies about ecological collapse (Diamond, 2004). Importantly, this evidence provides a historical context for our contemporary energy predicament: problems with growing energy/resource consumption and social and environmental sustainability (Rosa et al., 1988: 157).

Macrolevel Studies of High-Energy Societies

Analysis of energy flows in complex MDCs is no easy matter. Economists dominated energetic research after the oil shocks of the 1970s, and they emphasized the importance of energy to the economic performance of societies. Longitudinal research within societies and comparative analyses all suggested a strong relationship between the growth of energy production and the increase in measures of economic growth, such as the gross national product (GNP) (Cook, 1971). See Figure 4.2.

These studies interpreted economic indicators such as the GNP as indicative of social well-being, and since economic growth represented improvements in societal well-being, it was but a short step to infer that energy growth was essential to societal well-being (Mazur and Rosa, 1974). The implication was that constraints placed on energy consumption would lead to a decline in wealth, although much room remained for increased efficiency of energy use.

But note: When MDC market economies were separated from the LDCs and nonmarket socialist economies, this relationship virtually disappeared. Many studies supported this finding. These included cross-national longitudinal studies, studies examining the energy use of countries with similar living standards, case study comparisons (such as between the United States and

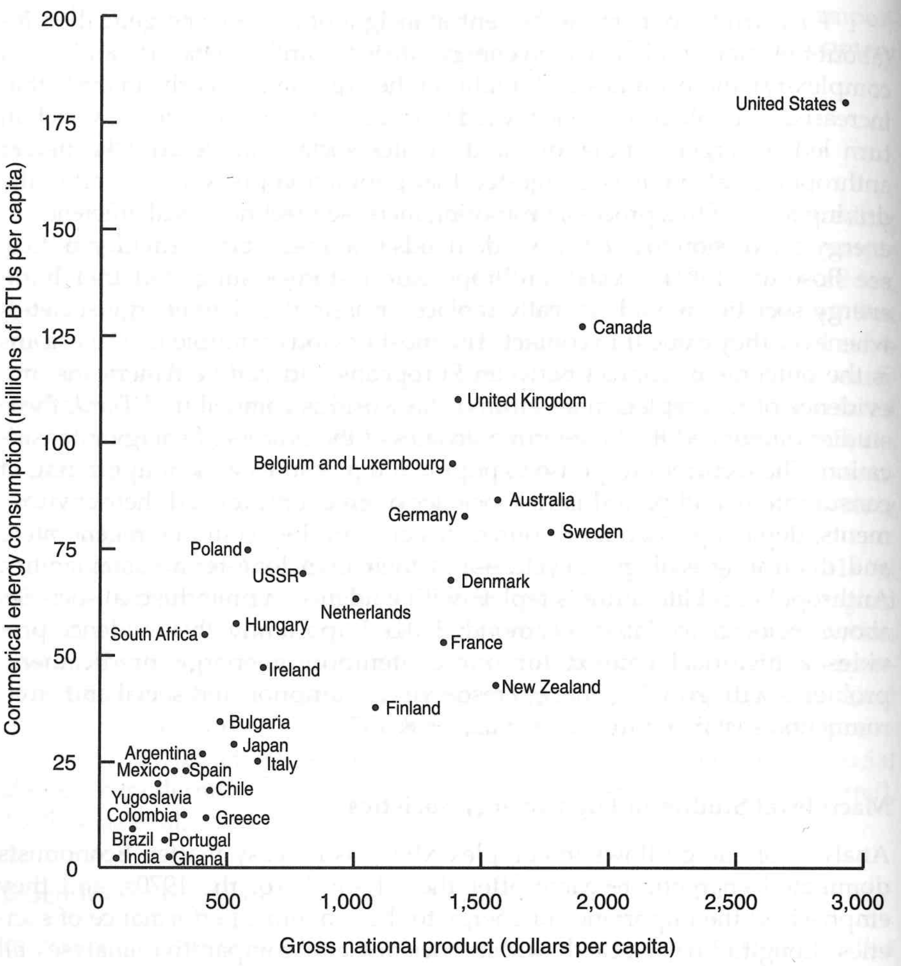


Figure 4.2 The Relationship Between Per Capita Energy Consumption and Gross National Product, 1971

Source: Adapted from E. Cook, 1971.

Sweden), and cross-national studies of the relationship between energy intensity, social structure, and social welfare (Rosa et al., 1981, 1988; Schipper and Lichtenberg, 1976). You can see the "looseness" of this relationship between energy consumption and gross national product measures in Figures 4.2 and 4.3, and particularly in the area marked off with an elliptical field in Figure 4.3.

Macrolevel studies and historical data point to the same conclusion: that economic development in the MDCs went through two phases, from (1) rapid industrialization and consumption being highly dependent on increased use of energy from fossil fuels, to (2) economic growth becoming less energy-intensive. In the latter phase, economic growth and social well-being can increase with decreasing energy intensity because of shifts in production from industrial to service sectors and because of the adoption of more efficient technologies. In other words, a threshold level of high energy consumption is probably necessary for a society to achieve industrialization and modernity, but once achieved, there is a wide latitude in the amount of energy needed to sustain a high standard of living. Given that latitude, industrial societies could choose slow-growth energy policies without great fear of negative, long-term consequences to overall welfare (Reddy and Goldemberg, 1990: 113; Roberts, 2004: 215).

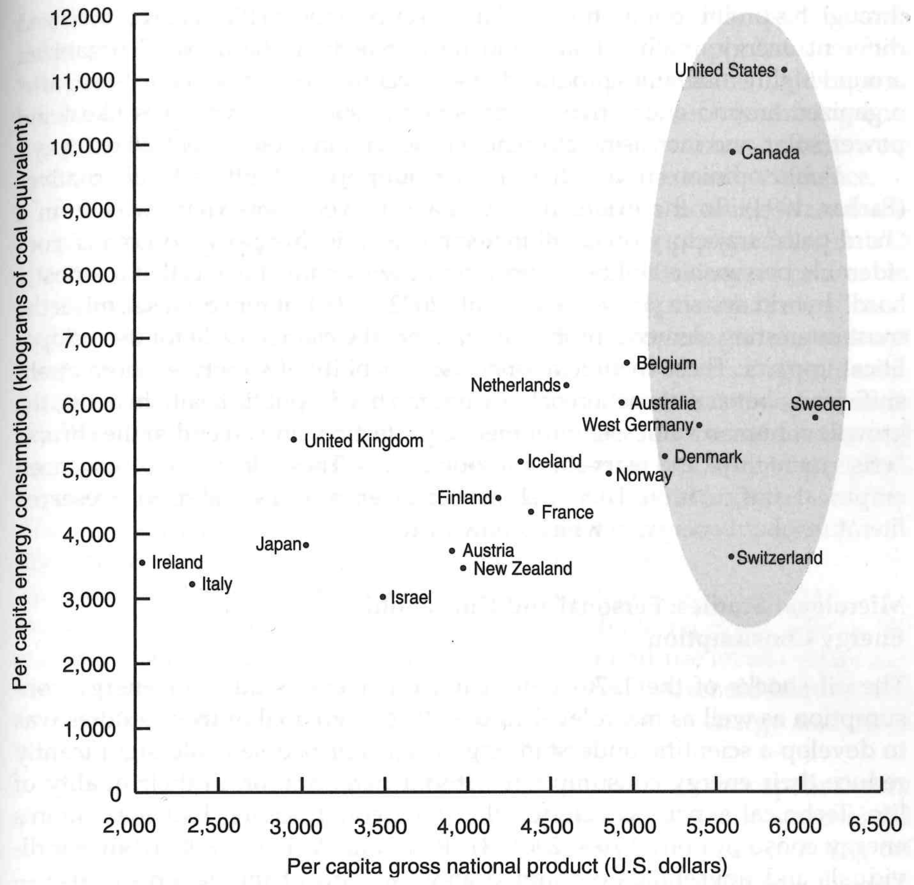


Figure 4.3 Per Capita Energy Consumption and Gross National Product in 20 Industrial Nations

Source: Adapted from Humphrey and Buttel, 1982, p. 159; and Sivard, 1979.

