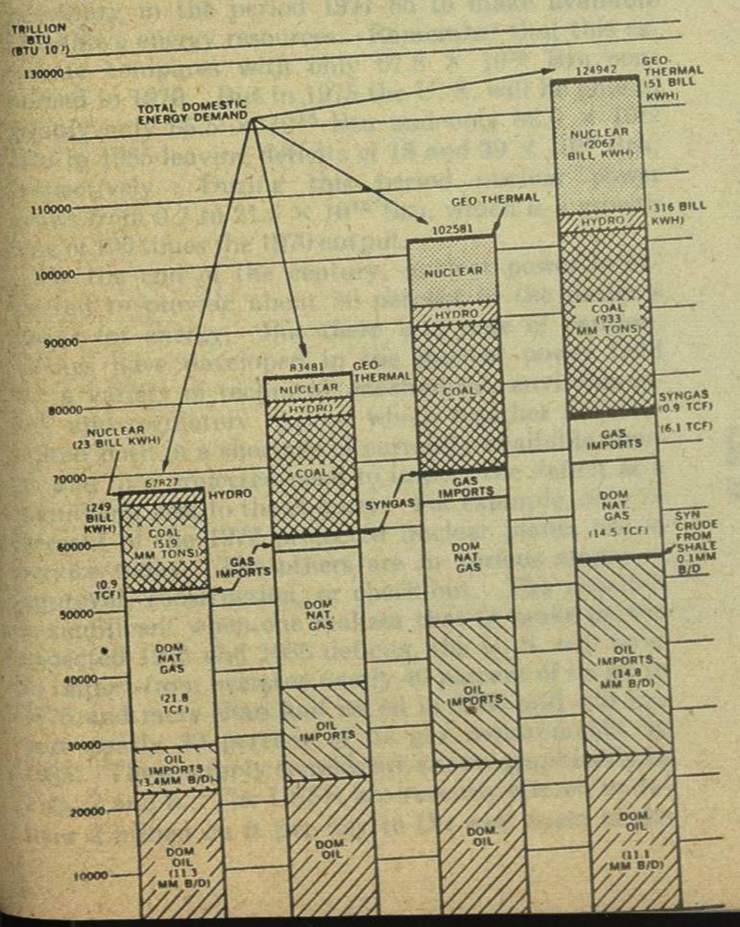
	1970	1975	1980	1985
Total domestic energy consumption	67,827	83,481	102,581	124,942
		Figure units in 10^{15} BTU		
Total projected domestic supply				
Oil	21,048	22,789	24,323	23,405
Gas	22,388	20,430	18,030	14,960
Coal	13,062	15,554	18,284	21,388
Hydropower	2,677	2,840	3,033	3,118
Nuclear	240	3,340	9,490	21,500
Geothermal	7	120	343	514
Synthetic oil	—	—	—	197
Synthetic gas	—	380	570	940
Total domestic supply	59,422	65,453	74,073	86,022
Shortage indicated	8,405	18,028	28,508	38,920
Projected imports and other Means for supplying fuels to make up for shortage				
Imported oil	7,455	15,284	22,163	29,997
Imported gas	950	1,610	3,880	6,280
Additional coal production	—	756	1,643	1,762
Additional residual fuel imports	—	378	822	881
Total	8,405	18,028	28,508	38,920

Fig. 6 U. S. energy outlook—National Petroleum Council, Nov. 1971.

Fig. 7 Energy supply sources—National Petroleum Council, 1971.



diately preceding and following this period. During the decade 1950 to 1960 the per capita GNP grew slowly. It was almost flat, rising from about \$2500 to \$2700, while from 1960 through 1966 it grew from \$2700 to more than \$3400. If it were able to continue at that rate, the per capita GNP would have reached more than \$4,000 today. This would have produced a real increase in GNP of more than \$100 billion. Think what this extra \$100 billion could do to meet the needs of the nation. Since federal income is approximately 18.6 percent of GNP, there would have been an extra \$18.6 billion available to meet pressing housing and other social needs even without raising taxes. It is also important to recognize that the current budget for the federal government already includes more than \$60 billion for income security and \$25 billion for health and education. It is obvious that the elimination of the federal investment in space technology amounting to about \$3 billion would hardly have a significant effect in providing additional money for these other programs, but it could have a devastating effect if reductions in space technology are continued and are followed by similar reductions in other technology areas such as pharmaceutical, chemical, nuclear, and electronic research.

