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SOME CRUCIAL ISSUES IN NUCLEAR ENERGY[1]

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The future projected in the recently issued Project Independence Report[2] calls heavily on nuclear energy. What must be done to assure that nuclear energy will play the role expected of it in these projections - i.e., what must still be done to validate the nuclear option? Validating the nuclear option requires us to improve technology and to implement new policy. But of all the issues that might compromise nuclear energy the most important now appears to me to be the public acceptability of nuclear energy. Much of my talk will, therefore, be devoted to the crucial issue: is nuclear energy acceptable?

[1]For presentation before the IEEE Nuclear Science Symposium, Plenary Session, Shoreham Hotel, Washington, D.C., December 11, 1974

[2]Federal Energy Administration, John C. Sawhill, Administrator, "Project Independence", U. S. Government Printing Office, Washington, D.C. (November 1974).

DISCLAIMER

Nuclear Energy and Project Independence

Perhaps the most surprising projection of the Project Independence Report is that - if oil remains at $11 per barrel - then the total demand for energy in the United States in 1985 will be around 103 mQ per year, rather than the 115--120 mQ which has been the more common prediction.[3] If conservation is practiced to the extent deemed possible, the prediction for energy demand in 1985 is 94 mQ. These projections are to be compared with the 75 mQ used during 1973.

Of the 103 mQ energy demand predicted for 1985, nuclear energy is expected to supply 12.5 mQ. This corresponds to an installed capacity of about 200,000 kilowatts electric, which is about 22% of the total projected electrical capacity in 1985. Nuclear power is expected to supply so large a fraction of our total elec-

[3] National Petroleum Council, "U.S. Energy Outlook: Energy Demand", Energy Demand Task Group, J. A. Coble, Chairman, Washington, D.C. (1973)

tricity because it is judged to be the cheapest source of base-load electricity. If nuclear plants could be built more quickly the fraction would be even larger. Thus, if the nuclear option should falter between now and 1985, the Project Independence Report predicts a shortage of about 10% of our total energy - some 6,000,000 barrels of oil per day equivalent. If this actually were imported oil, it would cost the United States $\$25x10^9$ annually, would place enormous pressure on world oil supplies, as well as cause difficulties throughout the economy.

Beyond 1985 Project Independence's projections are not as detailed. In the post 2000-period, oil and gas will be severely depleted; synthetics from coal or from shale will be needed, but probably cannot fulfill our entire demand simply because so much coal would be needed. Even if our energy demand after 1985 increased by only 1.6% per year, we might use $3x10^9$ tons of coal annually compared with our current $600x10^6$ tons, and the amount would continue to grow thereafter.

We understand that the future is unpredictable, that even the elaborate econometric analysis of Project Independence is fallible. Yet, however one looks at the matter, it appears that some non-fossil source must play an increasing role in our future energy system. Of the four non-fossil possibilities - geothermal, fusion, solar and fission - geothermal appears to be rather a small and localized source; fusion still is faced with scientific and technological uncertainties; solar electricity is intermittent and will probably be very expensive (though solar heating and cooling may be practical rather soon); and only nuclear fission seems to be both technically and economically attractive.

Validating the Nuclear Option: Technical Issues

What must we do to make certain that energy from nuclear fission will be available to our society in 1985, in 2000 and beyond? I shall enumerate some of the technical uncertainties, and some non-technical uncertainties; usually the two are interwoven.

1. Ore Supply

Even if our demand for nuclear electricity is as little as 200,000 kilowatts electric (12.5 mQ) in 1985, we shall still need 45,000 tons of uranium for light water reactors in that year. In 1973 we mined 13,000 tons of uranium, though we have capacity for 18,000 tons. We may therefore be required to expand our production of raw uranium about three-fold within the next 10 years. To do this is probably possible, but it is by no means totally assured. We must find the new uranium ore, arrange for its mining, and for its milling: all of these steps take time - for example, as much as five years for a new mill, eight--ten years to find and develop new ore bodies.