This evidence has profound implications for understanding and addressing the current world energy predicament, but it has not had much impact on political debates and discourse about energy. For instance, Amory Lovins, cited earlier, had a significant impact by popularizing energy frugality through his prolific publications and media appearances (1977). He emphasized different energy "paths" that could be pursued: A "hard path" organized around highly fossil fules produced in very centralized ways, and a "soft path" organized around alternative energy sources (such as renewables like wind power, solar, and increasing efficiency) produced in more decentralized ways.

Public opinion surveys have shown support for "soft path" alternatives (Farhar, 1994). To the extent that we have moved somewhat away from a "hard path" trajectory (in small increments)—it is due partly to Lovins' considerable persuasive abilities—resulting in what some have called a "mostly hard" hybrid system (Lutzenhiser et al., 2002: 238). But for social scientists the most interesting elements of the soft path are the claims made for its sociopolitical impacts. These include an increased viability of society, economic self-sufficiency, better satisfaction of basic human needs, public health benefits, the growth of human values, environmental protection, and an end to the chronic "crisis mentality" and fears about resource wars. These claims, of course, need empirical confirmation. There is, however, an empirical social science research literature about energy, to which I now turn.

Microlevel Studies: Personal and Household Energy Consumption

The oil shocks of the 1970s stimulated microlevel studies of energy consumption as well as macrolevel studies. The main goal of these studies was to develop a scientific understanding of whether people could significantly reduce their energy consumption without deterioration in their quality of life. Technical experts concluded that they could, saving half the nation's energy consumption (Ayres, 2001: 31; Ross and Williams, 1981). Since individuals and households consumed about a third of the nation's energy—roughly evenly divided between transportation and home needs—they were viewed as a vast untapped potential source for energy conservation that would be responsive to social policy.

Engineering perspectives guided early microlevel studies, assuming that energy consumption could be easily explained by physical variables such as climate, housing design, and the efficiency and stock of appliances and vehicles (Rosa et al., 1988: 161). As applied to vehicles and transportation, the design of more efficient vehicles caused effective energy savings in the 1980s and early 1990s. The fuel efficiency of American cars and trucks doubled as the cumulative result of many engineering changes significantly contributed to increasing the nation's energy efficiency. Changes such as installing catalytic converters to reduce urban air pollution also addressed other environmental concerns (Bleviss and Walzer, 1990: 103, 106). These were engineering modifications that over time changed the machines driven and the composite fleet of cars and trucks, but not alternations or curtailments in the driving behavior of Americans. The only successful behavior change of the era was the one mandated by law, lowering the federal interstate speed limit from 75 to 55 mph (later, as you know, it was raised back to 65 mph, and 75 mph in some states). Attempts to encourage *voluntary* behavior change and curtailment, such as driving less, car pooling, bicycling, walking, or making greater use of mass transit, were dismal failures—at least on a scale large enough to make much difference.

As with transportation, energy conservation in housing was dominated by energy engineering perspectives emphasizing physical variables like climate, housing design, and the number and efficiency of household appliances. Unlike transportation, however, the assumption that reengineering homes and appliances would significantly reduce energy use was not confirmed. For instance, the Princeton University Twin Rivers Project, a massive and detailed five-year field research effort, found that townhouses in similar housing tracts with similar square footage, number of rooms, and appliance packages varied enourmously in energy consumption, when occupied by families of similar size. The energy use of new occupants could not be predicted from that of the previous occupants, and the impacts of lifestyle on household energy consumption was dramatic (Rosa et al., 1988: 161; Socolow, 1978). Furthermore, other studies of nearly identical units occupied by demographically similar families have reported 200 to 300 percent variations in energy use, and in particular end-use levels. Vastly different amounts of energy were used for appliances, household heating and cooling, hot water, and so on. The "average consumer" in energy analysis is somewhat mythical (Lutzenhiser et al., 2002: 240).

Much of this research was not guided by a particular concept or theory and sought commonsense ways of asking people to reduce household energy consumption, such as turning down their thermostats, closing off unused rooms, or taking shorter showers. As policy-oriented research, early post–oil shock studies provided information and education programs about conserving energy, including home energy audits. They were consistently unsuccessful, and their only successes focused on giving consumers better feedback information about their consumption. They did, however, recognize a particularly difficult barrier to the self-monitoring of energy use in households: that energy is largely invisible.

Unlike early studies, later studies of household energy consumption were guided by two conceptual models: an *economic-rationality model,* favored mainly by economists and engineers, and an *attitude-behavior consistency model,* favored by social psychologists. The economic model emphasized that humans "rationally" respond to changing energy prices, given the presence of more efficient technologies. While escalating energy prices and efficient technologies played an important role in energy conservation, a large body of research suggested that economic analyses exaggerate their importance, while underestimating the effects of noneconomic behavior in shaping energy flows (Lutzenhiser, 1993). Partly because of the relatively constant (or "inelastic") nature of energy demand, behavior is slow to respond to price changes, and many energy-use behaviors remain unexplained by price changes.

Furthermore, the acquisition of accurate and reliable *information* about energy use, prices, investment costs, expected savings, and other nonprice factors are assumed, but ignored by a simple economic-rationality approach (Gardner and Stern, 1996: 100–124; Rosa et al., 1988: 162–163). Even when consumers claim to be well informed about energy and believe they are acting in an economically rational way, they may be mistaken. Since energy use is invisible and intrinsically difficult to quantify and analyze (even for experts), people are forced to develop ad hoc ways of accounting that—quite reasonably—overestimate the cost of conservation investments. Because people must pay attention to larger goals and tasks, many routine energy-related actions simply go unnoticed. For example, studies about household energy-related behavior that asked people to keep diary records reported that people were surprised at how often they "caught themselves in the act" of doing things like opening doors, peering into the refrigerator, or running hot water (Lutzenhiser et al., 2002: 246–247).

In contrast, attitude-behavior approaches seek to discover the effect of attitudes on energy problems and consumption. Researchers understood attitudes broadly as having cognitive, affective, and evaluative dimensions and focused on how education and information could change energy-use behavior. But studies often found discrepancies between attitudes and behavior. Attitudes may not overcome barriers to change, price and affordability, lack of knowledge, or energy-use conditions that are found in society rather than personal choices (such as the kinds of homes and autos being marketed). One study of household energy-use curtailment analyzed the interaction of price and attitudinal factors. It found that as the kind of energy-saving activity went from easy and inexpensive (such as changing temperature settings) to difficult and expensive (such as insulation and major furnace repairs), attitudes became less powerful as predictors of energy-use (Black et al., 1985, cited in Gardner and Stern, 1996: 77). The conclusion reached by many studies is that while prices and other economic factors play a significant role in household energy behavior and decisions, they can be limited by social, psychological, and marketing factors, such as the vividness, accuracy, and specificity of information; the trustworthiness of sources of information; institutional barriers to investment; and other noneconomic factors (Stern and Aronson, 1984).

Other studies about values and attitudes that more carefully controlled for differences in information found powerful effects of personal values—moral obligations to change—that often outweighed the power of price incentives (Heberlein and Warriner, 1983). Still others suggested the importance of involvement in civic and neighborhood organizations as predictive of energy conservation behavior by households, particularly in the contexts of community conservation programs (Olsen and Cluett, 1979; Dietz and Vine, 1982). Importantly, studies found that socioeconomic status shapes the modes of energy conservation behavior. More affluent households invest in energy efficiency, while poorer households cope with energy problems by lifestyle modifications and curtailments (Dillman et al., 1983; Lutzenhiser and Hackett, 1993).

