[COMMITTEE PRINT]

ERDA AUTHORIZATION HEARINGS FOR FISCAL YEAR 1978 ON NUCLEAR POWER: ISSUES AND CHOICES

A REPORT OF THE NUCLEAR ENERGY POLICY STUDY GROUP

BY THE

SUBCOMMITTEE ON FOSSIL AND NUCLEAR ENERGY RESEARCH, DEVELOPMENT AND DEMONSTRATION

OF THE

COMMITTEE ON SCIENCE AND TECHNOLOGY U.S. HOUSE OF REPRESENTATIVES

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LETTER OF TRANSMITTAL

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, D.C., April 5, 1977.

Hon. OLIN E. TEAGUE,
Chairman, Committee on Science and Technology, House of Representatives, Washington, D.C.

DEAR MR. CHAIRMAN: The issues surrounding the role of nuclear energy are of intense interest.

A report on these issues entitled "Nuclear Power: Issues and Choices", was recently prepared by the Nuclear Energy Policy Study Group, sponsored by the Ford Foundation. The report is helpful to us at this time since proliferation has become a matter of national attention. To better understand the views and opinions of the study group our subcommittee asked for their testimony as part of its hearings on the ERDA authorization for fiscal year 1978. Among the major issues it discusses are:

(1) The reprocessing and recycle of plutonium;
(2) The breeder reactor program;
(3) The management of nuclear waste;
(4) The expansion of uranium enrichment capacity;
(5) The export of nuclear technology and materials; and
(6) The available resources for uranium and fossil energy.

These issues are presently being addressed in our fiscal year 1978 ERDA authorization hearings and the belief that the prevailing views on these issues should be aired and debated in a public forum has led me to provide this print which I believe will be of real interest to all concerned parties.

WALTER FLOWERS,
Chairman, Subcommittee on Fossil and Nuclear Energy Research, Development and Demonstration.

Staff Comments

NUCLEAR CHOICE STUDY

1. The data used for the uranium supply is not well documented and is based on the conclusion that if the price rises that the supply can be located and recovered. These assumptions are different from most conservative estimates projected by the government of 1.8 to 3.7 million tons and are based on a classic economic theory that when the price rises an adequate supply will follow.

2. The report relies on a widely-used model, the Energy Technology Assessment model, where outcomes are dependent on the choice of the supply function. Therefore, staff concludes that the panel relies upon an argument based upon a model that could produce equivocal results.

3. The cornerstone of the report appears to be a concern with the implications of plutonium reprocessing for nuclear weapons proliferation. The report concludes that the costs of not developing the breeder are small. Its primary concern is that the commercialization of breeder technology will require reprocesssing which will further the international problems of plutonium proliferation. This conclusion is not shared by other responsible persons and groups, some of whom testified during the Authorization hearings.

4. The Ford study was put together by a group drawn heavily from academe. They have little direct experience of utility problems or international markets. Thus, they have not assessed the potential impact of program cuts on the attitude of the lending community in terms of the availability of investment capital. Also, their view that nuclear plant construction can be expedited does not recognize NRC rulings which have not implemented standard plant design.

5. In addition, the group appears to have been funded to write a report and was responsible to itself for the writing and conclusions contained in the report. The usual process of review by others of each particular section or a peer review for the overall effort was not followed. Furthermore, now that the report has been written the group has disbanded. Questions and other comments cannot be addressed to the group as a whole. Follow-up studies are not ongoing activities of the group. Therefore, the panel is no longer a resource for careful examination of the issues.

6. The study does not deal in depth with the issue of development and demonstration for breeder technologies. The technology for LMFBR applications in this country is many years away since we have not even built a demonstration facility at this time. By their own admission, the group stated on the record at our hearing that they did not consider the question of whether the breeder program should be larger or smaller. This issue is also key to nuclear technological development and needs to be addressed in any report which purports to be a discussion of nuclear choices and alternatives.

7. The timing of the arresting of U.S. breeder development as a gesture to reduce the risks of international proliferation is not discussed. There is no comparison of the merits of completing technology development on the LMFBR and then offering to defer commercialization versus deferring technology demonstration (CRBR) indefinitely. Neither is there any discussion of the economics of various "technical fixes" which might be employed to limit proliferation in a plutonium economy such as transporting the reprocessed fuel in "hot" form so as to preclude terrorism or "spiking" the plutonium with uranium to make separation more difficult. Indeed, the study does not separate out the risk of terrorism from the danger of third-world separation capability for weapons production. Alternate fuel cycles are mentioned but there are no outlines of an alternate program to the uranium-plutonium cycle which requires accelerated R. & D.

8. The resource data is also quite inadequate in its discussion of coal availability. Coal resources are indeed large and constitute many years of available supply. However, the problems in mining the coal and using it in this country have not been overcome so that any projections which call for four billion tons of coal production by the year 2000 can only be labeled extremely optimistic and are open to serious debate.

9. The utility industry would be the ultimate customers for a breeder technology. As regulated industries, profit is not the sole driving force for investment. Their systems must be reliable. Their regulatory situation, economic and environmental, must be stable rather than uncertain. The Ford-Mitre study assumes that economics is the sole motive force for utility behavior. To those familiar with utilities this makes some of the conclusions unrealistic.

THE REPORT OF THE NUCLEAR ENERGY POLICY STUDY GROUP, NUCLEAR POWER ISSUES AND CHOICES

THURSDAY, MARCH 31, 1977

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON FOSSIL AND NUCLEAR ENERGY RESEARCH,
DEVELOPMENT AND DEMONSTRATION,
Washington, D.C.

The subcommittee convened, pursuant to notice, at 9:40 a.m., in room 2123, Rayburn House Office Building, Hon. Walter Flowers, Chairman, presiding.

Mr. FLOWERS. We will come to order, please.

In concert with our hearings on the fiscal year 1978 ERDA authorization, the subcommitteee will hear from the nuclear energy policy study group which recently issued a report entitled, "Nuclear Power, Issues and Choices." The report was sponsored by the Ford Foundation and chaired by our principal witness, Mr. Spurgeon Keeny. It dealt with nuclear energy issues facing this country at the present time and its future role in an overall energy policy.

In keeping with the subcommittee's policy of publicly reviewing as many facts and issues on energy policy under its jurisdiction as possible, we look forward to your testimony.

Mr. Keeny, you have several members of the study group with you and we will ask that you introduce them and proceed as you see fit.

Let me say that we do deeply appreciate your making this effort to be with us on rather short notice. It is of such extreme importance. I know that a great deal of hard work went into this study and we feel that this is a good forum in which to air some of the things contained in the study. So welcome to our subcommittee and please proceed as you see fit, Mr. Keeny.