In the longer range, to inventory and operate plants built by 2000 will require several million tons of uranium: almost surely more than we now know exists in high grade ores. We shall not, of course, deplete low-grade uranium ore significantly; but if we depend only on light water reactors, and to some extent on high temperature gas-cooled reactors, both of which use uranium rather inefficiently, the digging of so much low-grade ore will seriously damage the environment. It seems clear that we shall want to locate more uranium ore of high quality if we depend on light water reactors.

2. Separative Work Capacity

We now have capacity to produce 17,000 separative work units per year. The Atomic Energy Commission's proposed expansion program would add another 10,000 SWU's, which will be sufficient to meet estimated domestic and export requirements until the early 1980's. After that time we will have to add additional capacity that will require heavy capital investment. Both the questions of availability of ore and of separative work capacity are as much matters of mobilizing to get on with the job as they are matters of improving technology.

3. The Breeder

The requirements for uranium ore and for separative work that I have quoted may be either too high or too low. Thus, one of the major arguments for the breeder is not that we know our ore reserves are inadequate and the separative work may not be on the line in time, but rather that the breeder tends to eliminate uncertainty in policy planning. If 25 years ago the General Electric Intermediate Breeder Reactor Project had been converted into a fast breeder project instead of being diverted to the Submarine Intermediate Reactor, we would probably be deploying breeders today. Many of the troublesome arguments as to whether we will deplete our ore supplies or lack the required separative work capacity would thereby be alleviated. This simple argument, drawn from history, is the strongest justification for proceeding with the breeder - so that

25 years hence we shall not again be confronted with serious uncertainties.

4. Reactor Safety

The safety issue has both technical and non-technical components. From technology we can estimate the probabilities and consequences of a reactor accident; how much safety we want is a non-technical question. The Rasmussen study[4] predicts the probability of a reactor melt-down in a 1,000 Mwe light water reactor to be no more than one in 17,000 per reactor per year; the probability of a fatality for 100 reactors is predicted to be around one in 300×10^6 per years; the maximum accident to a single reactor (which might occur once in a billion years) is calculated to cause about 2,300 acute deaths, and 3,200 latent cancers.

Obviously, despite Rasmussen's great contributions to the

[4]Reactor Safety Study: An Assessment of Accident Risks in U. S. Commercial Nuclear Power Plants, WASH-1400 (draft), U. S. Government Printing Office, Washington, D.C. (August 1974)

methodology of probability analysis of unlikely events, there will never be a definitive answer to the question: How safe is a reactor? Critics of the study insist that fault-tree analysis, in principle, is inadequate or that the numbers in the analysis are incorrect. The Rasmussen study, plus the experience we have had thus far, suggests that an accident is very unlikely and that its consequences, measured objectively, are usually rather small. Nevertheless, the Rasmussen study, as do all such studies, does not eliminate the possibility of a very unlikely - almost hypothetical - accident that would be comparable to the worst man-made disaster, but far less than natural disasters, such as the Bangladesh typhoon.

5. Reactor Siting

No matter what the risks of nuclear energy are, and different people perceive them differently, there will always be incentive to reduce these risks. One way of reducing the risks is by adopting a more rational siting policy for reactors and for reprocessing and fabrication plants. Several possibilities such as placing reactors underground or off-shore have been discussed. One that I have espoused is the nuclear energy center.[5] If reactors and their sub-systems are clustered into energy centers so that all lines of communication are internal, many hazards could be reduced. Diversion of fissile material would be made difficult since one would need to guard only the "basket", not the eggs. Reactors built serially would be constructed by a stable work force and operated by a supercritical cadre. The reactors would be better built and better operated; accidents of whatever sort would be less likely. Isolating nuclear generation at relatively few sites reduces the area that could conceivably be at risk of contamination.

Weighing against such cluster siting are these technical issues: the heat island effect, transmission of power from such centers, and

[5]Alvin M. Weinberg, "The Moral Imperatives of Nuclear Energy", Nuclear News 14, 33-37 (December 1971).

vulnerability of the power system to failure of a center. The pros and cons of centers are now being actively argued; and Title II, Section 207, of the Act creating the Nuclear Regulatory Commission requires the NRC to conduct a comprehensive study of nuclear energy centers, and to report the results by October 1975.[6]

Validating the Nuclear Option: Non-Technical Issues

There are two different non-technical obstacles to validating the nuclear option: institutional obstacles and basic questions of the acceptability of nuclear energy.

