SOME COMMENTS ON OUR ENERGY PROBLEMS

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ACCORDING TO RECENT POLLS, the past severe winter seems finally to have convinced a majority of Americans that there really are serious energy problems. They also seem to be convinced that something must be done and may even be prepared to take some conservation measures that do not come naturally. In retrospect, while the Arab oil embargo prepared the way for this change in public opinion, too many believed that this was just a temporary crisis, soon to pass completely. As a good many people have said for several years, the quickest and most effective action is conservation. Whether the American public or the Congress will be enthusiastic about the effects of vigorous conservation remains to be seen.

Actually it was predicted more than twenty years ago that our oil and gas production would begin to be inadequate if demands continued to increase as they have. For the past ten years it has been quite clear that we would soon be heavily dependent on foreign oil. With oil at roughly two dollars a barrel, however, and gas at very low prices, oil and gas continued to replace our other energy sources. Energy was so cheap that many heating and cooling systems in use today were designed to be very wasteful of oil or gas because it was cheaper to waste energy than to design and build more efficient systems. The same has been true for American automobiles. The cost of gasoline was a very small fraction of the operating cost. It was much more important to have reliability and few repairs, and if the public wanted heavy, high-powered cars there was not much operating penalty. It has taken more than three years to get a change in this view but the balance seems now to be shifting. We find ourselves with an economy which uses about twice as much energy per person as some of the nations of Western Europe with comparable gross national product per capita.

In order to get a better idea of what our requirements are now and what they may be in the future, a few numbers are needed.[1] Our total energy use reached 75 quadrillion British thermal units (frequently referred to as quads or Qs) in 1973, equivalent to about 35 million barrels of crude oil each day of the year if all forms of fuel were converted to oil. We produce something over 8 million barrels per day (MMB/D) in the United States now. During 1976 we imported not quite as much from outside the United States. A year ago for the first time we imported, for a short time, more oil than we produced. This past winter we did it again for a longer period. During 1974 and 1975 our energy use *in toto* dropped back somewhat but in 1976 our energy use increased to 73 Q, an increase of nearly 5 per cent over 1975. This was in spite of numerous shortages and some efforts by industry to cut back energy use.

It is interesting to note that the lower gross national product in 1974 was accompanied by a sharp decrease in energy use. To what extent we can cut energy use without adversely affecting GNP remains to be seen.[2] There is undoubtedly waste of energy of almost every sort but to cut all of this waste will require major replacement of capital equipment. This can only be done over a longer time span and at considerable cost.

In recent years after the extensive replacement of coal by oil and gas which were more convenient, cheaper, and less polluting, about 45 per cent of our total energy came from oil and about 30 per cent came from gas. The remaining 25 per cent

[1] The figures used in this paper have been obtained from the recent draft Federal Energy Outlook-77, produced by FEA, from the report of the Ford Foundation Study "A Time to Choose" or from the study prepared by H. T. Franssen of the Library of Congress. The first of these is the most recent and most extensive. In addition, it is updated yearly.

[2] Sir William Hawthorne, Chairman of the British Advisory Council to the Commission on Energy Conservation, tells me that they believe for Britain that the ratio of the energy increase per year to the growth in GNP must be roughly between 2/3 and 1. This may be lower for the United States at present, partly because of greater energy waste and extravagant use of oil in transportation. It would be surprising, however, if this ratio were very much smaller for the United States.

has come principally from coal with some from hydroelectric sources and a smaller amount from nuclear reactors. Our energy produced annually from coal is not quite as much as it was in 1920.

Now oil costs more than five times as much as it did a few years ago and there is not enough gas to satisfy the demands, as we have seen during the past winter. What we can do right now is conserve energy. But can we solve our energy needs for the future just by conservation? In order to examine this question we should look at how we use our energy. This has been studied carefully and of course can be broken down in several ways. If, however, we confine ourselves to general categories especially to locate the major users, we find that roughly 40 per cent of our energy is used by industry, 25 per cent in transportation, 20 per cent for residences, and about 15 per cent for commercial use such as stores and office buildings. In each case this includes all energy including the fuel needed to produce the electrical energy used in each category. Any energy saved will help, but major savings can only be obtained in the major categories. So far, the prospective savings in industrial use are modest and not major. New industrial plants will doubtless use energy more efficiently. In transportation, use of smaller cars can make a significant effect. Some savings can be achieved for residential use but, if residential use including electrical energy is 20 per cent of total energy use, conservation cannot be accomplished in residences alone.