STATEMENT OF SPURGEON M. KEENY, JR., CHAIRMAN OF THE NUCLEAR ENERGY POLICY STUDY GROUP, ACCOMPANIED BY KENNETH J. ARROW, RICHARD L. GARWIN, HANS H. LANDSBERG AND WOLFGANG K. H. PANOFSKY

Mr. KEENY. I am pleased to respond to the committee's request to discuss the report of the Nuclear Energy Policy Study Group. This report, Nuclear Power Issues and Choices, was released last week The report was prepared during the past year by an independent study group of 21 individuals and funded by a grant from the Ford Foundation to the Mitre Corp.

The fundamental objective of the study was to assess nuclear power in broad perspective relative to other economic energy, social and security problems and objectives. Having developed a framework for policy decisions, the group considered some of the specific policy problems in nuclear power now facing the U.S. Government.

The report's principal findings which were agreed to unanimously by the group are set forth in the report's overview which I have submitted to the committee for the record.

Before turning to the substance of the report I would like to introduce my colleagues who are with me today to discuss the report with you.

[Introductions were made.]

Mr. KEENY. The members of the group who are not here today are Harold Brown, Albert Carnesale, Abram Chayes, Hollis Chenery, Paul Doty, Phillip Farley, Marvin Goldberger, Carl Kaysen, Gordon MacDonald, Joseph Nye, Howard Raiffa, George Rathjens, John Sawhill, Thomas Schelling and Arthur Upton. I would like to point out that all of the members of the group were in agreement on the findings, conclusions and recommendations of the study.

Mr. FLOWERS. I think that is most amazing.

Mr. KEENY. Mr. Chairman, would it be useful if I gave a brief statement of the principal findings of the study group's report before I turn to questioning?

Mr. FLOWERS. I think that would be the way we could best use our time. I'm sure questions will arise. I think if you gentlemen would just speak as freely as you can. We would like to develop a feeling for what you did, how you proceeded in arriving at these very difficult unanimous decisions.

Mr. KEENY. In presenting this brief summary I want to emphasize that the study group's complete statement on the subject is set forth in more precise detail in the overview and in the supporting chapter of the report itself.

In assessing the role of nuclear power, the study group concluded that nuclear power is an important competitive source of energy that should play a role in the development of our energy resources. At the same time, we concluded that nuclear power is not absolutely indispensible to the future energy supplies and economy of the United States or the world. We concluded that it can contribute relatively little to relieve the immediate short-range energy problems facing the Nation today. For these reasons, a central theme of the report is that there is time for judicious, careful decisions on nuclear power development and utilization, taking into account social costs and security implications, of which the most serious is the potential proliferation of nuclear weapons.

Despite this cautious approach, the report concludes that the expansion of our future electric power capacity in this century should be based on a mix of nuclear power and coal.

The report does not deal with the immediate problems of petroleum and natural gas supplies, but taking a longer view of the energy economy emphasizes that the world is not running out of energy. There will be adequate supplies of energy in the future, although at higher prices.

In this century oil and gas will continue to be the principal energy sources but in decreasing proportions. There are vast supplies of coal available at roughly current costs. There will probably prove to be considerably more uranium available at competitive costs in the future than presently is estimated. Although not competitive for base load electric power generation in this century—and probably not in the early decades of the next century—solar, geothermal, and eventually fusion energy could supply essentially unlimited amounts of energy but at considerably higher costs.

The report further concludes that these anticipated long-term increases in energy costs will not have a fundamental effect on economic growth and need not affect basic lifestyles.

Looking more narrowly at the economics of nuclear power, we examined the somewhat confusing comparative economics of nuclear power and coal, which is the principal alternative for electricity in this century. We concluded that electricity from nuclear power is and probably will continue to be somewhat cheaper on the average than electric power from coal. However, coal will continue to be competitive in many areas of this country and will clearly be preferable in some areas.

Uncertainties in these economic costs, however, could shift the economic balance either way, to make coal more competitive or to improve the present apparent small advantage of nuclear power.

In this close economic situation we spent a great deal of time in the report examining the comparative impact of nuclear power and coal on human health and environment. We concluded that nuclear power appeared to compare favorably with coal from the point of view of the social costs even when the possibility of accidents was included in the comparison. In any event, the uncertainties in the social costs are so great that they do not provide a basis for changing the study's basic economic findings on the comparison of nuclear and coal for electric power generation.

More specifically, in the area of social costs we concluded that in normal operations nuclear power had considerably less adverse effect on health and the environment than coal. We also concluded that nuclear waste can be adequately and permanently disposed of despite the poor record of waste management to date.

When nuclear accidents are considered in this comparison the situation is less clear, since the nuclear accident probabilities are extremely uncertain and a single accident could have a very severe impact. Nevertheless, even when extremely pessimistic assumptions are considered about the possibility of nuclear accidents we concluded that the impact of nuclear accidents on health on a average rate-of-loss basis is within the broad range of possible effects from coal on health and the environment.

At the same time, the report emphasizes the importance of reducing the health threat from both coal and nuclear power. Specifically we recommend stricter siting of nuclear plants, since most of the risk comes from a few sites poorly located with regard to population and meteorological conditions. We also recommend more emphasis on improving the inherent safety of the current generation of nuclear reactors rather than simply confirming that the plants meet existing regulatory standards. With regard to coal, we also recommend further reduction in the emission of sulfur-related and other pollutants and again greater attention to siting.

In this general context of the economic and social costs of nuclear power, we concluded that the most serious risk associated with nuclear power is the potential impact on the proliferation of nuclear weapons.

In examining this question, we emphasize that the problem is political in nature and solutions to proliferation must in large part be addressed as political problems. We also emphasize that proliferation is not uniquely connected with nuclear power, since other nations can and have developed nuclear weapons directly and not as a spin-off of their nuclear power programs. We have also emphasized that this problem is not within the unique control of the United States since nuclear capabilities are clearly widespread within the world at the present time.

Nevertheless, we did conclude that nuclear power can seriously complicate the proliferation problem if plutonium is introduced into the fuel cycle. To introduce plutonium into the fuel cycle can cut the time for decisions of other countries to undertake nuclear weapons programs and will greatly complicate the problem of theft or diversion of nuclear materials.

Within this general context of our assessment of nuclear power, the report makes the following recommendations on problems that are currently directly before the U.S. Government:

One, we recommend that plutonium reprocessing and recycling in current reactors be postponed indefinitely since it has little, if any economic significance. Estimates indicate that it would at most reduce the cost of electricity by a few percent during this century.

Second, we recommend that the commercialization of the breeder be deferred and that the breeder program be recast as a long-range insurance program against high future energy costs. Although the breeders are a major long-range energy source, we conclude that they will not compete with the current generation of reactors in this century and will, at best, have only a small economic advantage in the early decades of the next century. We will want to return and discuss the breeder question in more detail.