Taking together the macro and micro studies of energetics, one thing is obvious: Energy behavior and consumption are far too complex to be accounted for by either a simple economic-rational or attitude-behavior model. Scholars need an integrated conceptual framework that combines economic, social, and attitudinal factors (Stern and Oskamp, 1987). One does not now exist, but summaries of research literatures provide some clues. Economic incentives for energy conservation are likely to be effective when

1. They are directed at specific external barriers, such as costs, access to credit, tax relief, or "inconvenience."
2. Significant barriers are not located in the larger social system. These might include urban sprawl with large distances between work, home, and shopping, the "inconvenience" factor, or the unavailability of super-insulated houses or efficient autos if they are not on the market.
3. They are not counterproductive, such as raising energy prices (without compensatory policies) that force low-income or elderly people to choose between heating homes or buying food in the winter.
4. They are combined with other influence techniques, such as information, public campaigns, curbside recycling programs, and moral and ethical arguments. (Gardner and Stern, 1996: 120–122)

Similarly, information and attitude change programs are more effective when they provide

1. *Accurate feedback* that ties information directly to people's behavior. One of the successes of early household energy conservation programs was to provide people with information about current energy use.
2. *Modeling* that provides illustrations about effective energy-use curtailments (rather than simply discussing the problem). Studies have, for instance, shown people videotapes about effective methods of energy-use curtailment rather than resorting simply to moral persuasion.
3. *"Framing"* messages to be consistent with people's worldviews and values. North Americans, for instance, are more receptive to arguments about improving "energy efficiency" than to those framed in terms of energy conservation. (Gardner and Stern, 1996: 83–88; 2002: chaps. 4, 5)

Despite the different approaches to understanding energy consumption, there seems to be a consensus that better ones must be more directly concerned with the *social contexts of individual action*—a recognition that behavior is inherently social and collective. Individual consumers often pursue social (and often noneconomic) ends when making energy-related decisions. This means that factors such as status display, ethical consumption, and pollution reduction influence how consumers assess incentives. Furthermore, various groups of consumers evaluate incentives differently (Stern et al., 1986: 162). A better approach to understanding energy consumption will require understanding how economic, attitudinal, and social processes interact to represent the complexity of real-world energy consumption. It will also require analysts to understand how technologies diffuse, as well as social networks and organizations. This becomes obvious when you think about it. Energy consumers get goods, services, information, housing, automobiles, and so forth through social networks and organizations that affect energy demand, use, and the environment. These include networks and organizations of architects, builders, subcontractors, code officials, automobile dealers, utility company representatives, appliance salesmen, and so on. They regulate and mediate the structure of relationships between consumers and manufacturers, and usually such intermediaries have few incentives to pursue energy efficiency (Lutzenhiser et al., 2002: 248, 255; Stern and Aronson, 1984). There are more clues about dealing with the present energy predicament in the world's present energy system, to which I now turn.

THE PRESENT ENERGY SYSTEM AND ITS ALTERNATIVES

I noted earlier that most (84%) of the world's present energy needs are supplied by finite or nonrenewable resources, and that most of that comes from three fossil fuels: oil, coal, and natural gas. Renewables such as hydropower, solar, wind, and biomass supply the remainder. Traditional biomass fuels such as wood, crop refuse, and dung are important fuels in poorer LDCs, where they may be commercially traded or obtained by foraging outside commercial markets.

See Table 4.2 for the percentages of the commercial energy flows in 1999 for the world and the United States. These proportions have not changed much in the recent decades. But they do change slowly, because of changing availability, costs, and technologies. In fact, there have been significant changes in the proportion of different fuels in the world's energy flows in the twentieth century. Coal declined from 55 to 23%, oil increased from 2 to 39%, natural gas rose from 1 to 23%, nuclear energy increased from 0 to 6%, and renewables (mainly wood and flowing water) decreased from 42 to 16% (Miller, 2005: 352). Other renewables, such as wind power, solar energy, geothermal, and hydrogen, together make up only a small fraction of U.S. and world energy flows, but some are growing at a rapid rate and have great future potentials.

Table 4.2 Commercial Energy by Source for the World and the United States, 1999

	World	*U.S.*
Nonrenewable	*84%*	*94%*
Oil	33%	39%
Coal	23	23
Natural gas	22	24
Nuclear	6	8
Renewable	*16%*	*6%*
Hydropower, solar, wind	6	3
Biomass	10	3
	100%	100%

Source: Adapted from the U.S. Department of Energy, British Petroleum, Worldwatch Institute, and the International Energy Agency. Cited in Miller, 2005: 352.

Fossil Fuels

This chapter discussed supply issues and other problems with most of the fossil fuels earlier, so I won't repeat that here. I should not, however, note some of their advantages. *Oil* is relatively cheap and easily transported, and it has a high yield of *net useful energy*. Net useful energy is the total useful energy left from the resource after subtracting the amount of energy used and wasted in finding, processing, concentrating, and transporting it to users. Oil is a versatile fuel that can be burned to propel vehicles, heat buildings and water, and supply high-temperature heat for industrial and electricity production.

Coal is everybody's least favorite fuel. But, there's an awful lot of it. Known and probable coal deposits could last the world between 200 and 1,125 years, depending on the rate of usage (Miller, 2005:364). Burning coal produces a high useful net energy yield, and because its mining and use is highly subsidized and many costs are externalized, it is the cheapest way to produce intense heat for industry and to generate electricity.

Natural gas, which I did not say much about earlier, is a naturally occurring geological mixture of methane, butane, and propane. In contrast to coal, it is clean burning, efficient, and flexible enough for use in industry, transportation, and power generation. It generates fewer pollutants, particulates, and CO_2 than any other fossil fuel: Natural gas releases 14 kilograms (kg) of CO_2 for every billion joules of energy produced, while oil and coal release 20 and 24 kg, respectively. But methane emission from leakage and incomplete combustion is a heat-trapping greenhouse gas 25 times more potent than CO_2. Like oil, natural gas is concentrated in a few parts of the world. Conventional supplies of natural gas and unconventional supplies (at higher prices) are expected to last from 62 to 125 years, depending on how rapidly its use grows. The Middle East, Russia, and Canada contain more than 70% of the world's known reserves, and production from Canadian wells, from which the United States imports the most, is expected to peak between 2020 and 2030. While natural gas can be shipped by pipeline cheaply on the same continent, it must be converted into *liquid natural gas* and shipped in refrigerated tankers to move it across the oceans—at present a difficult, dangerous, and expensive undertaking (Miller, 2005:362–363). Incidentally, coal can be used to produce synthetic natural gas by gasification or liquification, resulting in what is called "syngas." But its production and use and produces about 50% more greenhouse emissions. Without huge government subsidies, most analysts believe that syngas has a limited future (Miller, 2005: 365–366). Because of the advantages of natural gas over oil, coal, and nuclear energy, many analysts see it as the best fuel to help make the transition to improved energy efficiency and greater use of renewable energy in the next 50 years.

Besides their technical advantages, other advantages of fossil fuels are economic, political, and institutional. Quite simply, even with their problems, we have an enormous *sunk investment in infrastructures* to produce, process, and use them. To develop new energy technologies that are economical and practical on a wide basis requires large investments and decades of experimentation. Not surprisingly, the rules of the present energy economies were established to favor the systems now in place, not new possibilities, whatever their advantages. Maintaining the fossil fuel system has short-term but very real advantages for both individuals and the powerful corporate interest groups that profit from them. Historically, a set of tax biases and subsidies encourage the use of fossil fuels and favor present operating costs rather than long-term investment in alternatives.

Even though fossil fuel consumption will need to grow by 57% (2% annually) until 2020 to maintain their 84% share of current world energy, the "fossil fuel age" is probably coming to an end sometime in the next century. We cannot see its end, but its decline is already visible (Flavin, 2005: 30; Goodstein, 2004; Roberts, 2004). What could replace fossil fuels? Fifteen years ago, most experts would have said, with little hesitation, nuclear energy.

Nuclear Energy

Nonmilitary uses of nuclear energy produce electricity. In a nuclear fission reactor, neutrons split Uranium 235 and Plutonium 239 to release a lot of high-temperature heat energy, which in turn powers steam turbines that generate electricity. In principle, nuclear fission reactions are the same kind used in the atom bombs of World War II. The complicated systems required to regulate, modulate, contain, and cool such reactions make nuclear plants much more complex to operate than coal plants. I'm sure you know this is a very controversial way of producing energy.

