ENERGY SOURCES OF TOMORROW

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My subject today is energy sources of tomorrow. I should explain that I don't intend to talk very much about new and different ways of producing energy. Rather, I want to speak about the relationship between our environment and energy and try to point out where we are, where we are going, and how we might get there.

Energy and the Environment

In these days, energy and the environment seem to be inseparable subjects and perhaps properly so, at least until a better understanding of the relationship of energy to our civilization is achieved. So I propose to talk first about the environment. To begin with, an obvious but often overlooked point: - Energy in all its forms is part and parcel of the natural environment in which we live. The sun delivers to us, day after day, an extremely wide spectrum of radiant energy. On a worldwide basis, it gives us many thousands of times the expected rate of energy production - worldwide - from all fuel sources in the year 2000. Sunshine falling on the earth doesn't seem to disturb the earth a great deal - in fact, we couldn't exist if it did - and it seems fairly clear that the trivial amount of energy we generate in comparison to the amount the sun delivers will have practically no overall adverse effect based on the quantity of energy alone. This is not to say that there won't be local effects which, if we're not prudent, could be both severe and adverse. The generation of thermal energy from fossil fuels can impart some chemical pollutants such as carbon dioxide and sulfur to the atmosphere. Nuclear energy avoids these pollutants, but today's nuclear reactors generate some radioactive materials that would not otherwise be present on the earth, and we have to contain them and control them. All thermal power plants can discharge excess heat to streams or lakes or the surrounding atmosphere.

People like to talk about preserving things in their pristine state, which Mr. Webster says, refers to earlier times and carries with it the implication of purity and cleanliness and even an implication of an unchanging state of cleanliness. We know, of course, that nature doesn't act that way. Every mountain formed is being washed into the ocean. Streams carry millions of tons a day of good earth into the sea. Earthquakes change the face of the land. Plagues and pestilence wipe out whole populations of animals, birds, people and vegetation. The flourishing of one form of life is often at the expense of another. So the environment changes and, of course, it changes more rapidly if people are present, since man has a greater impact on his environment - for good or bad - than any other organism. Undoubtedly man currently is the great despoiler of the environment, but getting rid of man is not a very popular solution, although we might succeed in putting a halt to population growth. I believe, however, that as we learn more about energy and its relationship to society and to the environment, we will see that we need more energy, not less, if we are to keep our habitat favorable to our continued existence and comfort.

Energy in the United States

Fremont Felix, in the July 6 issue of ELECTRICAL WORLD, made some observations about energy production and society that are relevant to the current energy situation in the United States and to future trends in energy use. Some of his more significant points are these:

- The use of energy in the United States has been increasing at the rate of three to four percent per year for the last thirty to forty years. This is about the same rate of growth as the gross national product and is a little faster than the growth rate of population.

- Present per capita use of all energy (oil, coal, gas, uranium) in this country is growing at a rate of about thirty percent every ten years, though it may slow to perhaps twenty percent by the end of the century.

- Per capita consumption of electricity has multiplied almost 3-1/2 times in the twenty years between 1940 and 1960.

- The current ratio of electric energy use to gross national product is 1.66 kilowatt hours per dollar of gross national product. By the end of the century this ratio will probably be more than three kilowatt hours for each dollar of gross national product.

- Only 24 percent of total energy consumed in the United States goes to the generation of electricity whereas many countries including Japan, the United Kingdom, the Federal Republic of Germany, Canada, Italy, Sweden, Australia, Brazil, Switzerland, New Zealand, and others, use a much higher percentage.

- The United States just about matches the world average for kilowatt hours consumed per dollar of gross national product.

Jim Young (Vice President - Engineering, General Electric Company) put the matter well in a recent talk when he observed that the electric energy market is inelastic, "Producing more at lower cost does not establish more consumption. It is consumption that establishes production. Lighting to reduce crime and accidents; air conditioning and power to improve comfort and productivity; 26 million new household formations to be served in the 70's; prospects of urban residents for improving the quality of their life; and use of electrical energy to reduce pollution, and for treatment of gaseous, liquid and solid wastes - to mention just a few."

