trends in energy needs

Energy requirements and availability of energy supplies are subjects of increasing interest. Here is a briefing on U. S. energy requirements as related to total world requirements, on the sources of energy consumed in the U. S., the end uses of energy consumed in the U. S., and predictions as to the rate of increase in U. S. energy consumption.

FRANK A. RITCHINGS[1]

Ebasco Services Inc., New York, N. Y.

In 1958, with a world population of about 2.9 billion people, the total energy consumption of the human race was equivalent to consuming about 3700 million metric tons of coal. That energy was provided 54 percent by solid fuels, primarily coal; 30 percent by liquid fuels, primarily oil; 14 percent by gas fuels, primarily natural gas; and 2 percent by hydro and nuclear sources combined, but essentially hydro.

In 1968, with a world population of about 3.5 billion people, the total energy consumption was equal to consuming about 6000 million metric tons of coal. Three facts are of interest:

1 During the 10-year period 1958–1968 the world population increased by about 21 percent. However, the total world energy consumption increased by 62 percent. This means that energy consumption per capita increased nearly 35 percent in just 10 years.

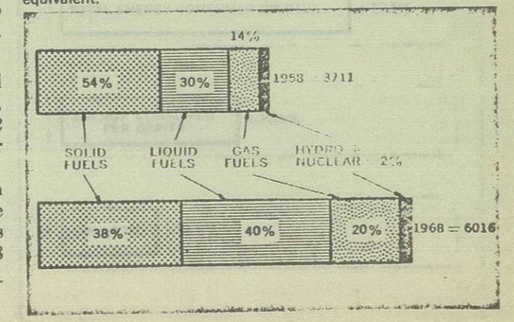
2 During that 10-year period, there have been significant changes in the sources of energy used. The net effect of this changing pattern of energy use is shown in Fig. 1. Solid fuels decreased from 54 to 38 percent of total energy consumption, liquid fuels increased from 30 to 40 percent, and gaseous fuels from 14 to 20 percent. Hydro and nuclear combined remained in the range of 2 to 3 percent.

3. The use of all raw-energy sources increased in absolute quantities. For solid fuels, 38 percent of 6016 million tons in 1968 represents 15 percent greater tonnage than 54 percent of 3711 million metric tons in 1958. Similarly, the consumption of liquid fuels increased by 118 percent, gaseous fuels by 130 percent, and hydro and nuclear combined by 80 percent.

Worldwide, the decreasing dependence on solid fuels and the increasing dependence on liquid and gaseous fuels indicates the preference for the fuels most convenient to transport and use. This same pattern is evident in the U. S.

It is also evident that the human race has a tremendous need for energy in all forms and that improvements in world economies and in standards of living are related to energy consumption. Further, the bulk of our energy need is today met by tapping our nonrenewable resources of coal, oil, and gas. While we have tremendous worldwide reserves of these fuels, our reserves are not infinite.

Fig. 1 World energy consumption, millions of metric tons coal equivalent.



[1] Vice-President. Mem. ASME.

Based on a paper contributed by the ASME Energetics Division.

TABLE 1 World Energy Consumption

Area	Per Capita Consumption (Kg Coal Equivalent)	Percent of World Energy Consumption	Percent of World Population
United States	10,331	34	6
Western Europe	3,312	19	10
U.S.S.R.	4,058	16	7
Japan	2,515	4	3
World Average	1,727	—	—
South America	653	2	4
Far East ex. Japan	182	3	28
Africa	294	2	10

Source: U.N. Statistical Papers

Average World Energy Consumption

While the 1968 average world energy consumption was the equivalent of consuming 1727 kg of coal per capita, there are tremendous differences in total energy consumption, even among the countries we consider highly industrialized and developed. Table 1 illustrates the differences for a few areas and indicates that the U. S. has the largest per capita energy appetite.

The per capita energy consumption in the U. S. is about six times the world average, three times the average for Western Europe, and from 35 to 55 times the average for the less developed areas of Africa and the Far East, excluding Japan.

The U. S., with about 6 percent of world population, consumes 34 percent of world energy. The U. S., together with Western Europe and the U.S.S.R., with a combined population less than 25 percent of world total, account for about 70 percent of world energy consumption.

It is evident from these data that industrialization, economic well-being, and general standard of living are directly related to energy use per capita. Just imagine the tremendous increase in world energy requirements if standards of living in the undeveloped countries could be raised. This is a significant political, economic, and engineering challenge.

U. S. Energy Consumption

Fig. 1 indicates that during the 10-year period 1958–1968 world energy consumption increased by 62 percent. During this period, total annual energy consumption in the U. S. increased by 50.5 percent, Fig. 2.