Three, the waste management program should be refocused on secure or retrievable storage of spent fuel elements without reprocessing.

Four, uranium enrichment facilities should be expanded when necessary under Government control to assure guaranteed fuel supplies for this country and abroad. This should be done so that there will be a clear alternative to the plutonium economy and a clear alternative to the proliferation of national enrichment facilities. At the same time, we suggest that there should be a critical reassessment of the extent and timing of these new facilities in view of the generally agreed upon reduced demand projections that have evolved over the last year or so and in view of the possibility of new technological approaches to isotope separation.

Finally, the United States should take the lead in building an international consensus, both of exporters and importers, on the need for restricting trade in sensitive facilities for plutonium reprocessing and uranium enrichment.

In closing, I would like to reemphasize that, despite our conclusions that focus on the desirability of deferring the plutonium economy for economic as well as security reasons, we did conclude that nuclear power in the form of the present generation of reactors would and should, in a mix with coal, provide the basis for expanded electric capacity in this century. This, we believe, is a proper economic response and provides a hedge against the rather substantial uncertainties that still exist in the economic and social impacts of both coal and nuclear power.

Mr. Chairman, this is my summary of the main themes of our report, and my colleagues and I will endeavor to answer your questions.

Mr. FLOWERS. Thank you, Mr. Keeny.

Would any of the other gentlemen like to make a statement at this time, or should we just proceed to develop a dialog here? We are going to be very informal. Are there any additional supportive statements of any kind that you would like to make? If so, please feel free to do so.

[No response.]

Mr. FLOWERS. Good. We still have agreement.

I am going to start off with the bottom line of your report as far as I can see it, Mr. Keeny, and that is the proliferation issue as being so very important as to determine almost entirely the rejection of plutonium reprocessing technology and all of that has become so much a part of your ultimate decision. I am sure you must have wrestled with the issue as to whether or not our domestic policy will affect the worldwide policy. There is an old statement, how can you lead without leadership. If we abdicate our position of leadership, who are we to demand that the rest of the world will listen to us. How would you respond to that very vague and general proposition?

Mr. KEENY. Mr. Chairman, that is a good question and we spent a good deal of time debating it. One of the conclusions in the report is that the United States should continue in the nuclear business for precisely that reason. In addition to the economic pressures to do so, we would lose a great deal of our influence and leverage in the future course of nuclear power development if we withdrew completely from nuclear power.

Now, at the same time, we felt that even though the economic case for the plutonium fuel cycle was very fragile, if the United States chose to go forward with it, that decision would certainly tend to assure that this path of development would take place whether it was needed or not. On the other hand, if we restrain our development in this field, while we cannot guarantee of course that this will cause all other countries to change their plans, it will certainly encourage a broad reassessment as to whether plutonium reprocessing and recycle and very early breeders are in fact necessary and desirable.

Mr. FLOWERS. That would be so if the focal point was the economic proposition, yes. But the bottom line being the proliferation issue, I have a hard time coming to the conclusion that a nation like Japan or Germany or France, who do not have the wealth of natural resources that we do will arrive at the same conclusions. Their problems compared to ours are enormous, although we are the greatest energy user. Their incentive to withhold from the plutonium cycle is just not there, unless they just want to "do good." I just don't know that that's the real world.

Mr. KEENY. This is what concerns me, I think, more than anything else.

I would like my colleagues to comment on this question, too, but basically I would reiterate that our assessment indicated that plutonium reprocessing had little, if any economic significance in this century. And the same argument would apply to the economies of other countries. We think this problem should be addressed on a worldwide basis. Our concern was that there has been a general rather uncritical approach to this problem that just assumed that reprocessing and recycle was inevitable and automatic and absolutely necessary. Just on the economics alone, it is a very marginal proposition. In the case of the breeder, however, we think that the breeder as a long-term proposition may be an important source of energy, and we emphasize the importance of continuing an active research program. But we question that it will be economically competitive in this century. And again the same arguments that apply to this country would apply to other countries as well, because the competition here is between the breeder and the current generation of light water reactors. That same comparison would apply to other countries as well.

Mr. FLOWERS. I totally agree with your statement here. Many members would like to get into that, I know. That assumes—I think the largest supply of uranium is out there somewhere and it will be discovered and made available. If we had, say, two or three times as many light water reactors on line, wouldn't we run out of uranium at some point, unless we reprocess?

Mr. ARROW. Mr. Chairman, in the first place, if we have reprocessing with the present light water reactors, we essentially have a relatively mild stretching out of uranium supplies, perhaps no more than 15 percent or so, and at a very high cost. The evidence is that recycling is an extremely expensive operation. A country that tries to save uranium by stretching out the reprocessing will make very little and there is a very strong chance, in fact, that it is a losing proposition.

After all, the technology we are talking about is the same everywhere. The costs of uranium are pretty much the same everywhere, and the cost of uranium is not such an important part of the nuclear costs. It is not like coal fired plants, where coal is a much more significant item. So there is reason to argue that if we demonstrate by our actions our beliefs in the economic unimportance of plutonium recycling, this will have a demonstration effect upon others.

I would put the matter the other way. If we engage in recycling actively, it is hard for us to persuade anybody that recycling is not a good idea. If it's good for us, why is it not good for them? If we are saying it is bad, we should at least demonstrate our belief in a very concrete way for something we believe to be in their interest as well as our own. The question of self-sufficiency, of course, can be argued. These countries have, in fact, shown in the past 25 years that they are quite willing to be extremely highly dependent in a much more dangerous way upon the outside world, countries importing oil and coal, especially Japan and to a lesser extent England and France, important oil most especially. So they have in fact demonstrated the fact that we are living in an interdependent world where no country is self-sufficient.

Uranium is clearly a politically less dangerous thing to be dependent on than oil because stockpiling uranium is relatively inexpensive compared to stockpiling oil. If you are worried about future supplies, you can stockpile and uranium is much more compact. So in terms of dependence the dangers, once you go for a light water reactor economy, are considerably less than they were with the present oil economy, in which case Japan, for example, is totally vulnerable.

Uranium is not a monopoly of the United States. We are well endowed, but there is uranium in many other parts of the world. France, in particular, has access to uranium supplies on a scale commensurate with its needs. I don't know what it's relationships with other European countries are, but cooperation will take place.

We are concerned, of course, in total proliferation not with Japan or Germany at the present time. We are concerned with other countries. Our real leadership that we are trying to take is with respect to the other countries. Now, obviously it would be helped if the advanced countries join us and say all of us give up recycling. In that case, you probably have destroyed the basis for export of these facilities to developing countries where we would be much more nervous about proliferation.

Nevertheless, it would be very significant if the United States alone does it, which would say to the other countries we are not depriving you of a technology we think is valuable to ourselves. It may hopefully set some kind of example and precedent for the other countries.