In looking to the future, the Federal Energy Outlook of 1977 has projected the 1985 energy consumption at 91Q—a figure lower than the 99Q projected a year ago. In each case there is growth, but in the new projection the growth rate of total energy use is approximately 2.5 per cent per year. The largest saving is in transportation, arising from the regulations requiring that automobiles produced each year get on the average more miles per gallon and reaching 26 miles per gallon in 1985. The increase in gasoline prices since 1973 has not had much effect and it seems that price increases must be larger to change this. Similarly, taxes on fossil fuels could further decrease energy use and result in a still slower growth rate for total energy. Many misgivings have been expressed about the willingness of Congress to go along with such restrictions if they are proposed.

Still continuing with the relatively short-range problems up to 1985, we should ask the question: where will our energy come from to give this 91Q projected by the Federal Energy Outlook in 1985? The amount of oil, both domestic and foreign, would be about 19 MMB/Dy or about 40Q with about 40 per cent of the oil being imported. Gas is now estimated to be less than previously projected or about 19Q, mostly domestic. Coal is expected to increase from a present production of about 660 to 1,050 million short tons per year. Coal would increase as a percentage of total energy, gas would decrease and nuclear energy would increase from about 2 per cent of total energy to about 9 per cent. Hydro, geothermal, and solar energy would together make up about 3 per cent. Nuclear energy is currently expected to make up about 23 per cent of the United States electrical energy production with coal providing most of the remainder, except for oil and hydro and relatively small amounts of geothermal and solar energy.

If we look somewhat further to 1990 and the end of the century, the forecasts of FEO-77 show that, in spite of Alaskan oil, offshore oil, and increased secondary and tertiary recovery from old wells, domestic output will begin to decrease again after the small increase before 1985. It is hoped that coal will continue to increase and nuclear energy will increase more rapidly. It is forecast that our oil imports will continue to increase, although not nearly as fast as if there were no effort at conservation and if there were not sizable increases in coal and nuclear energy.

One might reasonably ask at this point what would happen if much stronger conservation measures were taken either by a tax on some or all fossil fuels, and decontrolled prices on gas or oil or both. With these assumptions, the amount of energy which would be forecast to be used in 1985 would be further decreased and might get down to 85Q or even a bit less. This would mean an energy growth of not much more than 1 per cent per year and, if we follow the British analysis, this would mean a real growth in GNP of less than 2 per cent per year. There is little in the reactions of Congress or the public to indicate that such a course would be acceptable.

In short, while we must strive to eliminate waste, we must take care that in cutting back our energy consumption we do not reduce our increase in GNP too far. Furthermore, increased use of both coal and nuclear energy will be required to make up the deficiencies in oil and gas.

Our inability to develop new sources of energy on the time scale we have been considering provides a serious limitation.

There are many who object to increased use of either coal or nuclear energy. One of the objections to coal is that underground mining has proven dangerous in many ways in spite of increased efforts to improve safety and cut down the incidence of the "black lung" disease. Surface mining both in the east and the west earned a bad name for ruining the countryside and is under attack by environmentalists. With sufficient effort, the site of a surface mine can be rehabilitated and provisions for this renewal must be made if surface mining is to continue, as it appears it needs to be. There is also a problem of the contaminants in coal, especially sulphur. At the present time there are strict regulations for the emission of sulphur dioxide from a coal-electric generating station or other major source of pollution. The standards are sufficiently strict that they cannot be met by many plants operating today and they continue to operate only by postponement of the effective date of the regulations. There are some promising ways for removing sulphur from coal and others for removing it in the combustion process but major changes in operating plants would be required. This is not only costly but takes time. Western coal contains less sulphur than much of the eastern coal but the heat content is only about two-thirds to three-quarters as much. In addition, most western coal requires long transportation to the place where it is burned and this is not only expensive but it takes energy in the form of oil to transport the coal. Coal is inherently dirty and difficult to handle, creating smoke which is full of particles. These are some of the reasons why it was replaced by oil and gas over the past thirty years. In spite of all these difficulties, we are destined to use our coal much more in the years to come and we are fortunate to have such large reserves in the United States.