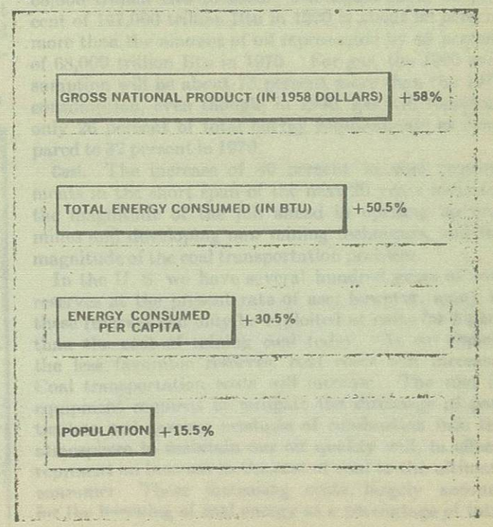
At the same time, our GNP, expressed in constant 1958 dollars, increased about 58 percent. Our population increased only 15.5 percent, resulting in an increase in energy consumption per capita of 30.5 percent.

Our population is currently increasing at the rate of about 1.3 percent per year, our total energy consumption is increasing at the rate of about 4.2 percent per year, and energy consumption per capita is increasing at about 2.7 percent per year.

The conclusion: Energy consumption is closely related to the total value of all goods and services produced in the U. S.; it is related to and is a vital ingredient of our economic growth, our per capita income, and the enhancement of our standard of living.

The fact that energy is a fundamental necessity of our economy only becomes apparent to the average citizen when he is deprived of its benefits, such as during an electric power failure, or shortage of gas or oil for heating purposes, or shortage of gasoline for his automobile. Temporary interruptions to energy supplies have been so infrequent in the past and of such short duration that few people realize that our economy is really dependent on an abundant supply of raw-energy resources at reasonable cost.

Fig. 2 U.S. energy consumption, percent change, 1968 vs. 1958.



During 1960, the U. S. consumed about 45,000 trillion Btu, Fig. 3. During the decade of the 1960s energy consumption increased by about 50 percent, so that in 1970 total U. S. consumption of energy increased to 68,000 trillion Btu annually. We expect that total energy consumption will continue to increase during the 1970s at about the same rate as in the second half of the 1960s, assuming no serious economic recession, so that by 1980 our total annual consumption will be at the rate of 104,000 trillion Btu, or about 53 percent greater than in 1970.

It seems reasonable that some day our rate of increase in energy consumption, in economic growth, and in value of goods and services produced will begin to slow down. Some day, we should begin to approach saturation in the improvement of our standard of living. No one has a crystal ball, however, that can predict when, or even if, this will occur. But during the decade of the 1980s our rate of annual increase in energy consumption is expected to slacken. Total U. S. energy consumption in 1990 will be 147,000 trillion Btu, or about 40 percent greater than in 1980, but even so our 1990 energy needs will be more than double the needs actually recorded for 1970.

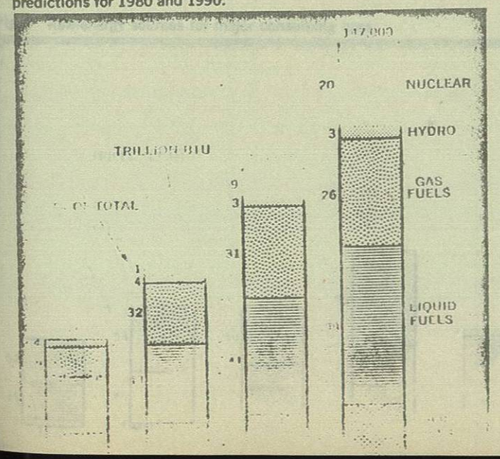
Many things might occur that could drastically alter these predictions of future total energy consumption, both in the U. S. and worldwide. All energy consumption affects our environment. In the past, our environment had a greater capacity to maintain itself than we had to influence its natural balance by our industrial and consumer-oriented activities. The by-products of energy consumption include the discharge of the products of combustion into our atmosphere and the discharge of heat into the atmosphere and into our water resources. With our increasing population and our increasing energy consumption for comfort, industrial uses, transportation, electric power generation, and other purposes, we must now manage and conserve our environmental resources. This is the thrust of environmental legislation.

Our predictions for 1980 and 1990 assume that methods and practices will be developed and adopted to manage our environment without curbing the increase in total energy consumption. These predictions also assume that through intensified exploration the natural resources will be found, developed, exploited, and transported to support the total energy needs of the country.

Fig. 3 also illustrates the major sources of energy and the changing consumer preferences for energy sources.

Nuclear sources provided an insignificant amount of the total energy needs in 1960 (so small it is not even shown on the bar) and only about 1 percent in 1970. We predict a rapid increase in the use of nuclear energy, primarily for electric power generation, and expect that nuclear will provide about 9 percent of total U. S. energy consumed in 1980 and 20 percent in 1990. It is largely the increase in nuclear that accounts for the decreasing percentages of energy to be provided by gas, oil, and coal during the next two decades and beyond.

Fig. 3 Actual U.S. energy consumption for 1960 and 1970 plus predictions for 1980 and 1990.



Energy Resources

This pattern of changing use of our raw-energy resources has been and will continue to be caused partly by consumer preference and partly by economics, which in turn is affected by availability and cost of the marketable reserves. The consumer has indicated a definite preference for the more convenient energy sources, i.e., gas and oil as compared to coal. As our indigenous resources of fossil fuels are consumed, we can expect the prices of those fuels to increase due to the normal relationships of supply and demand. This will increasingly make nuclear energy an economic raw-energy source, primarily for electric power generation.