Mr. Flowers. I want to withhold my further questions and give everybody else a chance. Then I will come back.

Mr. Myers. Thank you, Mr. Chairman. I too have a great deal of questions I would like to ask and certainly we won't get through all of them.

Because of the fact that we speak so much about the international implications and the need for leadership, did the study group contact any foreign government with respect to attitudes about proliferation?

Mr. Keeny. We did not directly contact any foreign governments. A number of members of the group had considerable knowledge and familiarity with the situation in other countries.

Mr. Myers. But in the construction of the study itself, you have no input as to the attitude of the foreign nations?

Mr. Keeny. Not directly.

Mr. Myers. It surprises me that you make the assumption that the impact of plutonium and the attitudes toward the impact on the economy to the breeder would have the same effect on our economy as it does other countries.

It seems to me, when you talk of the impact of the economy, you have to talk about it in relationship to the availability of energy, not just the cost of energy, and the factor of availability will weigh into the attitude about how it will affect the economy.

In relationship to that proposal, I imagine the group had a number of scenarios they pursued and either assumed that they were valid or invalid and I would like to speak briefly of a scenario and I would like to have you give me your opinion on it.

I think a scenario could be drawn up in that if in fact the United States were not to go the route of reprocessing and the breeder reactor that it would give certain signals internationally, No. 1, that we were not interested in a system which would make available to us from our sources of uranium supply approximately 50 times the energy we would have without reprocessing and without a breeder. So that other nations looking at that decision could assume that we were not interested in the most efficient use of natural resources. They could then conclude that we have not diverted from our practice in the past of inefficient use of energy and in fact we were making the decision on an international basis that we had the leverage to, in the long-term, compete rather dramatically and heavily for the remaining sources of the rapidly dwindling supplies of fossil energy, whether it is coal, oil, or gas, et cetera.

If the scenario were to go further and I were a country which has in the past not been able to compete very well with the United States for the sources, it would seem to me that you could put up a reasonable argument that my only alternative is to make international agreements with those countries who are going to use uranium to their greatest possible advantage, that being the breeder, and protect my future in that way, because I know I cannot compete with the United States whether it is for oil, for natural gas, for coal, or even probably the remaining supply of uranium for light water reactors.

Now, if you pursue that scenario it would seem to me that the effect of our getting out of the breeder program would have exactly the opposite impact that you have concluded, and that we are going to be very selfish about energy and we are going to pursue what we think is the best interest of the United States.

I would like to know, did you consider this scenario and how did you evaluate it if you did?

Mr. Keeny. We considered it very specifically, and I would emphasize that, one, we said we should continue in the nuclear power business; and, two, that we should continue a very active breeder research and development program. I agree with you that the breeder is a potential substantial additional source of energy in the future. Our problem with the breeder was our concern that the present program will not produce a breeder that would be competitive with the existing generation of light water reactors. This concern would apply not only to this country but to other countries as well. We think the breeder should be continued. It may prove in the next century to be an important source of energy and on that time scale we may in fact develop the institutions and techniques where we will be better able to deal with the very widespread plutonium economy that will result.

Mr. Myers. I find it difficult for you to be suggesting that we not pursue the Clinch River Breeder, which appears to me to be a very integral part of the research program for breeders. If in fact we were to retract from that or if we went with what I view to be the Carter budget at this time, that we would in fact be retrenching to the point that it could give some very bad signals with relation to where we are going to go in nuclear. I think you are saying we should pursue aggressively a policy for the breeder. I would like to see some recommendations as to what the policy is. At what level is it an insurance policy, and at what level is it just tokenism? I don't see that in this report.

Mr. KENNY. I am sure that a number of my colleagues will want to respond to that basic question. Our concern with the present program did hinge a great deal on the fact that an over-accelerated effort to develop the breeder could result in a breeder that simply would not be competitive, would not find a commercial market, and it is by no means obvious that this is the most effective way to ultimately introduce this potential source of energy. In our comment about Clinch River, it was simply that in the context of a longer term insurance program looking toward developing a better and hopefully more competitive product, that it might not be the most cost effective way to insure such a development program.

Mr. MYERS. What about the Phoenix Reactor?

Mr. KEENY. It is not obvious at all that the Phoenix Reactor is going to lead to a competitive product, that the French will in fact be able to sell abroad and it is also not at all clear at this point that the breeder reactor holds much promise for developing our undeveloped countries because of the high capital cost and the need to have it on a rather large scale in order to be economically attractive.

Mr. MYERS. If the two major alternatives to continuing the breeder program in your opinion are not economic at this time, what do we do? Just sit and wait with sort of miniscule programs and hope that somebody somehow devises a breeder, or do we wait for prices and shortages of other sources of energy to make it competitive?

Mr. KEENY. I would like Dr. Panofsky and Dr. Garwin to comment on this, but essentially you design a program that looks more toward an improved breeder on a longer time scale in the future.

Dr. PANOFSKY. Let me make two comments. The first question you raised about your scenario is that we, by deferring reprocessing, would give a signal to the world that we do not care about conserving our energy resources because we happen to be energy rich while others cannot afford that particular luxury. I would like to emphasize that we are recommending that the bulk of our waste disposal and storage be retrievable and therefore we have not thrown away the value of the uranium. All we are saying is—and this is really the whole thrust of our recommendation in the breeder area—that the commercialization decision can wait for several decades beyond the time table which is currently envisaged in official planning. The reason for that deferral recommendation is the simple fact that since nuclear energy is such a capital intensive activity the crossover in economic competitiveness between the LWR and the LMFBR will occur only after the fuel cycle costs have risen by a very large amount.

We have, of course, taken into account the French breeder program in regards to the Phoenix, and now the beginning of the Super Phoenix. We would like to point out that the French program is a *consecutive* program. The Phoenix has operated. It has given experimental results and now the French Government is proceeding to the Super Phoenix, which is to operate at 1,200 megawatts, relative to the Phoenix at 260.

What gives us trouble is that the early commercialization date which had been established in the U.S. forces a degree of *concurrency* on the

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existing program, so that the kind of learning which is involved in the French program would be denied to us. The FFTF has not yet run. We have gotten results from component checkouts and things of that kind. Therefore, the Clinch River design cannot benefit from operational results. This is the kind of thing you do if there is indeed great urgency for the product on economic grounds. It is the kind of concurrency which you do indeed find justifiable if it is an economic requirement to be ready by a certain time. But lacking that we believe that the concurrency of the current program is larger than need be, and which would also give you also higher cost of the final product.