In any case, I am persuaded myself that Mr. Felix's figures are a pretty reliable indication that the United States is not needlessly and wastefully generating and using electric energy. The fact is that we need power for either purifying or recycling wastes of all kinds and this, of course, is one key to a liveable environment. As population grows and we rub elbows more and more, we simply cannot sustain the standard of living we now enjoy let alone improve it and extend it for all our people unless we produce more electric power for each person.

What will our electric energy needs be over the next twenty years? By 1990, per capita gross national product probably will have grown by eighty percent so that each man, woman and child in the United States, on the average, will be able to buy almost double the products and services he now does. This kind of growth will be possible only if an adequate supply of electric energy is available. If past trends are a reliable indicator, we will need almost four times our present generating capacity by 1990. Unless we provide this generating capacity, the transportation industry, the factories, knitting mills, refineries, steel mills - in short, the tools of our economy will not be able to increase their output as they should, and our society itself will falter - our political institutions may be imperiled.

Fuels and Energy

The first thing to think about when we talk of increasing the supply of electricity is the supply of fuel, and of the various fuels, those of most immediate importance are the fossil fuels - coal, oil and gas. By the end of this century, even if nuclear generating equipment produces half of our electrical requirements, we may still need more than double the amount of fossil fuel we are using today for the generation of electricity. So, unless we can produce enough coal or oil for use as fuel and do it economically, we will have some lean years ahead. I stress the word economically because we have ample reserves of coal in the ground but the challenge is to get them out cheaply; to get them shipped cheaply; and to burn them cheaply while containing their noxious combustion products. The coal industry is aware of these challenges and it is in the interests of all of us that the industry meet them.

Oil will certainly play a major role in providing our energy requirements for some years to come. It, too, has its problems with air pollution because of sulfur content (the relatively sulfur-free crudes seem to be getting in short supply), but perhaps more important for the long run is that any continuing shortage of coal is apt to put such heavy demands on our oil reserves as to diminish them unduly from the standpoint of our best interests.

Viewed against this background, I think most people can agree with Glenn Seaborg in saying nuclear energy was discovered in the nick of time because we certainly do need new fuels and we believe that nuclear fuels can greatly ease the overall energy picture from the standpoint of conservation of resources, environmental impact and economics.

I would like to make it clear, however, that nuclear fuel is not a panacea, for moving as rapidly as we are able, we may still find this country seriously short of energy supplies.

Utilization of Nuclear Fuel

Briefly, we have proven reserves of almost 400,000 tons of yellow cake - the beneficiated uranium ore that corresponds roughly to coal or oil among the fossil fuels - counting both the Atomic Energy Commission's reserve stocks and uranium recoverable at prices up to $10 per pound. This amount is about enough to meet projected requirements for nuclear power through 1984. While a fourteen-year forward reserve is comfortable by most standards, we must improve the efficiency with which we burn nuclear fuels over the next two decades or face the likelihood of rising fuel costs; for unfortunately, the present generation of nuclear power plants recover only about two percent of the energy available in uranium.

One step in the improvement of our position with respect to nuclear fuel is effective use of plutonium recycle which can reduce raw fuel requirements per unit of useful energy produced by about twenty percent. Recycled plutonium is just beginning to be used by utilities in a cautious and semi-experimental fashion.

Another way to get more kilowatt hours from our nuclear fuel is to improve the thermal efficiency of nuclear power plants. The best type of reactor for accomplishing improved efficiency in the near term seems to be the high temperature gas cooled reactor.

A third method for improving the energy equivalence of our nuclear fuel resources is to develop the thorium-uranium fuel cycle to take advantage of the favorable nuclear characteristics of the isotope U-233 in thermal neutron reactors and to augment our uranium reserves with thorium.

Finally, there is the fast breeder type of reactor which uses plutonium as a fuel. There are two classes of this type of reactor of current interest, one cooled with liquid sodium and the other with an inert gas (helium). The liquid metal cooled fast breeder reactor is the concept on which worldwide attention has been focused and it is the object of major development programs in the United Kingdom, France, Germany, Russia, Japan and the United States. The United States' program in the fast reactor field is primarily oriented toward the liquid metal cooled concept; however, the technology needed for a gas cooled fast reactor is expected to be obtained from the high temperature gas cooled reactor insofar as the coolant is concerned, and from the sodium cooled fast reactor insofar as the fuel technology is concerned.