In the 1950s, researchers predicted that nuclear energy would supply 21% of the world's commercial energy. But by 2000, after almost 50 years of development and enormous government subsidies, and $2 trillion in private investment around the world, the commercial reactors in 32 countries were producing only 6% of the world's commercial energy and 19% of its electricity. The industry is now growing at well under 1% per year, and the construction pipeline is virtually empty: Only 23 reactors with a capacity of 16,000 megawatts (MW) are currently under construction (in the 1980s plants with more than 200,000 MW were in the pipeline). Two more reactors were shut down in 2005, bringing to 116 the total number of reactors that have been permanently taken off line since the age of nuclear power began. Only China plans to build more than 50 new plants by 2020 to reduce its dependence on coal.

The relatively conservative International Energy Agency forecasts that nuclear power generation will peak within 10 years and then begin a slow decline (Flavin, 2006; Miller, 2005: 369). In the United States no new nuclear power plants have been ordered since 1978, and all of the 120 plants ordered since 1973 were canceled. Forty three out of 104 operating plants have been shut down longer than a year to restore safety features. The Nuclear Regulatory Commission (NRC) has not been asked to license a (real) new plant in many years. In fact, it looks very much like a technological option that is slowly failing (Miller, 2002: 347). Why?

National security reasons are well known. Nations that have the technical capacity for nuclear power can also build nuclear weapons. So the diffusion of nuclear energy contributes to the potential proliferation of nuclear weapons and geopolitical tensions. Several international rogue nations, such as Iran and North Korea, are not open to international inspection, and are widely suspected of using the development of nuclear electricity as a cover for developing a covert nuclear weapons capability. By 2006, tensions between the United States and several rouge nations were intense and politically destabilizing.

Second and equally well known are the risks of nuclear meltdowns and accidents that tarnished the public image of the nuclear option. Some became household words: Three Mile Island (TMI), a U.S. nuclear plant in Pennsylvania that allowed radioactive gases to escape, and Chernobyl, a plant in the former U.S.S.R. (now Ukraine) that experienced a complete meltdown. At TMI, partial cleanup, lawsuits, and damage claims cost $1.2 billion, almost twice the reactor's $700 million construction cost. The Chernobyl meltdown burned uncontrollably for 10 days, releasing more radiation into the atmosphere than the Hiroshima and Nagasaki bombs combined. Prevailing winds and rain sent radiocative fallout over much of Europe, and was measured as far away as Alaska (Charman, 2006:12). Because of built-in safety features, the risk of exposure to radioactivity from nuclear power plants in the United States and most other developed nations is said to be very low. Even so, the U.S. Nuclear Regulatory Commission estimated that there is a 15 to 45% chance of a complete core meltdown at a U.S. reactor in the next 20 years, and that 39 U.S. reactors have an 80% chance of containment shell failures, or an explosion of gases inside containment structures (Miller, 2002: 348).

Third, unlike coal or natural gas-fuelled plants, nuclear plants do not produce CO_2 or other greenhouse gas emissions. But they *do* produce long-lived, low-level radioactive waste, which is now accumulating in storage facilities on nuclear plant sites. The federal government has defaulted on its commitment to take back nuclear waste and store it safely in permanent waste repositories. They would need to be secure from corrosion, leakage, earthquakes, or sabotage for a *long* time. Close to where you live, perhaps?

Fourth, and less widely appreciated, the planning, construction, and regulation of nuclear plants make them a very uneconomic investment. A state-of-the-art coal-fired plant is a much less costly way of generating electricity. Economics may be a more potent barrier to the expansion of nuclear energy than negative public opinion or antinuclear activists. Furthermore, dismantling and securing the world's aging stock of spent reactors and the disposing of nuclear wastes pose safety hazards, political problems, and economic costs that may exceed those of the development and operation of plants (Gibbons et al., 1990: 88). Banks and lending institutions in the United States are leery of financing new nuclear plants, and utility investors have largely abandoned them.

Remarkably, with its enormous costs, demonstrated potential for serious accidents, and destabilizing geopolitical qualities, the specter of global warming meant that nuclear energy is again touted as an indispensable solution to the world's energy problems. The cover of a January 2006 *Newsweek* trumpeted "The Return of Nuclear Power." But I agree with Christopher Flavin's commentary in *Worldwatch* magazine entitled "Nuclear Revival? Don't Bet on It!" (Flavin, 2006). If nuclear energy is not the best bet to weaken our dependence on fossil fuels, what is? Flavin notes that "renewable sources of power provide about 20% of the world's electricity today, more than nuclear power does, and that the generating capacity of new wind plants alone that were ordered in 2005 was triple the figure for nuclear power." (2006: 20).

Renewable Energy Sources

Renewable energy sources are both the oldest energy sources used by humans and those with the greatest potential to provide energy and address the many problems created by the present system. Today renewable energy sources collectively constitute only 19% of the world and 7% of the U.S. energy sources. Taken together with investment and technological development, energy from flowing water, biomass (plant and animal remains), wind, and the sun *could* produce half of the world's energy within the next 50 years; perhaps sooner if combined with comparable investments in energy efficiency. The principles of generating energy by each source are well established. Most, however, are not now practical or affordable for commerecial energy on a large scale, even though they are rapidly becoming so.

Hydropower

Hydropower uses water from dammed reservoirs to turn turbine engines that generate electricity. In 2002 hydropower generated about 20% of the world's electricity (6 percent of the total energy flow); 99% in Norway, 25% in China, and 7% in the United States (but 50% on the West Coast). According to the United Nations, only about 13% of the world's technical exploitable potential for hydropower has been developed, much of it in China, India, and South America (Miller, 2005: 395). Hydropower is highly dependent on topography and annual changes in stream flow, and in much of the world, the potential for hydropower is already developed. It is a mature technology, with a moderate to high net energy yield and fairly low operating and maintenance costs. Hydropower dams produce no emissions of CO_2 or other pollutants. They have an operating life span of two to three times that of coal or nuclear plants. *Large dams* can be used to regulate irrigation and to provide recreation and flood control. On the other hand, construction costs are high and they are not environmentally benign. They destroy wildlife habitats, uproot people, and decrease natural fertilization (resilting) of prime agricultural land and fish harvests below dams, which makes their development inappropriate in many parts of the world, particularly in the LDCs (Reddy and Goldemberg, 1990: 111).

Biomass

Most of the world's people, and about 80% of LDCs residents, burn *traditional fuels,* such as wood, charcoal, dung, or plant residues. These *biomass* fuels account for 4 to 5% of the energy used in the United States and Canada, 30% in the LDCs, and about 10% of world energy flows (Miller, 2005: 398). Such fuels have a low net energy yield and are dirty to burn, producing a lot of carbon particulate, carbon dioxide, and carbon monoxide as byproducts. Heating a house with a wood or charcoal stove produces as much particulate matter as heating 300 homes with natural gas.

But while people in LDC cities may buy wood or charcoal, the great human virtue of traditional fuels is that most people who use them do not purchase them. In rural areas, the women and children usually gather twigs and branches or animal dung for cooking fuel instead of buying wood. Because most of the huge rural LDC population is poor and depends largely on noncommercial sources of energy, per capita use of commercial energy is much lower than in MDCs. Unlike fossil fuels, biomass is available over much of the earth's surface. In principle, biomass fuels are renewable and environmentally benign. But often the pressure of growing populations has stripped the land of trees and vegetation in the search for fuel wood, contributing to deforestation and desertification. The forests of China have been cut down for centuries, and the search for fuel wood today exacerbates desertification, soil erosion, and environmental degradation in much of sub-Saharan Africa, Nepal, and Tibet (Reddy and Goldemberg, 1990: 111).