Mr. MYERS. Let me give you another scenario. Suppose we invest in Clinch River and we come down to 1986 and we have a technology which we feel is too risky to go ahead with and so we do away with it and we have lost essentially a couple billion dollars. So couldn't the scenario be drawn also that we could afford to do that much better than a lot of the smaller nations, and if in fact we withdraw from a breeder reactor, withdraw from a position that the world can see that even if it is slightly less efficient that there will be a breeder alternative and some companies, who, at this date, whether we agree with it or not, see the breeder as an alternative for them and an only source of energy, would not be inclined to feel that they had to make investments during this period of time in a breeder, if in fact they saw that development they may not make the investment. If in fact they don't see the development in the United States, they may make the investment; and because of the fact that it has a much larger impact on their gross national product or their available sources of economic viability, they would be pushed to a decision of commercialization much harder than the United States would be. They could less afford to get out of the program if it were a bad technology, whereas we could possibly do it if we had to.

Dr. PANOFSKY. We do in no way propose to withdraw from the breeder program. On the contrary, we have not designed an alternate program to the degree of detail to determine whether the alternate program which would fit the economic situation would be substantially less expensive than the present one.

Further we believe that the time at which there would be a crossover in the U.S. between economic competitiveness of the breeder and that of the LWR, would not be substantially different from that of foreign countries. So, therefore we do not believe that your assumption that the urgency for having the breeder commercialized would be larger in foreign countries, is in fact correct.

Mr. FLOWERS. I am going to yield now to Mrs. Lloyd from Tennessee.

Mrs. LLOYD. Thank you very much. I appreciate you gentlemen appearing before us today. I think that Mr. Myers and others have gone through several scenarios for us. I think we have reviewed our status internationally as it applies to this program, and so I would like to touch a little bit on the uranium availability issue. One of the dominant reasons used to justify this study's recommendation for delay was the possibility, you said, that substantially more uranium would be available than you had previously thought possible. I did not see any new members entered into this discussion. The ERDA base of 3.7 million tons of domestic uranium resource included both reserves and the potential, and the ERDA midrange of 510 gigawatt reactors by the year 2000 was assumed for demand. But it did, however, state that full resource potential be used for a firm planning base for determining the time when this resource base would be fully committed. And then the shift to the breeder would become necessary. To me this logic fails for several reasons, one, this 3.7 million tons you have discussed includes 0.7 million tons of reserves, that's 19 percent. And you have 1.1 million tons of probable reserves; is that correct?

Mr. KEENY. I think so.

Mrs. LLOYD. And then 1.9 million tons of possible and speculative reserves. That is, 51 percent in possible and speculative reserves. Am I right?

Mr. LANDSBERG. Mr. Chairman, with your permission, since uranium is going to come up again and again, I may take something between 5 and 10 minutes to lay out our assumptions and procedures.

Mr. FLOWERS. I think that would be very good. Please do.

Mrs. Lloyd, could we let the gentleman go ahead and you could retain your time to question. Let us let him talk to the uranium thing.

Mrs. LLOYD. Please proceed.

Mr. LANDSBERG. Let me try to lay out what our reasoning was. As we all know, since we have not measured and discovered all of this material, there is great room for argument in this. This has always been true in the minerals industry.

To begin with, we have abstained from devising independent uranium estimates, as you say. We did not think we were in a position to do that. Moreover, by a very long shot the data that ERDA does publish are based on very thorough research. They got most of their information from the industry, and there simply is no other good source available for this data. So we started with the ERDA set. And what we did is in a sense just what you were saying.

We assessed the nature and characteristics of these data and we finally decided that one would be on the side of prudence if one used these data as being real. Let me add, then, that in addition we thought that they not only were real but they were on the conservative side. There are a number of reasons why we think they are on the conservative side. That did not make us add to it numerically. We never said there is 1, 2, or 3 million more. But we simply said it was conservative.

Let me quickly run through the reasoning that the committee agreed was proper. No. 1, the uranium industry is a very young industry and until recently has had a very limited objective. Its objective until 3 or 4 years ago was to find uranium to sell to the Government at a fixed and rather low price, somewhere between $6 and $8. That is what it was supposed to do and what it did.

Now, the industry has been very successful in its search to meet that objective. It has done that in a very limited, geological and geographical setting, in a very narrow area of the rocky plateau. Indeed the industry has been so successful that until 3 or 4 years ago it was a badly depressed industry. It has only now come out of it with vengeance.

No. 2, it is in our judgment very unlikely that what is reported in the ERDA statistics fully reflects reality. For instance, no search has ever been made for high-cost uranium. If you consult the statistical data of the uranium industry which are being put out every year at Grand Junction, you will find that the overwhelming part of the high-cost uranium is located in the same so-called properties in which the low-cost uranium is located. It simply appears as a byproduct of looking for cheap uranium. That has been the story in the past and the statistics are quite convincing on that. There is no reason why the industry, in fact, should have done anything different because there was no market for it.

If you are interested, I will refer to the tabulation I have in mind in the published statistics. It is also interesting to see how industry looks at this, and let me just read two or three sentences from a statement that was in the course of a national academy study. Two years ago, the Committee on Resources and Environment, an official of Kerr-McGee, which I'm told is one of the large uranium producers, said as follows:

> We have discoveries which were made several years ago which have not received enough evaluation as yet to be included even in a potential category.

He is talking about discoveries, not speculation.

> Other discoveries upon which we have been working for 10 or more years still have not received the development drilling necessary to convert substantial sources of the reserve from the potential category to proved reserves.

I think that is going to one of the points you are raising.

> The rate of development drilling is a function of our mining plant and in many cases the total reserves will not be finely defined until relatively late in the mining cycle.

That is an industry point of view from one of the largest producers. And so in industry's own description the data are not a full reflection of what is, in fact, known somewhere.

The next point I would like to make is that the increase in exploration and in drilling activity and expenditures, which has been very large, will take some time to be reflected in the statistics. Let me read a couple of sentences from John Patterson, of ERDA, who is one of the very, very well informed people in ERDA on uranium. He said recently:

> Significant reserves have been developed for which data are not yet available to ERDA and hence are not included in the reserve additions. If proper accounting could be made of all of these factors, the exploration results would look considerably more favorable than the published reserves indicates.

In other words, there is quite a lag here, and people who say nothing is really happening will have to hold their horses, so to speak.

Another important point: Much has been made of the fact—the apparent fact I should say—that findings have——

Mr. FLOWERS. Excuse me. Mr. Harkin would like to ask a question.

Mr. HARKIN. In connection with what Mrs. Lloyd was just asking, what do you consider to be high-cost uranium?

Mr. LANDSBERG. In this context we have to consider high-cost uranium only the $15 to $20 category. If you are familiar with the categories in which these are cast, that is the high element of the cost categories, between $15 and $30. We do not have any data of any uranium that is higher cost, and there is a lot of that around, but industry simply had no incentive whatsoever to look. Whatever they have found they have found on the way, and as the citation from the Kerr-McGee official shows, they know a heck of a lot, but there has been no reason to put it into the record as far as they are concerned.

