ENERGY

by

Elias P. Gyftopoulos

Massachusetts Institute of Technology[1]

Energy is sometimes called the lifeblood of our societies because it is an essential ingredient of all our activities. It sustains the production of food. It lights, heats and air-conditions our homes, offices, and stores. It powers our cars, tracks, trains, ships, and airplanes And it fuels the manufacture of a myriad of industrial products.

When used wisely, energy makes our work much more productive. It expands our capabilities, and allows us to create more results so that an ever increasing number of individuals can enjoy humane, healthy, and intellectually gratifying lives.

For industrialized nations, the commercial sources of energy are primarily fossil fuels -- crude oil, natural gas, and coal,-- and to a lesser degree water falls (hydroelectric plants), and uranium (nuclear reactors) for the production of electricity. The more advanced a nation is, the more energy it consumes. With about 5 percent of the world population and 25 percent of the world products and services, the United States consumes about 25 percent of the world energy production.

---

[1]Article prepared for the 1988 edition of the Lincoln Homework Encyclopedia, June 1987.

By contrast, less developed countries -- 4 out of 5 billion people on earth -- use much less energy per person. For about 2.5 billion people, most of the energy comes from the burning of firewood, charcoal, and animal and crop residues. All are anxious to raise their living standards at a fast pace. They may not be able to accomplish this just and worthy goal, however, partly because energy in the future may be very expensive.

Energy Consumption

In 1984, world commercial energy consumption was 7,200 million metric tons of oil equivalent, abbreviated toe.[2] Consumption by region, source and population are listed in Table 1. On a per person basis, Canada consumed 8.8 toe per person, the United States 7.8, the Soviet Union 4.8, and Western Europe 3.4. By contrast, developing countries consumed 0.4 toe per person.

Trends and Prospects

In the post World War II years, energy production was increasing faster and faster, especially that of oil and gas. Liquid and gaseous fuel reserves were being discovered at rates higher than consumption and at lower costs. It all changed in the 1970's. In the United States reserves were not coming on stream as fast as production required. In the 1950's, 1 1/4 barrels of oil were being discovered for each barrel

---

[2]One metric ton of oil equivalent (toe) is the amount of energy contained in 7.3 barrels of crude oil, 44,000 cubic feet of natural gas, 1.8 tons of bituminous coal, or the energy necessary to generate 4,400 kilowatt-hours of electricity in an average fossil-fuel fired modern power plant.

1984

Commercial Energy Consumption

(million metric tons of oil equivalent)

	Oil	Natural Gas	Coal	Hydro-electric	Nuclear	Total	Percent	Population (millions)
North America	791.4	505.8	466.2	154.6	101.3	2019.3	28.0	260
Western Europe[a]	591.0	190.1	256.7	107.0	104.6	1249.4	17.4	375
Oceania[b]	35.5	14.4	34.6	9.3		93.8	1.3	25
Japan	214.6	33.1	64.0	19.8	30.6	362.1	5.0	120
USSR	447.8	439.4	357.0	53.0	25.0	1322.2	18.4	275
Eastern Europe[c]	98.7	77.0	274.2	7.2	7.5	464.6	6.5	115
Developing Countries[d]	579.7	139.3	260.4	111.0	13.2	1103.6	15.3	2550
China	85.8	10.8	466.5	23.5	0.0	586.6	8.1	1053
World Total	**2844.5**	**1409.9**	**2179.6**	**485.4**	**282.2**	**7201.6**	**100.0**	
Percent	39.5	19.6	30.3	6.7	3.9	100.0		

Notes:

a. Western Europe includes Austria, Belgium, Cyprus, Denmark, Federal Republic of Germany, Finland, France, Gibraltar, Greece, Iceland, Republic of Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, Yugoslavia.

b. Oceania includes Australia, New Zealand, Papua New Guinea, Southwest Pacific Islands.

c. Eastern Europe includes Bulgaria, Czechoslovakia, German Democratic Republic, Hungary, Poland, Romania.

d. Developing Countries includes all Latin American, African (including South Africa), South Asian, Southeast Asian, and Middle Eastern countries.

Source: British Petroleum, 1985.

extracted, but by the mid 1970's this dropped to 1/2 barrel. The monies spent on new finds were much more than in the past. The investment in North Sea oil was about $10,000 per barrel of daily production, compared to the investment in the Middle East of only a few hundred dollars for the same daily rate.

In 1974, the Organization of Petroleum Exporting Countries (OPEC) raised oil prices from $2 to over $10 per barrel, and from 1979 to 1983 up to more than $35 per barrel. These increases havocked most of the world economies and brought them to a standstill. They also stimulated some extremely beneficial and permanent responses. Nations started looking for alternatives to OPEC oil, with some limited success. They also pursued cost-effective energy conservation programs.