I shall briefly mention a few of the institutional obstacles. One of the major problems facing nuclear energy is the difficulty of raising capital. Is the utility industry capable of providing the money needed to build nuclear plants - or, for that matter, fossil-fueled plants? These capital-intensive devices are expected to pro-

6"Energy Reorganization Act of 1974", Public Law 93-438, 93rd Congress, H.R. 11510, U. S. Government Printing Office, Washington, D.C. (October 11, 1974).

duce energy for 50 or more years. But, generally, the marketplace discounts long-term investments at a high rate - too high at present to attract the needed funds. Nearly 100 nuclear reactors have been deferred or canceled, partly because of the capital squeeze. Will the marketplace serve adequately for financing the nuclear enterprise; or do we see here a possible breakdown of the market mechanism? Will some modified market system be required to raise the necessary capital for such ventures?

Fragmentation of the utility industry places obstacles both in the way of raising capital and of establishing nuclear energy centers. Centers that generate, say 20,000 megawatts electric would in most cases require a consortium of utilities. Generally speaking, such centers might represent a separation of the wholesale generation of electricity from its retail distribution. This, in some ways, is reminiscent of the separation between wholesale and retail banking that occurred in 1935 when the Federal Reserve

System was established. Of course this does not imply that the generating centers would be Government-owned; but it seems clear that new organizations, however financed, would be required to operate the centers.

There are many other institutional questions that still beset nuclear energy such as Price-Anderson extension and one-stop licensing. But these are incidental to what seems to me to be emerging as the most crucial issue in nuclear energy: Is nuclear energy acceptable to the public? That the acceptability of nuclear energy is shadowed by doubt is particularly painful to those of us who have devoted our careers to peaceful nuclear energy and who 25 years ago were hailed as harbingers of a new and more abundant age based upon nuclear energy. Today many of us feel like Horatio at the bridge; often we find ourselves subjected to abuse, to accusations of dishonesty, or cowardice because we continue to insist on what was evident 25 years ago and - despite noisy protests - remains true today: that nuclear energy is, in fact, a good thing, not a bad thing; that it is man's great good fortune to have fallen into this miracle at the same time he began to use available fossil fuels at an alarming rate.

The opposition to nuclear energy is hardening. A recent utility industry poll suggests that 17% of those questioned were opposed to nuclear energy, 19% were undecided, 64% were favorable. There is a non-zero chance that the public will turn away from nuclear energy, that those who are intent on abolishing nuclear energy may succeed in so doing.

The major argument of those who wish to abolish nuclear energy is basically that the social institutions, the meticulous attention to detail that is demanded by nuclear energy if we are to use it extensively, is beyond man's capacity. If a serious accident should occur, the nuclear enterprise - according to its critics - would be stopped in its tracks. Therefore, they say it is better to halt the enterprise now when it is relatively small and not risk a shutdown of a major source of energy than to become too dependent on what some consider an undependable source of energy.

As one of those who ~~have~~ has pointed out the nature of the Faustian bargain inherent in nuclear energy - that in exchange for an inexhaustible and relatively cheap source of energy, mankind commits itself to a high order of care and social stability - I must take issue with those who conclude, as James Conant did some 20 years ago, that nuclear energy is not worth the candle[7], that the disposal of waste (to use Conant's example) posed an insoluble dilemma.

First with respect to the assessment of hazard, none can deny that nuclear energy is potentially hazardous. But even if the Rasmussen study is wrong by a factor of 1,000, and the risk of fatality per 100 reactors is one in $3x10^5$ years, not one in $300x10^6$, the hazard

[7]James Bryant Conant, "A Skeptical Chemist Looks into the Crystal Ball", CHEMICAL AND ENGINEERING NEWS 29, 3847-3849 (September 17, 1951).

is well below that posed by most other man-made activities. As for the disposal of wastes, the much maligned disposal in salt of solid wastes is simply that: much maligned. In the first place, there is every reason to believe that the ceramics in which the wastes are fixed will resist corrosion by water for a very long time, even in the most unlikely event that water reaches the wastes. One can calculate that after about 600 years in the salt mine the radioactivity of the wastes is, per unit volume averaged over the entire mine, considerably less than the radioactivity associated with the original uranium ore. We often forget that radium occurs in nature and that radium is much more hazardous than is plutonium. After 600 years or so, the net effect of processing uranium through a reactor and returning it to the ground is to reduce the hazard associated with the virgin uranium ore.