Let me speak just one moment about a very important problem here. It has been asserted that findings have declined, but if you put all of the uranium findings in the past into constant dollars, that is, if you eliminate the inflation factor—ERDA has for the first time done this last October in a very important publication— it turns out that in fact that is not true. Over the last 10 years, inflation excluded, the industry has added to the reserves about 50,000 tons per year. You compare this with 10,000 to 12,000 tons production, and that is surely not bad. They have added to reserves about four times each year. That comes out only if you eliminate the inflation factor.

Mr. FLOWERS. I think we could resume Mrs. Lloyd's question now.

Mrs. LLOYD. Thank you very much. If we estimate 2 million tons of reserves, would this change your feelings toward the breeder program at this time?

Mr. LANDSBERG. I think I can give an answer to that one and then leave it up to others to supplement or correct me. If you had 2 million tons—you are saying you are fairly sure it is really there and minable and millable—that is roughly the equivalent of 400 1,000-megawatt reactors operating for 30 years. We are now roughly at about 60,000 megawatts of capacity. It would take us quite a while to get to the so-called mid-5 to 10 estimate. In other words, 400,000 megawatts for 30 years, it seems to me, a situation in which the judgment on the breeder would not have to be altered.

Mrs. LLOYD. Let me back up a minute. It is my understanding that we hope to have 200 light water reactors on line by 1985.

Mr. LANDSBERG. Two hundred in place, under construction, or ordered. I doubt they would be on line by then.

Mrs. LLOYD. If this projection holds true, would not this number of light reactors take care of our committed reserves of uranium?

Mr. LANDSBERG. No; we also made that calculation. We took the 200,000-plus megawatt now in these three categories and we ran out calculation of what it would take and the figure is about 1.3 million tons to put them on line and run them for 30 years. On that one there is no question.

Mrs. LLOYD. But we are proceeding with a hypothetical solution to a problem. We really don't have an answer. We don't know that we have these.

Mr. LANDSBERG. I would disagree. I think we know a great deal about our uranium reserves, and I would like to comment on the potential resources if I may. And we do believe that between the reserves and the potential resources we have enough elbow room, given the continuously declining capacity outlook, to make decisions in a relatively relaxed mood and to go back to a broader research program.

I would like to answer your question about the potential resources. A lot hangs on that, as you quite rightly said, because the major part of this 3.7 or 3.6 million tons——

Mrs. LLOYD. I think our national security and economic stability is hanging on an answer to a hypothetical problem.

Mr. LANDSBERG. Let us see just how hypothetical it is. I think that is the problem now. I think the terms that are being used are not particularly felicitous. If you look at the definitions of these categories they are really quite realistic. They are very short, but they are very telling. Here is what the definitions are:

The probable potential resources are those estimated to occur in known productive uranium districts, in extensions of known depositions.

That is a definition which for any other mineral would be taken to indicate that we know what it is and where it is.

The second category, the definition for potential resources are:

Those estimated to occur in undiscovered or partly defined deposits, in formations or geological settings productive elsewhere within the same geological province.

Let me add that productive means that past production plus known reserves exceeds ten-tenths. This is not blue sky.

Finally, I would agree that we can leave speculative out, which was only 50 percent of the total, in any event. But let me read the definition.

Now, these kinds of definitions go with the descriptions of probable, possible and speculative. I think the terms are unfortunate. The mineral community is trying to get away from these definitions, but there they are. It does not suggest absence of knowledge. Each of these categories is defined by location, by type of rock and age of formation. I do not think they are in that sense as hypothetical as many people believe.

Mrs. LLOYD. Mr. Chairman, I ask unanimous consent, because I have some questions I would like inserted in the testimony today, and could they reply in writing?

Mr. FLOWERS. Certainly. Would it be possible, for us, Mr. Keeny, for our record to supply you with a few questions that if our time constraints this morning don't allow answering. Could you for the panel see that they are answered?

Mr. KEENY. Yes.

Mrs. LLOYD. I will yield my time.

Mr. FLOWERS. The gentleman from New York, Mr. Fish.

Mr. FISH. Thank you, Mr. Chairman. Mr. Kenny and panel members, I want to congratulate you on this report, which I understand is the hottest item in the book stores today. I cannot get a copy because there are 300 orders ahead of me.

Because the panel is such a prestigious group, and because of the timeliness of your report coming before this committee which is considering the ERDA budget, and of course prior to the President finalizing his proposals, this is a great public service. So having said all of that, it is with some temerity that I even embark on some questions here.

Mr. Keeny, you stated that your findings and conclusions are that, as a future electrical source, we must rely on nuclear and coal. Looking at page 59 in the table in your report, it would indicate that you anticipate by the year 2000 a tripling in demand for electricity. Is that correct?

Mr. KEENY. Yes.

Mr. FISH. What concerns me is that with a quick look through the report and the overview, there is a very short consideration given to conservation and energy efficiency to offset the increasing demand for electricity for the balance of this country. I wonder if you are familiar with a paperback entitled, "World Watch on Energy, the Case for Energy Conservation," which was prepared for ERDA. Its second sentence says, "For the next quarter century the United States could meet all of its new energy simply by improving the efficiency of existing uses." Now, I think they are talking in terms of perhaps graduated over the balance of the century a 50-percent increase in energy conservation, whereas ERDA is talking generally of 20 to 25 percent. But here is a conclusion that we can level off our need for an incremental annual increase, which I gather is 5½ percent which does get you the three-fold increase which is the industry projection. Could you explain what led your committee to accept an industry projection of a tripling demand by the end of this century and not go the route of really strong conservation?

Mr. KEENY. We did not accept any particular demand projection but rather analyzed and considered the significance of a range of demands. I think the group was very impressed, as you are, with the potential for conservation; and we did in fact discuss it, although it was not the central focus of our report. I think possibly Ken Arrow could explain a bit our view of conservation and our analysis of the problem.

Mr. FISH. If you would in discussing this just bear in mind that for me this is the predicate for the conclusion as to the great increase in nuclear-powered and coal-fired plants for the balance of the century.

Mr. ARROW. The first point to be made is that by and large, at least as far as the economic analysis was concerned, we regard energy as, after all, a commodity like any other. If to save energy you have to derive extremely high costs in other terms, we don't regard that as necessarily a social gain. We were concerned, of course, with trading off the problems of energy against those other social problems, such as proliferation or health and accidents. But we did not see any other reason to confine ourselves to slowing down energy for other reasons, because it's not economic.