From 1975 to 1985, the United States increased its economic output by 1/3 without increasing its energy consumption. We achieved this saving by avoiding thoughtless energy waste -- we turn the lights off in buildings that are not in use --, by manufacturing better equipment -- our cars travel 25 miles per gallon of gasoline instead of less than 10 in 1974 --, and by using more productive methods in manufacturing -- we recover waste heat and use it to generate electricity and steam for heating.

These successes plus the slowdown of economic activities have curtailed the demand for OPEC oil to about one half what it was over a decade ago, and eliminated the pressure for ever-increasing oil prices. So, as of 1986, oil sells for less than $20 per barrel, and very likely will continue to do so for some more years. Analogous comments apply to natural gas.

Energy Reserves

Fossil fuels are not renewable. As we use them, they are exhausted forever.

No one knows for sure how much oil, natural gas, and coal exists in the earth. At the 1984 rates of consumption and reserve estimates, most experts concur that oil and gas will continue as major energy sources only until the first half of next century, whereas coal will be available for a few centuries. This is not a secure outlook.

To continue our progress, and to satisfy the just and pressing needs of less developed countries, we must find at least one major new source of energy at a cost we can afford, and novel methods for cost-effective energy savings.

Sunpower and Nuclear Power

For the long term, all sources of energy currently in use will be inadequate. There exist only three possibilities for a new source: the sun, nuclear fusion, and nuclear fission with breeding. Each has its own set of scientific, technical, environmental, safety, economic, and political problems. All three must be researched and developed concurrently so that 40 to 50 years from now at least one will become a winner.

The sun is universally available and inexhaustible. Whether in the form of insolation, wind power, wave power, hydro power, heated ocean water, or biomass, this energy is free for capture and use almost every day, almost everywhere. The technology is known. The problem is that the cost of most of this technology is prohibitive. Solar energy experts are optimistic but not certain that the required cost reductions will be achieved.

Nuclear fusion -- the process of combining two special hydrogen nuclei at very high temperatures of 100 million degrees -- can become an inexhaustible source of energy. Excellent scientific progress has been made in understanding this process. However, we are very far from knowing how to translate this progress into practical, electricity generating devices. If all goes well, fusion may be commercial 50 years or so from now. No one can say for sure that all will go well.

Nuclear fission with breeding -- nuclear reactors that release energy by splitting uranium atoms, and that create more fuel than they consume -- may become an energy source for thousands of years. The technology is fairly advanced but not fully developed. It faces, however, serious opposition based on concerns about proliferation of nuclear weapons, safe disposal of radioactive ashes of nuclear fuels, and consequences of major accidents such as the one at Chernobyl in the USSR. Proponents argue that present nuclear power plants can be the cheapest, safest, and environmentally most benign sources of electricity. They are optimistic but not certain that the same will be true for breeder reactors.

Transition Sources

During the transition to a new major energy source, the alternatives to oil and gas are coal (directly or transformed into synthetic fuels), nuclear reactors without breeding, oil from shale and tar sands, geothermal energy, and special applications of solar energy. Each of these sources is surrounded by a combination of technical, environmental, safety, and economic issues that must be resolved over a

short period of time. In approaching the resolution of the issues, we must remember that none of the alternatives can by itself overshadow all the others, and that the approach must be balanced. For example, we must be concerned not only about nuclear safety but also about the environmental and climatic effects of burning coal.

Energy Conservation

In every activity there exist large margins for reducing energy consumption without strangling our economy, and without depriving ourselves of the benefits of energy services. We can save energy and money by using more insulation and better light bulbs in buildings, by manufacturing vehicles that travel more miles per gallon, and by making more steel per unit of energy consumed in steel plants.

Using the laws of physics, we can estimate that we waste about 90 out of every 100 units of energy's ability to perform useful tasks. Much of this waste is unavoidable. We will never be able to approach 100 percent utilization, even in the remote future. But a cost-effective reduction of waste to 80 or 70 out of every 100 units of energy consumed is a reasonable and achievable goal for the next few decades. A doubling only of the U.S. efficiency of energy utilization would provide the equivalent of today's OPEC production forever.

To achieve large and practical increases in energy end-use efficiency, we need to make long-term commitments in research and development of entirely new and cost-effective processes for every energy consuming sector of the economy.

In closing, we should emphasize that energy presents some obstacles to our future well-being and security but it also provides opportunities for important new developments in both energy supply and energy demand.

Bibliography

International Energy Annual 1984, Energy Information Administration, Washington, D.C.

World Resources 1986, World Resources Institute, Basic Books, New York (1986)

State of the World 1987, Worldwatch Institute Report, W. W. Norton & Co., New York (1987)

Learning about Energy, David J. Rose, Plenum Press, New York (1986)

British Petroleum, Statistical Review of World Energy, 1984 and 1985.