Effects of Atomic Energy

It really is fortunate that some decades ago a few farsighted individuals laid the foundations for what is now the atomic power industry. It is the power from nuclear energy which almost alone can sustain the American standard of living for the forseeable future under conditions as they are emerging both here and abroad. It is important to realize that total energy consumption increased by 50 percent in the decade 1960–70 (from 44.6 to 67.8 quadrillion Btu's). Total future U. S. energy requirements have been estimated by the National Petroleum Council as 83.5 $\times 10^{15}$ Btu in 1975, growing at 4.5 percent per year at 125×10^{15} Btu in 1985. This is shown in Fig. 6.

The energy crisis may perhaps be put in perspective by the following findings made by the 1971 report to the Secretary of Interior by his advisory National Petroleum Council: These are shown in Fig. 7.

1 NPC estimates U. S. energy consumption growth at 4.2 percent annually during 1971–85 with electric utility consumption rising at 6.7 percent per year. This is roughly 4 to 7 times the population growth estimated by the Bureau of the Census.

2 Oil imports will rise to 57 percent of oil consumption and 25 percent of total energy use in 1985.

3 Natural gas imports which now amount to 4 percent of gas supplies will rise to more than 28 percent in 1985.

4 Coal production will rise to 1,071 million tons in 1985 from 590 million tons in 1970 if SO_2 can be commercially controlled.

5 Nuclear power will rise from 23 billion kwh in 1970 to 2,068 billion kwh in 1985 or about 48 percent of electricity supply.

6 Energy sources other than oil, gas, coal, and nuclear will not exceed 3 percent of need by 1985.

7 Huge capital costs of about $375 billion will be necessary in the period 1971–85 to make available the above energy resources. Remember that this estimate compares with only 67.8×10^{15} Btu consumed in 1970. But in 1975 the U. S. will be able to supply only 65.5×10^{15} Btu and only 86.0×10^{15} Btu in 1985 leaving deficits of 18 and 39×10^{15} Btu, respectively. During this period nuclear power grows from 0.2 to 21.5×10^{15} Btu, which is a growth rate of 100 times the 1970 output.

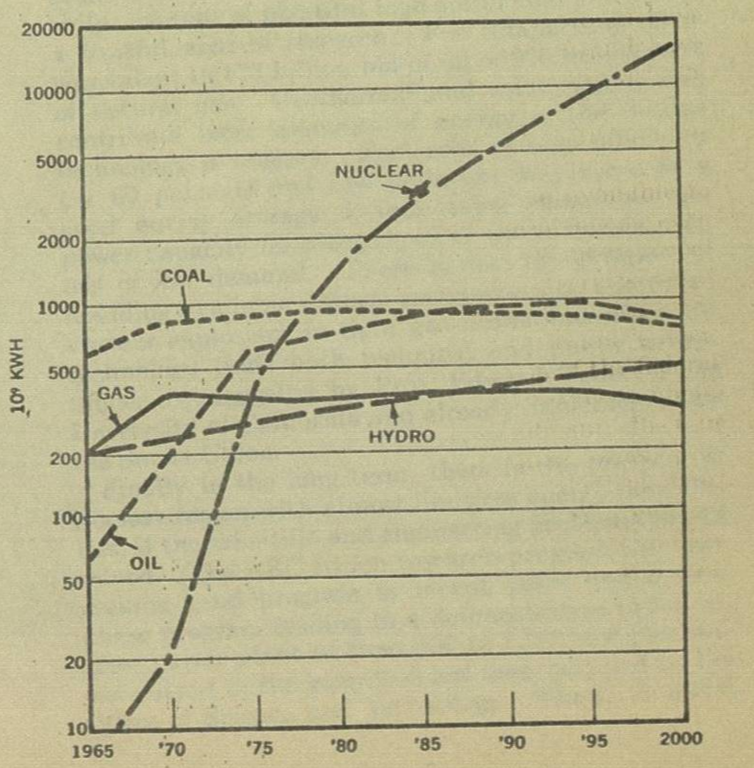
By the end of the century, nuclear power is expected to provide about 50 percent of the nation's needs for energy. But there is a note of caution. Delays have developed in the nuclear power field for a variety of technical, mechanical, environmental, and regulatory reasons which together have resulted both in a shortage of currently available energy and in a projected need to import the deficit at a significant cost to the country. For example, only 25 percent of the 1972 projected nuclear plants are in service today. The others are in various stages of approval, construction, or check-out. The shortfall is significant when one realizes that to make up the expected 1975 and 1985 deficits, the U. S. will have to import from overseas nearly 40 percent of its oil in 1975 and more than half its oil in 1985 and will import nearly 30 percent of its gas requirements by 1985. These supply sources are shown graphically in Figs. 7 and 8. The USSR has recently offered to deliver 2 billion cu ft per day to the east coast of the U. S. Soviet gas reserves have been estimated by academician V. S. Emelyanov as 1,860 billion cu m. But, an investment amounting to billions of U. S. dollars in Russia will be needed to produce and ship this gas even if reliability of the Russian source is assumed.