Do not be misled, however, by these declining percentages of energy consumption shown on this chart. The actual consumption of all fossil fuels will increase each year. Measured in tons of coal, 13 percent of 147,000 trillion Btu in 1990 is about 40 percent more coal than the tonnage represented by 20 percent of 68,000 trillion Btu in 1970. For liquid fuels, 38 percent of 147,000 trillion Btu in 1990 is about 90 percent more than the amount of oil represented by 43 percent of 68,000 trillion Btu in 1970. For gas, the 1990 consumption will be about 75 percent more than the 1970 consumption, even though, in 1990, gas will represent only 26 percent of total energy requirements as compared to 32 percent in 1970.

Coal. The increase of 40 percent in coal requirements in the short span of the next 20 years indicates the magnitude of the job ahead in opening up new mines and developing new mining techniques, and the magnitude of the coal transportation problem.

In the U. S. we have several hundred years of coal reserves at the present rate of use; however, many of these reserves can only be exploited at costs far higher than the cost of mining coal today. As we exploit the less favorable reserves, coal costs will increase. Coal transportation costs will increase. The cost of equipment required to mitigate the discharge of particulate and gaseous products of combustion into the atmosphere to maintain our air quality will, in effect, represent an increase in the cost of coal to the ultimate consumer. These increasing costs largely account for the lessening of coal energy as a percentage of total

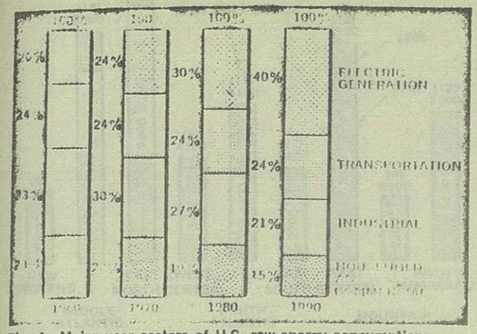


Fig. 4 Major user sectors of U.S. raw-energy consumption.

energy and the reduced rate of increase in coal tonnage requirements in the future.

Oil. Our proven U. S. oil reserves of about 39 billion barrels are only equal to about 11.8 years' supply at the 1970 consumption rate (as against 12 times in 1960). There are "probable" additional reserves (excluding Alaska) equal to perhaps 100 years' supply at the 1970 consumption rate. About 25 percent of our oil needs are imported. The huge reserves reported available in Alaska are only equal to about three years' supply at the 1970 rate of consumption. This example alone indicates the rate at which new oil reserves must be discovered and proven through an accelerated exploration program.

Gas. Our U. S. proven gas reserves of about 291 trillion cu ft are only equal to about 13.3 years' supply at the 1970 rate of consumption (as against 20 times in 1960), and there are probable additional reserves equal to 21 or more times the 1970 consumption.

In recent years, the annual rate of new discoveries of oil and gas has been less than our annual rate of consumption, resulting in decreasing reserves-to-production ratios.

An increase of 90 percent in annual oil consumption and 75 percent in annual gas consumption during the next 20 years certainly indicates the magnitude of the exploration program required both in the U. S. and worldwide to locate new reserves and develop new wells and transportation techniques.

The values on this chart indicate a cumulative 1970 to 1990 requirement of 12,600 million tons of coal plus 152 billion bbl of oil plus 600 trillion cu ft of natural gas.

Nuclear Fuel. The tremendous increase in nuclear energy indicates the need for an accelerated exploration program to locate economically obtainable reserves of uranium and other fissionable materials. Our presently known U. S. reserves of uranium are estimated to be adequate only through about 1981; however, the need for nuclear fuel will create an extensive exploration program. The reserves of fissionable nuclear fuel required will be significantly affected when the breeder reactor becomes a commercial reality, probably by the mid-1980s.

The history of the past indicates, for all fuels, that the amount of proven reserves is a direct function of the amount of exploration.

Although the problems of future supply are tremendous, these projections of future energy consumption assume that the required reserves will be available either by U. S. production or by imports from other worldwide sources.

U. S. Raw-Energy Consumption and Sources

How do we use the energy we consume? Fig. 4 shows the breakdown into major use categories (household and commercial, industrial, transportation, and electric generation) as a percentage of the total energy consumption each year. Here 100 percent equals 45,000 trillion Btu in 1960, increasing to 147,000 trillion in 1990 as shown in Fig. 3.

Fig. 5 illustrates the percentage of raw energy provided by the several types of fuel resources for each of these major use categories. Only 1970 and 1990 are shown to avoid making the charts too complicated and to illustrate a reasonably long-term trend of 20 years. Coal, oil, and gas are the principal raw-energy sources for direct use in the household, commercial, and industrial markets. Today coal is an insignificant contributor to household and commercial energy use. This market is served primarily by gas and oil because of consumer preference for the convenience of these fuels. We expect this situation will continue into the future.

For industrial use, coal is a significant energy source, but provides only about 28 percent of industrial raw-

Fig. 5 Raw-energy sources for major consuming uses.