There are a fair number of people including scientists and engineers who feel strongly that it is wrong to go ahead with the development of nuclear power. There are others who advocate an accelerated program of nuclear power including a prototype breeder reactor which has been in the process of design, development, and construction for a number of years and which still seems a long way from completion. There is no lack of varied opinion on this subject and reactions in both directions have unfortunately become very emotional.

There are about sixty operating nuclear power reactors in the United States at the present time. They currently produce about 9 per cent of our electrical energy. These nuclear reactors are all light water reactors in that they use ordinary water to slow down the neutrons emitted in the fission process. So far there have been no fatalities associated with nuclear accident or radiation from these reactors. In addition there is a similar safety record with even more experience for the light water reactors used by the Navy. The opponents of nuclear power say this is luck and the proponents say that a serious accident is very unlikely. A very detailed and costly study carried out under the supervision of Dr. Norman Rasmussen at the Massachusetts Institute of Technology has reported that the probability of serious accident which would breach the containing sphere and cause widespread nuclear contamination is exceedingly small. A draft of the report was circulated, comments received, and some changes were made before final issue. Most technical people agree that there is no significant radioactive contamination from a normally operating nuclear reactor. The concern comes from the possibility of accident. It is not possible for one of the current reactors to cause a nuclear explosion. It is conceivable that cooling water might become unavailable and such a reactor could get too hot and cause a steam explosion. There are, of course, elaborate provisions against such a happening. There are also provisions to contain such a steam explosion. Whether these are adequate is the point of argument.

The construction of nuclear reactors to produce electrical power has been attacked because there is not currently in operation a complete system for removing and storing the nuclear wastes. This problem should have had a solution before now but it was not attacked vigorously, early enough. At the moment there are several methods of disposing of nuclear wastes from power reactors, the most promising of which involves extended storage of the fuel elements before waste separation and then incorporation of the wastes in large borosilicate rods which are then sealed in metal and in due course put in one of the salt mines where they can be monitored. Some of these mines have been undisturbed geologically for millions of years. The argument has been made that, because the system is not currently in operation *in toto,* there should be a moratorium on nuclear power. The first step, however, is safe storage of the spent fuel rods for five years or more and this can be done now. A moratorium does not seem to be warranted for this reason.

Another objection to nuclear power has been that the plutonium generated in the reactor could, if separated, be used to produce nuclear weapons. There is no doubt that the possibility of proliferation of nuclear weapons is a very serious problem and I believe it to be the most serious difficulty. The plutonium produced in a power reactor is not of the grade most desirable for weapons but the technology of bomb construction is now widely enough disseminated that it would be possible, if such material were available, for a considerable number of non-nuclear nations to produce some sort of a nuclear weapon. Perhaps it would not be strong or reliable. As a consequence our government has been trying to limit the number of processing plants where plutonium can be separated, and there have been vigorous arguments recently about whether West Germany should furnish such plants to Brazil. As far as our own nuclear program goes, we must recognize that this is an international problem. Perhaps our safest course is to try to limit the number of places where fuel can be reprocessed. With our present involvement in foreign reactors, it seems that we must be able to reprocess or store fuel elements and to do it for nations with small or moderate capability. As to our separation of plutonium to use as fuel in reactors, there does not seem to me to be sufficient advantage to warrant this step for light water reactors. It has been pointed out that fissionable material would be an attractive target for terrorists. This applies to the transport and storage of nuclear weapons as well and the security measures for weapons have recently been revised and strengthened. These same measures can be applied to nuclear materials for reactors where they are needed.