Nuclear plant delays have an immediate cost impact to the consumers affected. For example, the Wisconsin Public Service Commission was recently requested to approve a 5.7 percent rate increase to compensate the utility for increased electric energy costs due to one to two years delay in approval and construction of two nuclear power plants, and the three-year delay in availability of Indian Point 2 is increasing costs to a similar, equivalent, rate increase.

Obviously, nuclear technology is an important, though often misunderstood, factor in both the near-term and long-term solution to energy, unemployment, and balance of trade problems. First; by selling nuclear fuel services and reactors abroad, it is contributing to strengthening the value of the dollar by reducing the balance of payments deficit. Second; by providing electrical and process energy, it is reducing the need for foreign oil, with all the attendant political, diplomatic, and financial strains which such reliance implies. Third; by helping to maintain an adequate supply of energy in this country, brownouts, black-outs, and shutdown of industry can be avoided.

Gerard C. Gambs, Mem. ASME, Vice-President,

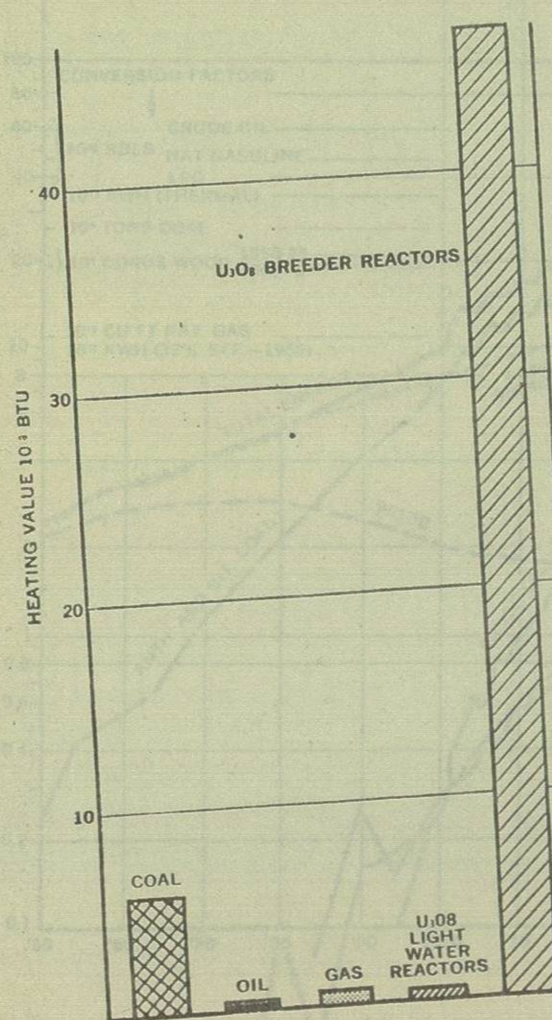
Fig. 8 Forecast of generation of electricity in U.S. by types of fuel.