Yet I cannot say, nor can anyone say, that immense damage cannot be caused by a grossly misoperating reactor - that, say, rather large land areas will not be interdicted for long times - if a reactor blew up and destroyed its containment under the worst possible conditions. It is simply that the probability of this happening is extremely small.

Such remote risks are acceptable only if one believes that the benefits one derives are commensurate with the risk. And in the debate that is now going on, it does not seem that the benefits in the risk-benefits equation are properly acknowledged.

First, let us not forget that nuclear base-load electricity is now cheaper than most fossil alternatives that can presently be installed.

Second, nuclear energy is cleaner than fossil-fueled energy. A typical coal-fired power plant may cause 50 deaths each year, according to estimates of B. L. Cohen[8]; the average life span of a city dweller is five years shorter than that of the country dweller,

[8]Bulletin of the Atomic Scientists, October 1974.

and this toll is probably in fair measure attributable to the burning of fossil fuels. A nuclear electric economy, including widespread use of electric cars, would avoid this damage.

One often hears from those who wish to abolish nuclear energy that solar energy is really what we should use; but this is surely a misrepresentation of our present knowledge. Solar heating and cooling will come, but will probably be expensive. As for large-scale, direct electrical generation from solar energy, the latest cost estimates, for example by Honeywell Company[9], are around 55 mills per kilowatt hour with one-half hour storage, and possibly double this amount with night-time storage. Other solar modalities (wind, ocean gradients, biological methods) might prove to be cheaper. But it seems imprudent to renounce nuclear energy for a prime source that is intermittent and might be five to ten times more expensive. Obviously, we must pursue solar seriously, and the budget for solar

[9] "Solar-Thermal Electric Power Generation - A Status Report", Honeywell and Black & Beach (December 4, 1974).

research has increased eightfold over the past three years. But we cannot depend on this source and reject nuclear energy without facing quite honestly and very squarely all the consequences of rejecting nuclear energy.

And, indeed, it is the refusal to face up to all the consequences of rejecting nuclear - social, political, economic - that seem to be the weakest point in the argument of the abolitionists: the additional burden of $6x10^6$ barrels of oil equivalent per day by 1985, perhaps three times this amount by 2000; the inexorable rise in prices of electricity and energy generally as increased use of oil and gas for electric power will drive up energy costs; the additional environmental damage which is inevitably caused by the alternatives to nuclear.

My response to nuclear abolitionism is not to reject nuclear energy; but to improve nuclear energy. When Ralph Nader first pointed out that automobiles cause 50,000 deaths each year, his response was to make cars safer - not to abolish them!

In the same vein, as we recognize the potential hazard of nuclear energy, we must not abolish nuclear energy but instead we must reduce any residual potential hazard of nuclear energy. I believe we ought to re-examine our siting policy and move forward with energy centers; particularly, I favor siting breeders in energy centers. We must continue to tighten our standards of workmanship, of meticulous attention to detail. We should investigate schemes for removing the transuranics from wastes and to make the wastes less leachable, even though our scenarios suggest that this may not be necessary. We must also strengthen the institutions charged with responsibility for generating nuclear energy.

No one can promise that these measures will be totally successful, and that the hazard of nuclear energy will always remain potential. But we must remember that, by contrast, the dangers of fossil energy are not potential; instead, they are real. In proceeding on a nuclear course - with its economic advantages - we accept the presumptive and potential risk of nuclear energy, but we avoid other risks that are real - not presumptive nor potential. This would appear to be a far more prudent course than the destruction of nuclear energy demanded by the nuclear abolitionists.