We have taken into account in these calculations—let me reemphasize what Mr. Keeny has just said—these are not taking projections from the industry. These projections have been worked out on our own on the basis of our assumptions. They represent an element of conservation already built in two different ways. One, we believe the most effective conservation is essentially cost-induced conservation. People will conserve because the price of energy has gone up, whether it be electric energy or most notably oil. Therefore, there is an incentive for greater efficiency in industrial heating, for improved efficiency in heating of houses and for cogeneration of electricity by industrial plants, so that electricity can be generated at the same time industrial heat is generated, with the resulting economy, and so forth and so on. The opportunities for conservation of course are very, very large and many of them will come at a very high price. Now, it is very difficult to carry through a really full-scale analysis of the economic cost of conservation because there are many thousands of ways in which you can conserve and it really requires a case-by-case analysis. We have assumed two things, one is that there is an effect, that the higher the price the more conservation is induced, simply through economic self-interest. That is probably the larger effect.

We have in addition assumed in the calculations that about a 10-percent mandatory conservation above and beyond what would be induced by cost. Now, the estimate of the effect to which price increases will cause energy conservation is of course very difficult to deduce from the historical record. We have made rather moderate assumptions. We did some calculations with more extreme assumptions, and I would indeed have gotten a far lower rate of increase in nuclear energy—it is reported in the paper.

It should be pointed out that we are not advocating any particular build up of coal-fired plants or nuclear plants. These are base forecasts for policy purposes. If in fact the rate of growth is lower or can be made lower by appropriate measures or by the mere effect of higher costs, then a fortiori all of the utilities will find themselves building electricity plants more slowly. Nobody will compel them to produce generators.

Mr. FISH. You are simply saying that if there is an increase in demand for electricity for the balance of this century what the source of power would have to be?

Mr. ARROW. That is correct. And if it is a lower one, the same arguments pretty much apply, by the way.

Mr. FISH. I realize that the very name of the study is "Nuclear Energy Policy Study Group," but is it fair to say that such matters as the fact that per capita we use twice the energy of other nations—a lot of people translate that into waste—that was not a large factor then?

Mr. ARROW. Yes; it was a factor in our assumptions. We took it as an indication of the effect to which price can reduce demand. On the whole, the price advantage is higher in this country. We used it to justify the argument. I guess we have been accustomed to criticism from the other side more than this, and we were concerned to show that our big thrust has been that energy is just one thing. We can reduce it without any fatal consequences for gross national product and economic growth. In fact, the effects of reduced energy or higher price, either one, the effects on economic growth are relatively modest. So in a way the thrust of our investigation is very much in line with the points you are making.

Mr. FISH. I would hope in the President's proposal there would be lots of areas where energy conservation would be mandated with not so much reliance on economic impact.

I forgot to say in my opening greeting, Professor Panofsky, to welcome you back and to thank you for your contributions to the other energy subcommittee in the last few weeks.

I wonder if one of you would comment on something Mr. Keeny was talking about, the difference between the health problems for coal and nuclear, and then you had some recommendations on one of them you said was stricter siting of future nuclear plants. Could one of you elaborate on what you mean by stricter siting in terms of population areas particularly and other factors?

Dr. PANOFSKY. In analyzing the total hazards due to nuclear plants, we were impressed by the fact that probably the largest contribution comes from the chance of accidents and the chance of accident in turn had been analyzed by the so-called Rassmussen report in considerable detail. Again, in reviewing the Rassmussen report, we were impressed that although we did not have very much criticism of the central estimate of accident probabilities we believe that the uncertainty of that estimate is very much larger than that given in the Rassmussen Report, and therefore the range of possible average health consequences might be larger. We were also impressed by the fact that the Rassmussen Report averaged the risk assessment very carefully in a way so that the contributions from individual sites did not become manifest. If you actually look at this in detail you find that four or five nuclear powerplants in the country dominate this risk and with those powerplants there is a correlation between prevailing winds with population concentration in large metropolitan areas.

Therefore, if it were considered to be necessary to reduce accidents, then one way of doing it would be to make a study of the correlation between meteorology and locations of large areas be a criterion, and that alone would be a lever to reduce the average risk to the population by one or two orders of magnitude. I would like to add, however, that we do feel that even without doing that at present and making the worst possible assumptions, that the nuclear risks tend to be on the low side of coal risks.

Mr. FISH. Professor, during the recent presidential campaign, President Carter mentioned on more than one occasion that he would look favorably on building future nuclear powerplants underground. Did your report come to any conclusion on that?

Dr. PANOFSKY. We did not reach a conclusion. We believe this is a matter where studies have been somewhat perfunctory and we believe that studies should be reintensified. We believe that in some locations that may indeed be a good thing but we did not have the tools at the time to actually come to conclusions.

Mr. FISH. Thank you very much, Professor.

Professor Landsberg, I was very interested in your comments on uranium and your comments on the data that ERDA supplied, and that you believe these estimates are conservative. Are you familiar with the National Academy of Sciences as yet unpublished findings which claim that in their judgment the ERDA numbers of $30 per pound are the upper limits of the reserve?

Mr. LANDSBERG. I've heard rumors.

Mr. FISH. I would appreciate it, Madam Chairman, if we could ask the professor if he wouldn't mind taking the time when he knows more about the National Academy of Sciences report, which I grant is yet unpublished, and only rumored, and since it is so contrary to your testimony, I think it would be very helpful for this committee to have your critique of the report. It gets down to the relationship of the millions of tons that will be available with the projections you have given us about the number of plants in 1985. And really they claim that what you claim is a conservative estimate is indeed the upper limit and so it leaves us in a quandary.

Mr. LANDSBERG. In a sense, I answered what was implied in your questions when I was previously asked if we assumed there were only 2 million tons it would make any difference to our conclusions. While I cannot speak for a committee of 21, which we cannot poll, from the memory of the discussions we have had, my answer would be no, it would not, because, as I said, this would be the equivalent of a 400 of 1,000 capacity running for 30 years. By now the estimates are already obsolete. And incidentally the same thing is true abroad. So in a sense I am answering your question. If you ask me suppose somebody said it was only 2 million tons, would it make any change, when we are saying that we need a very thorough and rapid confirmation, confirmatory work in the uranium resources field. This is very badly needed. We need to know more about the potential. We need to have more drilling done and probably done by Government because industry at this point is not full of incentives to do this. And we have to learn in the next 5 years far more than we know now, but the next 5 years is not a critical period in terms of the capacity we see ahead in those portions of the reserves that we know of.

Let me add only one point, suppose we had been here in 1968?

Mrs. LLOYD. I believe we are going to have to move along.

Mr. LANDSBERG. In 1968, the reserves we knew of were 456,000 tons, and now they are 712. In 7 years they have grown by 50 percent. In other words, it is too early to say this is all there is.

Mr. FISH. Thank you very much.

Mrs. LLOYD. Thank you very much, Mr. Fish.

Mr. Harkin?