Ford, Bacon, David Inc. of New York, has estimated that a delay of only 10,000 MWe requires the importation of 100,000,000 bbl per yr of oil. Since, Mr. Gambs does not believe it feasible to import the huge amounts of oil and gas that may be needed, he forsees a cessation of industrial plant expansion and rationing of fuels. The difficulty of importing such fuels can be seen from the President's Economic Report of January, 1972, in which a balance of payments deficit of $23.4 billion was recorded for 1971. Fuel imports can easily double this deficit before 1985, according to Deputy Assistant Secretary of Commerce Stanley Nehmer. However, economists will surely propose measures to prevent this from happening. Such measures are bound to have considerable effect on the lives of all of us. For example, in order to provide the energy expected to be used in this country in 1985, just 12 years away, at least 350 huge supertankers of a quarter million deadweight tons each, would have to be built during 1971-85 to carry the 14.8 million bbl of oil per day to the U. S. even if we could pay for it. Of course, huge new seaports and terminals would have to be built to accomodate these ships in an ecologically satisfactory manner.

We also would need to build new oil refining capacity of 2½ times the rate of the last decade if we are to reach the 10 million bbl per day new capacity required in 1985 and we are already behind schedule. Such delays will result in gasoline shortages which will reach the man in the street in the form of higher gasoline prices, restrictions on use, or both. Furthermore we would need to build 120 liquid-natural-gas tankers, each of 790,000 bbl capacity in the period 1971-85 to haul the 4 billion cu ft of liquified natural gas that must be imported in 1985 to supplement dwindling domestic supplies. Large liquefaction, storage, and gasification plants will obviously be needed to handle this large amount of liquified natural gas.

Fig. 9 Nuclear power, breeder reactors in particular, may prove to be a great energy assist in the years ahead.



With the help of Technology

How can technology help? In the nuclear technology area, efficiency in energy use and generation from fission reactors can assist in the immediate years ahead. Beyond this, there is the prospect of breeder reactors multiplying nuclear fuel reserves at reasonable prices (Z $15 U_3O_8) by more than a factor of 100 (to 33.6Q) as seen in Fig. 9. Note that Mr. Gambs raises this estimate to more than 45Q. These are estimates of proved reserves. The figures for coal drops to 0.3Q if we are talking about low sulfur coal and are raised to about 77Q if we want to use the current total estimated but unproved resources of coal. Incidentally, there is currently no economical and practical method of reducing the sulfur content of plentiful high sulfur coal and this is a fruitful area of research. For comparison 1Q is equivalent to 173 billion bbl of oil or 970 billion cu ft of natural gas. Geothermal and solar sources can contribute large amounts of energy if the needed technology is created. Fuel cells of high efficiency (~ 60 percent) and low pollution may serve as a good energy storage system using excess nuclear power capacity for electrolysis of water during periods of low demand. There is also the prospect of doubling available natural gas reserves by controlled nuclear explosions in tight gas formations when the technology finds both technical and public acceptance, as suggested by Prof. Edward Teller of the University of California and already implemented by the Soviet Union.

Finally in the long term, there is the prospect of nuclear fusion with almost limitless energy possibilities, if the scientific and engineering problems can be solved. The AEC fusion research program has been making good progress in recent years and a five-phase program leading to a demonstration fusion reactor power plant of from 500 to 2,000 mw continuous output in the year 2000 has been outlined by the Office of Science and Technology. The U. S. social goal of a continuing rise in the standard of living for more and more of its citizens, including winning the war on poverty, will require an increase in the per capita consumption of energy and so will attempts to improve the quality of life through environmental control. It has been estimated that these two goals alone can add 66 percent to the current per capita energy consumption (Chase National Bank). Fig. 10 shows the historical use and sources of energy in the U. S. since 1850 and projects future energy needs for the American standard of living. The precarious nature of our energy resources is clearly indicated. Note the role projected for nuclear energy. With confidence in the future and hope that the current environmental, technical, and economic problems can be solved, American utilities in 1972 ordered a record 39 nuclear electric generating power plants totalling 42,000 mw. If we are to provide the technology for future energy sources and thus help to provide a decent standard of living in the future for more and more of our citizens, it is important that the current downward trend in real national investment in research and technology be reversed. Fortunately, there are signs that this indeed will occur.

Acknowledgements

The data used in this article are derived from the President's Economic Reports of 1971 and 1972; Statistical Abstracts of the United States for 1970 and 1972; material presented at the Federal Executive Institute, the ASME Forum on the Energy Crisis, Nov. 1972; and other sources.

Fig. 10. U. S. energy consumption by fuels since 1850.