Looking forward to the next twenty-five to thirty-five years, it seems impossible that, with the prospect of diminishing sources of oil and gas, we can cover all of our additional needs by coal, even if our total energy use grows only moderately. We are going to need nuclear energy especially for areas where the pollution from coal would be very serious. The safety arguments do not seem to preclude nuclear reactors especially when they are compared with the safety problems of coal. We do need to continue to work to increase the safety of nuclear reactors and to minimize still further the possible damage from nuclear accident. The argument about relative costs of coal or nuclear production of electrical energy is an important one and depends heavily on the anti-pollution measures required for coal. After studying cost figures for large plants now under construction, there appears to be a somewhat greater cost for the average nuclear plant of a given size. There is, however, as much spread in the cost of coal plants in various locations. Cost of operation is expected to be somewhat less for nuclear plants. So, cost difference does not seem to be a determining factor.

We have coal reserves for many years, probably several hundred. The situation regarding uranium reserves is less clear. Our estimated reserves have decreased considerably in the past few years unless low grade reserves are included. Nevertheless, we probably have enough uranium to carry to the end of this century with adequate uranium to fuel the plants built between now and the year 2000 and providing fuel for a thirty-year life. This is a risky prediction involving as it does uncertainty about the uranium reserves in the future, uncertainty about the growth rate of our electrical energy production, and uncertainty about the number of light water nuclear reactors which will be built. It will require constant review.

Somewhat earlier, I referred to the breeder reactor. The fundamental principles of this reactor were worked out and proved about twenty-five years ago. It actually produces more fissionable material than it burns. For a good many years, our work on the breeder was not intensive, for the most part because of the low price of oil and gas. Our most recent work on a prototype of a commercial breeder reactor has not gone well and we are behind similar developments in Britain, France, and the Soviet Union. We might ask the question: If we probably have enough uranium to go as far as I indicated, de we need the breeder at all? As far as I can see, we do not need it soon, but we probably will need it before fusion or solar energy will be ready to take over any significant part of our electrical energy production. This means that research and development work on the breeder must be pushed now, especially to see whether some major improvements on present designs can be made. We do not need a crash program to build the present prototype demonstration breeder right now. We may need it later. Perhaps in the interim a better breeder reactor can be developed.

There are several sources of energy which so far have been mentioned only briefly or not at all. Some of these are available now and some are probably very long-range. The most promising of those for the long-range future are fusion and solar-electric and I shall come back to them shortly. We have some hydroelectric energy available now and it is a very satisfactory source. The difficulty is that the total installed capacity is only a small part of our total needs and the prospects for significant additions are not very great. We hear sometimes about the use of windmills of modern design and indeed they are being explored. There is little chance that windmills will make a sizable contribution to our energy sources but they may be useful, as they have in the past, in some remote locations. The use of ocean tides as a source of power has been suggested again and an installation is now in operation in France. In one or two special locations this might now be feasible in the United States but there is no chance that the tides can furnish any significant part of our energy needs.

Geothermal energy is a more promising source. At the present time geothermal steam is being used in California to produce electrical energy. The total present installations generate about 500 megawatts of electrical power, equivalent to a moderately large coal generating plant. New explorations indicate that there are more sources of geothermal steam and hot water than were known a few years ago. Possibilities exist for a significant but not major contribution to our energy supply.

Solar energy has many attractions. It is clean, reliable, and there is no depletion to worry about. For heating, in proper latitudes, it could be used now. At the moment, even with increased fuel costs it is not competitive with current sources. This can probably be solved. The sun, however, will help us as a major energy source only when it is used to produce electrical energy. This has been solved by photovoltaic means for our space vehicles but at a cost hundreds of times too high for successful competition with present energy sources. So far efforts to decrease the cost have had some but not nearly adequate success. Unlike the use on a space vehicle, a fixed solar energy source on the earth furnishes energy for only part of the twenty-four hours. There are presently no practical means of storing this energy. In addition to photovoltaic solar energy use, there is the possibility of collecting solar energy with mirrors for heating a steam boiler directly. A trial plant is now being built to see whether this is practical and economically feasible. At the moment, many practical problems need to be solved and there is a wide range of views regarding the operating feasibility of such an installation and serious doubts of its economic competition. Research is also being carried out on photochemical methods of producing energy from the sun but this work is still in an early stage. Considering all these methods of utilizing solar energy, it seems that, except for local heating, there is not much prospect that solar energy will make any major contribution to our energy resources in the next generation and it may be longer.