Biomass can be used to produce other fuels. In many LDCs, *biogas digesters* use anaerobic bacteria to convert plant wastes, dung, sewage, and other biomass fuels to methane gas. After the generation of methane, used for lighting and cooking, the solid residue can be recycled for fertilizer for food crops or trees. If allowed to rot naturally, traditional fuels would themselves produce atmospheric methane. China has about 6 million such biogas digesters, and India has another 750,000, most constructed since 1985. Biomass digesters can be built for about $50, including labor. They can protect the environment by avoiding the necessity of cutting trees for fuel, and do not make rural villagers dependent on expensive energy from big companies, cities, or big power grids. But they have costs and limits. The supply of biomass fuelstock often varies seasonally, and if used in biogas generators it reduces its availability for its usual use as crop fertilizer (Reddy and Goldemberg, 1990). Where low-cost plant material is readily available, there are other possibilities. *Ethanol* is now being produced from corn and plant residues, and the United States is, as you know, experimenting with it as a gasoline additive to "stretch" petroleum supplies (not surprisingly, Midwestern corn farmers support this experiment with biofuels). Brazil experimented with converting its vehicle fleet to run on almost pure ethanol, which is not techically difficult. Some have envisioned cultivating large numbers of rapidly growing plants such as cottonwoods, sycamores, shrubs, or switch grass biomass plantations of "BTU bushes" to produce biomass fuel. But this means the conversion of huge amounts of forest, grassland, or farmland into single-species *biomass plantations* and further accelerates declining biodiversity.

Wind Power

Wind generators basically hook modern windmills to electric generators to produce power directly. Such power can only be produced in areas with enough wind. When the wind dies down, you need backup electricity from a utility company or some kind of energy storage system. Furthermore, unlike coal or oil, which pack a lot of energy in a small amount of fuel, the amount of wind that blows across each square meter carries only a little bit of power. It takes the combined effort of *many* wind generators installed across large areas of land to produce as much energy as a single fuel-burning power plant. Even with these limitations, wind power has a *vast* potential. According the 2003 *Wind Report* 12, "wind parks" on only one-tenth of the earth's land could produce twice the world's projected demand for electricity by 2020 (Miller, 2005: 396).

BOX 4.2 BIODIESEL?

Diesel fuel is an old idea. Rudolf Diesel, who invented the diesel engine, ran his demonstration model on peanut oil. Diesel engine fuel can be made from a variety of vegetable oils, including soy, palm, rapeseed (canola), and sunflower oil. Such biodiesel is cheaper and more environmentally friendly than petroleum diesel. Biodiesel fuels (from all sources) produce net greenhouse gas reductions like ethanol made from sugar cane and corn. By one estimate biodiesel typically reduces CO_2 by 41%, more than three times the reduction from corn ethanol. But, there are problems. For instance, Brazil's production of biomass ethanol requires just 3% of its agricultural land. But to supply 10% of the U.S. needs from biomass and biodiesel fuels would require 30% of its agricultural land. To supply palm oil, for instance, Malaysia plans to convert 3 million hectares of its tropic forest (about the size of Massachusetts) into a palm plantation. Opponents say producing biodiesel on a large scale would trash rainforests, deplete water reserves, reduce biodiversity, and raise food prices. While the small-scale production of biodiesel from waste oil and low-level conversion of oil crops could deliver a modest reduction in greenhouse emissions, the environmental benefits don't scale up. (*New Scientist*, 2006: 38-40)

In some areas the wind blows continuously, such as in the 12 contiguous U.S. Rocky Mountain and Great Plains states from the Canadian border to Texas. This region contains 90% of the wind power potential in the United States, which the U.S Department of energy (DOE) has dubbed the "Saudi Arabia of wind." Similar windswept areas around the world could produce a substantial proportion of world electricity needs. Wind generators produce no CO_2 or other air pollutants during operation, they need no water for cooling, and their manufacture and use produce little pollution. Some critics have charged that wind turbines suck birds and migratory birds into their blades. But, as long as wind farms are not located along bird migratory routes (which are mapped by very sophisticated studies), most birds learn to fly around them. Studies demonstrate that larger numbers of birds die when they are sucked into jet engines, killed by domestic and feral cats, and crash into skyscrapers, plate glass windows, communication towers, or auto windows. The land occupied by wind farms can be used for grazing and other agricultural purposes.

Wind energy is no longer a research project: It works, and works cheaply and reliably enough to compete with other energy sources. Between 1980 and 2004 the price of a kilowatt hour (kWh) of U.S. wind electricity dropped from 40 cents to about 4 cents, making it competetive with about the same price as electric power from coal, natural gas, or hydropower, and three times cheaper that electricity from nuclear power. With the same government subsidies as those sources, its price could drop to 1–2 cents per kWh, making it the cheapest way to produce power. Recognizing these economic advantages, several large corporations have begun investing in wind power (General Electric, Royal Dutch Shell), signalling a transition underway (Flavin and Dunn, 1999; Miller, 2005: 396–397; Sawin, 2005b). Despite the fact that it now produces only about 1% of the world's energy, it is a fast growing source (between 22 and 30% from 1995 and 2004). It accounts for twice as much electricity as produced by nuclear plants, 10 times as much as it did in 1990, and may produce 10 to 25% of the world's energy budget by 2050. In 2004, the world's leading producers, Germany, The Netherlands, the United Kingdom, Denmark, and Spain, produced twice as much wind energy as did the United States (Flavin and Dunn, 1999: 28; Sawin, 2005b).

Solar Energy

The direct use of energy from the sun has the greatest potential as an alternative energy sustainable source. An enormous amount of radiant energy falls on the earth's surface, which—if trapped and converted into usable forms—could supply the energy needs of the world. The total potential of *solar power* is enormous but, like wind power, it is variable, only possible where and when the sun shines, needing storage and backup systems. Solar radiation intensity varies by latitude and with the weather, but still, solar energy is available 60 to 70% of the days in the northern tier of American states, and 80 to 100% in the southern half of the country (U.S. Department of Energy, 1989). In the sunny regions closer to the equator that include many LDCs, the potential for solar energy is enormous and could supply much of the world.

Solar energy is now practical for space and water heating. The technology of using solar collectors for these purposes is relatively simple. For an investment of a few thousand dollars, using skills possessed by the average carpenter, it is possible to *retrofit* an older home to reduce the use of fossil fuels for heating water or rooms. A *passive solar heating system* captures sunlight directly within a structure through windows or sunspaces that face the sun and converts it into low-temperature heat. The heat can be stored in walls and floors of concrete, adobe brick, stone, or tile and released slowly during the day and night. *Active solar heating systems* have specially designed collectors, usually mounted on a roof with unobstructed exposure to the sun. They concentrate solar energy, heat a medium, and have fans or pump systems that transmit space heat or hot water to other parts of a building. The potential is very large for reducing America's combined heat bill this way. On a lifetime-cost basis, solar space and water heating is inexpensive in many parts of the United States. But since subsidies of fossil fuel prices make them artificially low in the United States, active or passive solar investments have been lower since the 1990s than after the oil shocks of the 1970s—when energy prices were higher and a number of tax incentives (briefly) existed. In many warm, sunny nations, such as Jordan, Israel, and Australia, solar energy supplies much of the hot water now, as it does for new housing in Arizona and Florida.

Photovoltaic electricity (PVE) is produced directly when semiconductor cells that create an electric current absorb solar radiation. You are probably familiar with PVE cells that energize small calculators and wristwatches. In many ways PVE is *the* superb energy source to create electricity: It creates no pollution, has no moving parts, and requires minimal maintenance and no water. It can operate on any scale, from small portable modules in remote places to multimegawatt power plants with PVE panels covering millions of square meters. Furthermore, most PVE cells are made of silicon, the second most plentiful mineral on the earth's surface (Weinberg and Williams, 1990: 149). But unlike windmills and solar space heating, producing wafer-thin silicon semiconductor solar cells is a high-tech business with considerable costs. Unlike the land around wind generators, land occupied by solar panels cannot be used for grazing or agriculture. But solar panels can sit on rooftops, along highways, and in sun-rich but otherwise empty deserts. Furthermore, the use of land would not be excessive. Hydropower reservoirs use enormous amounts of land, and coal mining needs more land than solar generators, if you include the area devoted to mining.