I could, of course, dwell on the many technical problems associated with bringing fast breeder reactors into practical application. I think most of these problems are recognized by most of the scientists and engineers working in this field, and I would prefer now to address myself to the economic problem of accomplishing the satisfactory development and commercialization of the fast breeder types of plants.

The Commercialization of the Breeder Reactors

We are all familiar with how the light water reactor business got established. Very briefly, after substantial experience with the Navy program and the successful operation of Shippingport, Yankee, and Dresden I, the manufacturers felt that it would be feasible to establish a market for light water reactors in economic competition with fossil-fueled power plants. To do so required the use of a dynamic pricing policy coupled with reasonably repetitive designs and with the manufacturers assuming the full risk by quoting turnkey plants with guaranteed performance on a fixed price basis. The beginning of commercial nuclear power was the announcement of the Oyster Creek plant in 1963. There followed a rapid increase in orders, peaking in 1968 and falling off abruptly in 1969. The industry now seems to be entering a more stable period.

The pattern was consistent, with one important exception, with the way in which the equipment manufacturers and the utility industry traditionally financed the introduction of new and improved technology where the manufacturers funded the cost of research and development and took the risk of marketing a new or improved product with the expectation of being able to provide a reasonable rate of return for their shareholders as the new business grew. The utilities, of course, compensated the manufacturers in time through purchase of their products. The one significant exception in the marketing of nuclear power was the fact that the nuclear steam supply system represented a quantum jump in technology over the conventional fossil-fueled generating plant. Previous improvements in turbines and boilers that came about through the new developments of the equipment manufacturers were typically gradual and represented a thoroughly tested and conservative scale-up of existing art. No doubt, and in large part because of the quantum jump in technology, there were large sums of money lost by the manufacturers in launching the light water reactor business, and today's prices reflect some correction due to this experience. The pattern used in establishing the light water reactor business does not appear to be a practical method for the commercialization of the fast breeders. There are several reasons for this:

First, the technology of the fast breeder is going to be extremely difficult to master - not so much in the narrow sense of building one or two plants and getting them to run, but rather in the sense of having a complete command of the technology in design, in construction, and in maintenance such that the owner and operator can be assured of reliable on-line performance for fast breeder reactors as a class of plants. In the past, I have used the term "power-worthiness" to suggest that what is required is quite like the sea-worthiness of ships or the air-worthiness of airplanes. Dependability is of prime importance since any deficiency will require increased reserve capacity with resulting increased capital costs.

Second, providing proof that a given design can demonstrate this dependability is an expensive matter. Costs of initial demonstration plants of moderate size have been variously estimated at from $500 to $1000 or more per kilowatt - two to four times the going cost for light water nuclear plants. The financing of several such plants is beyond the capability of the manufacturing industry and it is questionable how much the Government will contribute - particularly if the utility industry, which is most concerned, does not itself carry a major share of the load.

Third, even if such medium sized plants are fully successful, there remains the problem of financing and building plants of larger and more economic size (about 1000 to 1500 MWe). Any reactor vendor will undoubtedly need to construct and put into operation several such plants before costs will be proved and economic operation demonstrated. At this point in time, it does not appear that the traditional division of responsibilities and risks among the government, the equipment manufacturers and the utility industry is likely to prove adequate to a timely commercialization of the breeder.

Of course, we have asked ourselves whether ordinary economic forces don't come into play and accelerate this development. These forces include the rising costs of fossil fuels, the cost of meeting environmental restrictions and any rising trend in uranium prices that may appear. With regard to uranium prices, they seem to have been stable or actually declining over the last several years, and since there is still a stockpile hanging over the market and a restriction on imports that will sooner or later have to be removed, there is little prospect of a rising price trend for the next few years. Eventually, uranium prices must rise and bring into focus the economic significance of the breeder reactor which lies in the fact that it can almost certainly be competitive with fossil-fueled plants even if uranium prices increase to as much as $50 per pound.

The difficulty today is that the economic forces affecting the equipment manufacturers are not of themselves sufficient to determine the optimum schedule for the successful development and marketing of the kind of "power worthy" breeder reactors we will need to have by the mid 80's.