The fusion process as a source of controlled energy has been worked on for more than twenty-five years. There have been many problems and many successful solutions. So far there has been no device in which more energy has come out than has been put in. In addition there are many practical problems for large-scale plants. In spite of this, fusion is still considered as a promising source of energy for the long-term future. Fusion is not a completely clean source of energy, because of the large numbers of high-energy neutrons which produce radioactivity in many substances. In addition, some technical people believe that the principal way that a fusion reactor will be used is as a source of neutrons for a near-critical fission assembly. Fusion would tap an almost limitless source of fuel since the basic fuel is deuterium. This can be extracted from sea water with some difficulty and cost. Although fusion is a promising source of energy, the solution of problems encountered has been slower than anticipated some years ago. It is unlikely to be a significant source of energy for more than a generation to come.

My conclusion is that we must conserve energy vigorously now and some of this will hurt. Conservation will not solve our energy needs for the long-range future. Some growth in energy will be necessary for the foreseeable future, especially if raw materials are more difficult to obtain. We must work hard at some of the long-range sources such as fusion, solar-electric, and geothermal, realizing their long time scale. We must work at the breeder and try to correct some of its presently unsatisfactory features. For the next generation or more we must rely on increasing coal and light water fission reactors for our energy needs. Finally, we must do our best to find new sources of gas and oil for those uses, including petrochemical, for which it would be difficult or impossible to find substitutes.

Addendum, April 29, 1977

The foregoing paper was written in March, 1977, and presented to the American Philosophical Society on April 21. President Carter delivered a speech on his energy program to a joint session of Congress on the evening of April 20. His speech concentrated on conservation measures required to diminish our dependence on foreign oil and to cut back generally our growth rate in the use of energy. He proposed various measures required to shift our energy consumption away from oil and gas, including a well-head tax for domestic oil and possible increased taxes on gasoline if consumption does not decrease. He called for a 10 per cent decrease in gasoline consumption by 1985.

Only a relatively small part of his message was concerned with longer-range problems but he stated clearly that the United States must develop greater use of both coal and light water nuclear reactors. For the former he used the same projected figures for coal production in 1985 as were presented here from FEO-77. For nuclear energy, he referred to 63 nuclear reactors now in operation and 70 more now licensed for construction as those in immediate prospect. The President pointed out that even with energy conservation it will be necessary to use increasing amounts of nuclear energy. He proposed that the present licensing procedures for nuclear reactors be simplified and speeded up. His message to Congress was accompanied by a fact sheet (*New York Times,* April 21, 1977) in which it is stated that he

> . . . has decided to defer indefinitely the construction of the Clinch River Liquid Metal Fast Breeder Reactor Demonstration Project and to cancel all component construction, commercialization and licensing efforts for the United States breeder program and to redirect efforts toward evaluation of alternative breeders, fuels, and advanced converter reactors with emphasis on nonproliferation and safety concerns.

The President has asked other countries to join in examining other methods for meeting future needs for nuclear power. Earlier he took a strong stand to stay away from a plutonium fuel cycle and to restrict the export of the necessary reprocessing facilities. The fact sheet now indicates that the United States will reopen the order books for uranium enrichment services. In addition the President proposes ". . . to guarantee the sale of enrichment services to any country which agrees to comply with our nonproliferation objections and is willing to accept certain conditions." In addition the fact sheet stated that the United States will expand its enrichment capacity and that the new facilities will employ the centrifuge method of separation at a 90 per cent saving in electrical energy.

Longer-range research and development did not play a major role in the President's message or the accompanying fact sheet. Solar energy for heating will be encouraged by tax credits and photovoltaic, geothermal, and other sources will get increased support. Fusion research was not mentioned.

There is little doubt that the program will undergo modifications in the months to come. Various criticisms have already been made both from within the United States and from other countries.

It is a far-reaching and vigorous program directed at a realistic confrontation of our energy problems especially in the near future.

In addition, a very good report prepared by the Nuclear Energy Policy Group under the chairmanship of Spurgeon M. Keeny, Jr. has become available (*Nuclear Power Issues and Choices,* Ballinger Publishing Company, Cambridge, Massachusetts, 1977, sponsored by the Ford Foundation and administered by the Mitre Corporation).