The main obstacles to the spread of PVE technology are its high cost (per megawatt), and the significant costs of building an infrastructure of solar panels. As you might guess, at present PVE accounts for a miniscule portion of world energy flows. Even so, like wind power, PVE is growing rapidly for several reasons. PVE generators have found niche markets in the world economy, where they are the cheapest way of delivering electricity to 2 billion rural villagers without having to extend centralized power grids from cities or big regional plants. By the late 1990s, PVE electricity was growing rapidly in places like Vietnam and Jamaica, where sunlight is plentiful. Increasingly, PVE cells are used to switch railroad tracks, supply power for rural health clinics, operate water wells and irrigation pumps, charge batteries, operate portable laptop computers, and power ocean buoys, lighthouses, and offshore oil-drilling platforms. Production costs of solar generators continues to drop. Japan, with its troubled nuclear system, instituted significant tax subsidies for the installation of PVE generators in both homes and industries. Several European nations are also in the process of removing the traditional subsidies for coal and oil and transferring them to wind power and

PVE. As a result, the megawatts produced by PVE generators increased from 89 to 1,460 megawatts between 1996 and 2005, and the sales of PVE cells increased 43% in 2000. If governments have been slow to recognize the huge potential LDC markets for PVE, corporations have not. By 2000, corporations like British Petroleum and Shell Oil were investing heavily in the development of PVE (Dunn, 2001c: 46–47; Li, 2006; Sawin, 2005b: 34).

Hydrogen Fuel

If you took high school chemistry and conducted *water electrolysis,* running electricity through water and splitting water molecules into oxygen and hydrogen atoms, you can understand the potential of using *hydrogen gas* as a fuel. You could make hydrogen using solar, wind, or conventionally produced electricity. It is a clean-burning fuel with about 2.5 times more energy by weight than gasoline. When burned, it produces no heat-trapping greenhouse gases, but combines with oxygen in the air to produce ordinary water vapor. Hydrogen can be collected and stored in tanks like propane is today, or it can be transported by pipeline. It is easier to store than electricity. It will combine with reactive metals to form solid compounds called *hydrides,* which could be stored and heated to release hydrogen as it is needed to fuel a car or furnace. Unlike gasoline, accidents with hydride tanks would not produce dangerous explosions. A versatile fuel, hydrogen could be used for transportation, heating, or industry. *Fuel cells* that combine hydrogen and oxygen gas to produce electricity could power autos, trucks, and buses. Such cells have no moving parts and energy efficiencies several times larger than today's internal combustion engines. Unlike conventional batteries in electric vehicles, fuel cells need no recharging and, as long as hydrogen fuel is available, could be resupplied with fuel in a matter of minutes (Miller, 1998: 424).

Gradually switching to hydrogen and away from fossil fuels as our primary fuel resources would mean a far-reaching *hydrogen revolution* on a profound scale. Technical and social transformations required over the next 50 years could change the world as much as did the agricultural and industrial revolutions. Theoretically, a hydrogen fuel economy could eliminate much air and water pollution, greatly reduce the production of heat-trapping greenhouse gases, reduce the need to use scarce fuel reserves, lower problems associated with fluctuating energy prices, and loosen energy constraints on economic development. An attractive long-range vision is to generate electricity by PVE, wind, or some other ecologically benign technology, and use it in electrolysis to create hydrogen fuels. A solar-hydrogen economy would be based on resources that are more abundant and evenly distributed than fossil fuels and could reduce the geopolitical tensions and costs produced by dependence among nations (Flavin and Dunn, 1999: 36; Hydrogen International Research Center, 2006; Weinberg and Williams, 1990: 149).

What's the catch? Well, there are some big ones. *First,* hydrogen (H_2) is locked up in water and organic compounds like the fossil fuels. *Second,* it takes energy and money to produce H_2 from water and organic compounds. Although I have written about H_2 as a fuel, it is not directly a source of energy, but a way of storing energy by using energy from other fuels—and lots of it! *Third,* fuel cells are the best way to use hydrogen to produce electricity, but current versions are expensive. We could use heat and chemical processes to separate H_2 from the complex carbon-based molecules of coal, natural gas, ethanol, or gasoline, but at present, doing so is more expensive and produces more CO_2 than does using these fossil fuels directly (Miller, 2005: 401–402).

In sum, hydrogen power has only theoretical potential, but it is an enormously attractive one. It would be particularly valuable when, or if, land or water constraints become serious. In 1990, for instance, experts estimated that the PVE hydrogen equivalent of the world's *total* fossil fuel consumption could be produced on 500,000 square kilometers—less than 2 percent of the world's deserts (Weinberg and Williams, 1990: 153–154).

Efficiency as a Resource

Even with such an impressive menu of alternatives to fossil fuels, it is important to emphasize that efficiency is the cheapest, easiest, and fastest way to address our present energy predicament. We often forget just how effective a tool efficiency has been. Between 1975 and 2000, even as the U.S. economy grew by 50%, our energy intensity fell by 40%, mostly through improved technology, policies, and marketing. By the late 1970s government mandated new energy efficient appliances, new building codes requiring double-paned windows, better insulation, and more efficient heating systems—all of which made households more energy efficient. The changes were effective but mostly invisible, and did not alter comfort or lifestyles. The energy savings in new refrigerators alone, when multiplied by the number of American households, helped avoid the construction of 40 new power plants. Most dramatic, however, was the improvement in vehicles. Between 1977 and 1985, despite a booming economy that grew 27%, oil demand fell by more than one-sixth. The world learned that America had a powerful weapon of its own: efficiency (Roberts, 2004: 218).

Pardoxically, efficiency's huge success was also its downfall. As oil prices fell, few consumers saw reasons to continue conserving. Conservative politicians, beginning with President Reagan, regarded conservation as governmental instrusion into the marketplace and a surrender to OPEC. Arriving in office in 1980, Reagan encouraged a massive buildup of power plants, new coal mining operations and domestic oil production. In 1986 he froze the CAFE fuel standards created by President Carter that had been so effective, and within several years, American automakers were producing (and consumers were buying) new less efficient autos and SUVs with every model year (Roberts, 2004: 215–220). U.S. energy intensity rose again as a sucession of conservative politicians, particularly George H.W. Bush and George W. Bush, said in effect, "You don't need to conserve; we'll go and get the oil for you" (Nemtzow, cited in Roberts, 2004: 220). By 1994, for the first time in history the United States was importing more oil than it could produce. Efficiency (conservation) was over, dismissed as a relic of the 1970s.

In fact, energy efficiency hardly ceased to make economic sense. In the U.S. power sector alone, we could reduce our electricity rates by 40% and cut CO_2 emissions in half by upgrading power plants and transmission systems (Roberts, 2004: 220). As Amory Lovins, an outspoken efficiency advocate pointed out, "Just a 2.7 miles-per-gallon gain in fuel economy of this country's light-vehicle fleet could displace Persian Gulf import entirely" (cited in Roberts, 2004: 215).

Efficiency also makes corporate sense. According to David Goldstein of the Union of Concerned Scientists, "Anywhere companies have pursued energy efficiency, they have ended up making money, even if making money wasn't their initial goal" (Cited in Roberts, 2004: 225). America has many ways of increasing energy efficiency; in order of increasing price, they include:

1. Converting to efficient lighting equipment, which would save the United States electricity equal to the output of 120 large power plants, plus
2. $30 billion a year in maintenance costs. Using more efficient electric motors, saving half the energy used by such
3. Motor systems, which would save the output of 150 large power plants and repay conversion costs in about a year.
4. Eliminating pure waste electricity, such as lighting empty offices
5. Displacing electricity now used with better architecture, weatherization, insulation, and solar energy for water and space heating
6. Making appliances, smelters, and the like cost-effectively efficient

Amazingly, these five measures could quadruple U.S. electrical efficiency, making it possible to run the economy with no changes in lifestyles and using no power plants, whether old or new (Lovins, 1998). With the impressive benefits of improving energy efficiency, there are obviously some powerful barriers to change.

Like all calculations, those about how much energy could be saved by efficiency depend greatly on the technical and political biases of the people who do the calculating. But on the *conservative* end, it seems certain that the North American economies could do everything they now do with current technologies and costs, using *half as much energy* (Meadows et al., 1992: 75). This figure is not merely speculative. Europeans use about half as much energy per capita as do U.S. and Canadian citizens and have equivalent lifestyles. Possibilities for "mining" efficiency are producing a profound shift in thinking. Economists traditionally viewed conservation and environmental protection as involving only economic restraint, higher costs, and curtailment of consumption. But some now envision a vast future market for efficiency as profitable for investors, and the basis for a virtual "second industrial revolution." Nations that fail to develop "greener" economies are likely to lose out economically as well as environmentally (Brown, 2001; Hawken, Lovins, and Lovins, 2000; Flavin and Dunn, 1999; McDonough and Braungart, 2002). I will return to this theme, particularly in Chapter Seven.