Financing Problem

Both industry and government are addressing themselves to this question of the source of financing for advanced development for the power industry. Everyone seems agreed that a breeder reactor is an ultimate necessity unless the controlled thermonuclear reaction is successfully developed much sooner than we now think possible. Moreover, this opinion seems to prevail on a worldwide basis and for very good reasons - including the need for more electric energy with reduced environmental effects. Several ideas have been put forward as suggestions for solving the financing problem. Some of these ideas are the following:

- It is suggested by some that the government finance the design and construction of a demonstration plant (perhaps permitting a consortium of manufacturers to participate so as to share the experience, then permitting a consortium of utilities to operate and maintain it so as to develop and share the necessary operating and maintenance experience). This would be followed by an initial round of demonstration plants of large size that might be partly financed by the government. After this step the utility industry would carry the load.

- Another suggestion is that of persuading the utility industry to get together with its various State regulatory bodies to work out an arrangement under which the funding of design, development and reduction-to-practice of advanced power plants would be provided for in the rates charged to utility customers. For example, one-tenth of one mill/kwhr would provide an income of some $150 to $300 million per year through the next decade and this could go a long way toward financing the fast reactor program. The Chairman of the Federal Power Commission has stated that "the electric utility industry should bear a substantially greater proportion of funding this program."

- A third idea is to impose a Federal tax on electricity corresponding, in a way, to the Federal gasoline tax with, however, a proviso that would let utilities themselves have a voice in allocating some portion of the funds to developments of their own choosing - provided such developments fall into categories approved by the Federal Government.

Considering that utilities today are spending only a fraction of one percent of their revenue for equipment development, it would seem that direct funding by the utility industry itself on a pay-as-you-go basis might have considerable merit, although I am well aware of the problems and pressures on utility cash flows that have developed in the last three years.

Now if I may summarize:

- Cleaning our environment, making necessary provisions for the additional people coming into our population, and trying to maintain a reasonable advance in the standard of living will require more energy (about two to three times as much by the end of this century), and a much greater proportion of this energy must be converted to electric energy. We will probably need at least six times the present electric energy capacity by the year 2000.

- In the face of these needs, we are at the present time experiencing a "national energy crisis" in the words of the Chairman of the Federal Power Commission, Mr. Nassikas. Compounded of many factors, the solution of this problem is not presently in sight. Unless a solution is found, the economy and our standard of living may both falter and even decline, and the extent to which this would imperil the fabric of our society and our democratic institutions cannot be exaggerated. Energy is such a basic commodity that its rationing would bring about basic and undesirable changes in our economic and political fabric.

- The proper use of nuclear fuel can help to solve the energy crisis - but it cannot do it alone. Solutions must also be found for the production, distribution and clean and economic utilization of fossil fuels in adequate amounts.

- There is a time limit on the present inefficient methods of utilizing nuclear fuels. Today only about two percent of its available energy is utilized and supplies of this fuel will become expensive and perhaps marginally economic unless the more efficient breeder (which can use fifty percent of the energy in the fuel) is introduced.

- Introduction of breeder reactors and their commercial establishment present difficult and serious financial problems to the electric power industry. The government has helped and in my opinion will continue to help in the research and development area. The government will also provide limited assistance in the demonstration phase. But the utility industry itself must provide the leadership and a major portion of the financing of the demonstration phase of development. This point has also been stressed publicly in a broader context by the Chairman of the Federal Power Commission. It seems evident that the utility industry must consult with its regulatory bodies and that new rate policies and/or new accounting policies must be set that will permit adequate financing of power plant design and development.

- Finally, and closely related to the question of the source of financing for power plant development is the question of who directs the development program - and how do we assure that sound and realistic judgments are made in setting objectives and assessing priorities for developing effective power systems. In the last analysis, I believe this is a total system problem that must include system design, the optimum choices of power generating and transmission equipment, of power plant sites and environmental compatibility. These matters require strong utility leadership. They can no longer be the subject of uncoordinated local decisions. Planning must be coordinated on a regional and national scale. In my view, it is clearly in the interest of the utilities to accept this leadership.