BARRIERS, TRANSITIONS, AND ENERGY POLICY

Our energy *predicament* has intrinsic links to other social and environmental problems. These include pollution, loss of biodiversity, environmental degradation, health problems, urban sprawl/congestion, a large national debt and balance of payments problem, geopolitical costs of maintaining access to oil and gas fields, and a volatile economic dependency that amplifies international instability and sometimes war. In LDCs the energy predicament is related to deforestation, desertification, barriers to development, poverty, and hunger. Most ominously, our present energy system is thought to be a chief culprit in the most serious macrothreat to the future of humanity: anthropogenic climate change.

Barriers to Change

We have a rich menu of technical possibilities that could move the world toward more efficient, affordable, and environmentally friendly energy systems. With these possibilities, if renewable energy is so great, why does it only produce 16% of world energy and 6% of energy in the United States? There are obviously some powerful barriers to change.

First, renewable energy has and continues to receive much lower tax breaks, subsidies, and research and development funding that do fossil fuels or nuclear energy. For instance, the 2005 energy bill considered by Congress contained huge subsidies for fossil fuel industries, but very few for alternative fuels. The weight of public policy makes it a very uneven playing field. If it were levelled, alternative energy would develop rapidly, according to most experts. Even as energy problems mount, the huge *sunk investment* in existing energy systems and infrastructures accumulated over the last century make policies to prop up the failing system seem more rational than those that promote change (Fowler, 1992: 76; Miller, 2005: 391).

Second, like many other social problems, the salience of energy problems follows an *issue-attention cycle,* a cycle of rising and falling concern due to energy-related national events and the volume of media coverage they attract (Downs, 1972; Rosa, 1998; Mazur, 1991). When supplies increase and prices moderate, the combination of public concern and media attention that would impel political action is at a low ebb (Joskow, 2002: 105). That was the fate of global warming, a premier social problem after the long hot summer of 1989, but which "cooled" in the 1990s, only to return slowly to public debate and discourse (Ungar, 1992, 1998). Safe to say that with warm winters, devastating hurricanes, and $3.00 a gallon gasoline, by 2006 both global warming and energy are high-definition social problems that have our attention again!

Third, energy policies have been fragmented, contradictory, and often paralyzed. In the United States, energy policy has been separated by fuel type, with different institutional associations, interests, and regulatory bureaus for each, with few attempts at broader coalition building. The Bureau of Mines deals with coal problems and interests, the Department of Interior with gas and oil, and the Nuclear Regulatory Commission with nuclear energy. Electricity is regulated differently in each of the 50 states. The net result is that government energy policies have intervened in markets with supply-side policies that subsidize costs and increase consumption rather than promote efficiency and alternative fuels (Switzer, 1994: 138).

A *fourth* barrier to effective energy policies is that they need to be articulated on a global basis. Even dramatic improvements in energy efficiency will not be sufficient to protect the global environment if they are confined to the MDCs. Pleas from MDCs to address global environmental and climate problems through energy restraint will fall on deaf ears in the LDCs, unless the MDCs can find ways to help them achieve increased economic well-being and environmental protection at the same time.

Transitions and Policy

Even with such powerful barriers to changes in policy, it is important to underscore that the world changes, including the web of connections between energy and societies. This means that, as always, *some kind of energy transition is underway.* Consider two previous world energy transformations.

Before the industrial revolution, people depended for energy on a combination of traditional biomass fuels (like wood and dung), animal power, and water power. Beginning in the 1800s, a new energy regime evolved around coal, which was the foundation for a steam-powered industrial system. (The term *energy regime* means the network of industrial sectors that evolve around a particular energy resource, as well as the consequent political, commercial, and social interactions.) The coal regime diffused around the world in the late nineteenth century; between 1850 and 1913, this single energy resource went from providing 20% to more than 60% of the world's total commercial energy. Until 1915, petroleum had a niche market for kerosene to light lamps and was between three and twelve times as expensive as coal in Europe and North America. But under the stimulus of converting naval ships and military vehicles, a petroleum-based energy regime was established more rapidly than it could have been by private enterprise alone. The share of world energy provided by oil grew from 5% in 1910 to over 50% by 1973, and after World War II it was the key resource for transportation, electricity generation, and heating in most of the industrialized world (Podobnik, 1999).

The Present and the Foreseeable Future

What kind of world energy transition are we in the midst of now? I rely on appraisals by the World Energy Commission (WEC) and the International Energy Agency (IEA). The WEC, founded in 1924, represents diverse energy organizations from a variety of MDCs and LDCs, the World Bank, national utilities, energy research institutes, and former energy ministers. The IEA is much newer, formed in the wake of the 1970s oil shocks, and represents mainly MDCs: 26 countries such as the European Union, the United States, Australia, Japan, Turkey, and Japan. By 2010 they predict that 90% of the world's primary energy mix will be composed of fossil fuels, and the LDCs will continue to move away from traditional fuels such as wood and animal dung.

Neither the WEC nor the IEA foresee significant changes in the present mix of commercial fossil fuels. Both foresee a significant growth in the world commercial energy consumption. The WEC works with hypothetical scenarios to project the growth and patterns of world energy consumption to 2020. A high-energy scenario projects an 82% growth in world commercial energy consumption, but in its *most likely* scenario, the WEC projects a 50% increase in world commercial energy consumption. The third WEC scenario involves a "massive drive to raise energy efficiency." This scenario assumes the increase in the use of natural gas with rapid expansion in energy from renewable sources such as hydroelectric, wind, and solar power, and a modest increase in nuclear energy. Growing international concern of the oil-importing nations for the long-term availability and price of oil would drive this scenario. Key players would be LDCs without the money to import fossil fuels or develop nuclear plants, but rich in wind, solar, or biomass resources (Humphrey, Lewis, and Buttel, 2002 : 138–140).

Except for this "massive drive scenario," neither the IEA nor the WEC envisions renewable sources playing a major role in the world commercial energy mix for the next two deacades. Neither organization discounts the importance of renewable energy sources, *but not until sometime beyond 2020.* The stubborn fact is that, even under optimistic conditions, no combination of alternative/renewable fuels would be able to meet the world demand for energy for many decades. In the words of the WEC, "Even given clear and widespread public policy support, the new renewables (such as solar and wind energy production) will take many decades to develop and diffuse to the point where they significantly substitute for fossil fuels" (World Energy Commission, 1993: 94).

In the energy transition of the twenty-first century, oil, like coal in the late nineteenth century, is entering a state of slow growth and relative stagnation. Experts estimate that production will peak sometime between 2010 and 2020 and thereafter begin to decline (Hirsch et al., 2005; McKenzie, 1992; Podobnik, 1999). Sometime in the twenty-first century, a new and more diverse world energy regime will emerge. In this new regime a more diverse mix will continue to rely on oil and coal when possible, but also on more natural gas and a rapidly growing decentralized mix of nonrenewables like wind, solar, and solar-hydrogen energy. These are mainly now in niche markets with a small proportion of the world's total commercial energy budget, but with a greater share than oil had in 1910 (Podobnik, 1999). This new regime would be a "bridge" economy—a transitional phase arresting the worst of the current energy trends while giving us more time and flexibility eventually to create a radically different energy system. The United States could encourage this transitional stage by (1) immediate moves to expand natural gas imports, (2) the rapid deployment of a carbon tax, and (3) dramatically improved automotive fuel efficiency. The gas bridge economy might last for two or three decades, and the emissions growth rate would begin to slow. Fuel cells would be slowly but steadily penetrating both the automotive and stationary power markets and laying the groundwork for the eventual emergence of a hydrogen economy, once technology makes hydrogen from renewables cost competitive (Roberts, 2004: 313, 315).

IN SUMMARY: ENERGY AND THE RISKS WE TAKE

Let me return to the future scenarios of the world energy system projected by the IEA and the WEC for the first several decades of the twenty-first century. They project between 50 and 80% increases in the consumption of commercial energy, primarily met with carbon-based fossil fuels like oil, coal, and natural gas.

Wow! What risks are involved in such enormous increases? There are two kinds. The *first* is global and long-range, but nonetheless powerful. How would the increased carbon emissions from such increases contribute to an already warming global climate? The *second* kind of risk is social and political. What will be the global consequences of the growing energy dependence among nations, of MDCs on LDC resources, and the aspirations of people everywhere? What kinds of social and political instabilities will result within and between nations, partly driven by the energetic base of social life and the world network of nations (Humphrey, Lewis, and Buttel, 2002: 171)?

PERSONAL CONNECTIONS

Consequences and Questions

Here are some questions to help you think about your personal relation to energy consumption and a variety of social and environmental issues.

1. Chapter Three argued that our carbon-based energy system is one of the primary drivers of global warming. The average human sends the equivalent of his or her body weight of carbon into the atmosphere for about every $200 spent. That figure is based on a world average: As North Americans, you and I probably contribute much more. Do the math: How much do you think you, or you and your family, contribute? Multiply by 300 million Americans (deduct some for children when you do).

2. This chapter noted that as nations move from LDCs to MDCs and from early to late industrial (more service-based) economies, they become more energy efficient per unit of economic output. Yet the data displayed in Figure 4.3 demonstrated considerable variation among developed market economies in the relationship between energy input and economic output, with Americans leading the pack in terms of energy inefficiency. Given what you know about conditions and lifestyles in America and other nations, why do you think that is so?

3. Since transportation is such an important part of our energy budget, here's a pointed question: If you drive a car, how much would gasoline have to cost per gallon to induce you to cut your driving by a meaningful amount? How might people with different occupations answer that question differently? What other changes in community life would make it easier for you to do this?

What You Can Do

Small lifestyle changes that relate to possibilities for greater energy frugality are well known:

- Drive less, keep your car tuned; when possible walk, bicycle, or ride the bus or commuter train; car-pool.
- Insulate your house and turn the thermostat down in winter; adjust to changing temperatures by changes of clothing rather than heating or cooling your house; run appliances frugally, and replace them with more energy-efficient appliances when you can.
- Buy "green goods" that have less stored energy used in their production by the time they get to you. Etc., etc. . . . (You know the litany of small things you can do. If *many* people did them, they would add up.)

The larger and more meaningful lifestyle changes are more difficult, challenging. They require more planning, investment, and working toward integrated lifestyles. What do I mean?

- Plan to live close to where you work, reducing both transportation time and costs. Perhaps you can find an appropriate job close to where you live, or move closer to where you now work. Either is likely to be a challenge, and there are some important barriers for most of us.
- Choose a career that enables you to "walk lightly" regarding energy and other impacts on the environment—in other words, one that rewards frugality. Exactly what kinds of careers would those be? I'm not sure I know, but I think it's meaningful to pose the question. Buddhism emphasizes the notion of "right livelihood" as an ethical imperative. What would right livelihood mean in an ecological sense?
- In general, try to simplify your life in ways that still support your sense of well-being. Doing this is not easy. It raises issues about how you could do this (if you wanted to—and many don't!). It also forces you to examine the exact sources of your sense of well-being.

Real Goods

The bicycle. The bicycle is the most thermodynamic and efficient transportation device ever created, and the most widely used private vehicle in the world. The bicycle lets you travel three times as far on a plateful of calories as you could walking. And it's 53 times more energy efficient—comparing food calories with gasoline calories—than the typical automobile. Nor do bicycles pollute the air, lead to oil spills and oil wars, change the climate, send cities sprawling over the countryside, lock up half of urban space in roads and parking lots, or kill a quarter million people in traffic accidents each year. The world doesn't yet have enough bikes for everybody, but it's getting there quickly: Best estimates put the world's booming fleet of two-wheelers at 850 million—double the number of autos, and growing more rapidly than the auto fleet. We Americans have no excuses on this count. We have about as many bikes per person as do the Chinese. We just don't ride them as much.

I admit to being a bike enthusiast (some of my friends have different words for it!). Like many American kids, I grew up riding a bike (a big heavy Schwinn is the one I remember) and didn't discover lightweight bikes with gears until midlife. I found cycling a life-saving form of exercise and a mood enhancer. I enjoy weekend rides through the green fields of the urban hinterlands and discovering the diversity of urban neighborhoods in a more intimate way than I ever could by driving around in my car. I'm fortunate to live close to my work (about 20 minutes away by bike). Usually my car sits at home in the driveway. I don't envy my colleagues, some of whom live 30 miles away in the suburbs (a real drive, by Omaha standards, but a cakewalk in Chicago). They are connected to work by a nerve-racking four-lane auto umbilical cord.

MORE RESOURCES

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ELECTRONIC RESOURCES

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U.S. Department of Energy

www.eia.doe.gov/
Energy Information Administration; sources, environment, forecasts

www.em.doe.gov/index4.html
U.S. DOE; Office of Environmental Management organizations

www.worldenergy.org/wec-geis/
The World Energy Council represents 90 nations and is accredited by the U.N.

www.iea.org/envissu
The International Energy Agency; about energy, environment, climate change, sustainable development

www.awea.org
American Wind Association

ENDNOTES

1. A futures market for commodities is one that attempts to avoid large, unpredictable price swings by allowing investors to commit to buy the commodity at a specified future date for a particular price. They gamble their profits on being right about future prices.
2. The oil slick from the 1990 Exxon *Valdez* accident is known to have killed 580,000 birds, up to 5,500 sea otters, 30 seals, 22 whales, and unknown numbers of fish. It oiled more than 3,200 miles of coastline. The final toll on wildlife will never be known because most of the animals killed sank and decomposed without being counted. Even after the most expensive cleanup in history, the congressional Office of Technology Assessment estimates that only 3 to 4% of the volume of oil spilled by the Exxon *Valdez* was recovered. Beach cleaning crews and their equipment consumed three times the amount of oil spilled by the tanker. The Exxon company shipped 27,000 metric tons of oil-contaminated solid waste to an Oregon landfill (Miller, 1992: 616–617).
3. A *calorie* is the amount of energy needed to raise 1 gram of water 1 degree centigrade.
4. Sir Patrick Geddes was a Scottish biologist, sociologist, city planner, and cofounder of the British Sociological Society in 1909. Unlike Spencer, he sought a unified calculus of energy flows to study social life (1890/1979). Wilhelm Ostwald and Frederick Soddy were both Nobel Prize–winning chemists in the early twentieth century. T. N. Carver was an American economist, who gave energetic theory an ideological coloration. He argued that capitalism was superior because it was the system most capable of maximizing energy surpluses and transforming them into "vital uses" (Rosa et al., 1988: 150–151).
5. The most meticulous study of contact between high- and low-energy societies is Pelto's 12-year study of the consequences of the introduction of snowmobiles among the Sami people (Lapps) of northern Finland. The introduction of snowmobiles and repeating rifles were the energy and technological means of the gradual absorption of the Samis into Scandinavian societies. They readily adopted these material culture items, and it transformed their life. It vastly increased the geographic mobility of hunters and the amount of game that could be killed. It shortened the workweek of hunters and trappers, increased their leisure time, increased their earnings, and established a new basis for stratification in their communities (based on who owns and who does not own a snowmobile). It also generated a serious ecological imbalance, as populations of snowbound game animals were wiped out. And it increased their dependence on the Finns, Swedes, and Norwegians for gasoline, consumer goods, and so forth (see Pelto, 1973; Pelto and Muller-Willie, 1972: 95).

CHAPTER FIVE

Population, Environment, and Food

Fertilizer and agrochemicals ready to be applied to farmland. Such "technified farming" is more productive, but it may pollute ground water, leave toxic residues in soil and on crops, and reduce the biological diversity of nature. Producing and applying such agrochemicals may use a lot of fuel and resources, adding to the cost of modern agriculture.

The earth's rapidly growing population makes more demands on all kinds of natural resources and increases the amount of waste and pollution produced.