Mr. HARKIN. Thank you, Madam Chairman. I too want to say that I appreciate the fine work that you have done in putting out this book. I only wish that perhaps we could have had this discussion a little bit later on so I would have time to read it all and think about it a little more deeply than I have had a chance to in the last few days.

In just perusing it in the last few days, I have come up with a number of questions. I am somewhat encouraged by what has happened in terms of the breeder program, encouraged by some of the facts that you have brought to light on the breeder program.

As I understand it, what you are basically saying is that in terms of the breeder program that there is really no necessity to commercialize it at this time, but that basic research ought to continue on the breeder program in building up our store of knowledge so that if something does happen in the next 30, 40, or 50 years, that then we can begin to commercialize. Is that a fair assessment?

Mr. KEENY. I think that is exactly correct. It is really a double insurance program: One, insurance if there proves to be very little uranium or if the rate of demand for electricity grows much more rapidly than anyone expects now; and two, on a longer term horizon, insurance that with increasing energy costs other alternatives simply will not emerge that are in fact competitive with the breeder. Since we know technically that a breeder clearly can be built this is an insurance.

Mrs. LLOYD. Would the gentleman yield?

Mr. HARKIN. Yes.

Mrs. LLOYD. I would like to point out that the CRBR is an R. & D. project, and how are we going to find out unless we do have a test program? This is one-third to one-fifth the size of a commercial breeder. Let us put this back into perspective and say this is R. & D. and it is basic research and how are we going to find out unless we continue our research?

I thank the gentleman for yielding.

Mr. HARKIN. Do any of you gentlemen have a comment on that remark?

Mr. GARWIN. I think we should distinguish among the various phases of development and research and commercialization. Costs increase enormously as one gets closer to the point of having something which is fully developed and can be sold on the marketplace. What we advocate is going really quite far beyond basic research. It is a broader program and a deeper program which goes into other kinds of breeders, into technology for handling coolant, for reprocessing, and so that when the time comes, looking ahead 20 or 30 or 40 years, and we see that we will need the breeder, need it because an intensive national uranium resource evaluation program shows 10 or 15 years from now that we have a certain amount of uranium, then we can plan and then we will get a better breeder than if we spend a lot of money on this particular point.

Mr. HARKIN. Let me pursue that then.

One of the concerns that I have in studying this whole energy program over the last couple of years I have been on this committee is that we tend to do what I call leapfrog technology. In many cases that really tends to get us in a lot of trouble. We really have not staged out our research program. We talk about the fast-flux test facility and that some of the data and things we will get from that, that we ought to analyze that and do that stage first before we go on to the next stage. I am concerned that we might be leapfrogging and in fact it would cost us a lot of needless dollars, wasted, and might in fact set back the whole program sometime in the future.

Mr. GARWIN. That view is in fact one which is reflected in the report. If there were a critical need, a demonstrated need, but what we are doing now might be reasonable, although we should be more careful about it.

Mr. HARKIN. I have the same concern about the fusion program, that we might be doing some leapfrogging there also in not proceeding on a stage-by-stage basis, but I don't want to get into that. I want to ask you about coal production. I am concerned—of course, whenever you are talking about providing energy—and of course what Mr. Fish said about the tripling of electric demand—I don't know if that's really true and I don't know if it necessarily will triple by the year 2000, but how do we bring coal production up to meet the level of electric generation that we may need on whatever basis you want to assume our electric demand growth will be? How do we bring that coal production up from the present level to the level that will be needed without seriously damaging the environment, No. 1, and having it cost a lot of money to repair the environmental damage?

And second, there is just the cost alone of taking out that coal and transporting it and taking care of the waste it will generate. How will you bring up this coal production in just a few years?

Mr. KEENY. This study is not really a coal study. We did discuss it. And we were persuaded as to the extent, the vast extent of reserves that exist essentially at current costs. And I think we were persuaded in general terms that it would be technically possible to increase the rate of production at a rate commensurate with the demands that are considered in the study.

At present, as I understand it, coal is really a demand-limited industry and we do discuss in some detail the fact that there is a large array of regulatory and institutional problems that will have to be resolved if such an expansion in coal is in fact to take place. I believe it is our general belief that this could be done acceptably with environmental considerations and that costs of transportation and new capital for new mines and facilities were taken into account as part of the future cost for coal. We did not, I don't think, as a group, come to any specific recommendations or conclusions of precisely the proper path to take in resolving some of the institutional problems that do in fact exist. Mr. Landsberg or others may want to comment on it.

Mr. LANDSBERG. Only to say that you have put your finger on a very important spot here. We do highlight the constraints under which the coal industry is working, and as Mr. Keeny says, demand is a very important one. As long as the utilities are constrained in their use of coal because of environmental standards they are not going to be very forthcoming in switching to coal. In fact, that is what has been happening. The transportation problem is another one, for instance, in the West where there is not enough, and in the East it is antiquated. We make the point that while the resources are there and probably at a level cost availability, that that does not mean they can be readily translated into production. If we are serious about having coal be a bigger share we list the things that have to be done.

Mr. KEENY. In our assessment of the comparative economics of coal and nuclear we assumed that coal will meet the current environmental standards. If coal ignored environmental standards, it would be cheaper probably than nuclear.

Mr. HARKIN. Let me move to another area and that is alternate energy sources. On page 138 you make a statement that for the longer term one or more of the solar energy methods may provide a significant fraction of energy in the United States but not until rather far into the 21st century and with a price premium over nuclear and coal power. I guess that statement kind of disturbs me. I understand all of the figures you put out in terms of the watts of energy hitting from the Sun every year and I have been through that whole thing. But there seems to be some kind of breakdown between the statistics and the applicability of solar power.

In other words, when I tell people back in my district that this is a fact and that solar energy is not going to be applicable for cost competitive until far into the next century, I am hit with the fact that, for example, there was a new bank just built, the first commercial building in the State of Iowa heated and cooled with solar energy. It came on line last month. I have visited it a couple of times and we are now collecting data on it. But when they first designed the building about a year and a half ago they estimated that they would recoup the cost of that system over and above the cost of the normal gas system, heating system, in something like 50 years. But the banker said well, what the heck, I want to go ahead and do it anyway. He had a lot of money, apparently.

So he went ahead and built it. Now today they estimate that they will recoup that cost in less than 10 years. So when I tell him that it won't be feasible until far in the next century he says there's something wrong because it's working for me. And there is a big bank that is operating right now.

How do you answer that kind of a question?

Mr. KEENY. I think part of this is confusion in terminology, and I would like Dr. Garwin to comment on it afterwards, but our focus on solar power here has been as a source of central base electric power.

Mr. HARKIN. Maybe that's the key.

Mr. KEENY. When we say that it won't be competitive in this century or in the first decade of the next century we are referring to solar power as a source of electricity for base power. We know that for certain special purposes such as water heating and house heating it may already in certain locations be competitive and this application can take up some of the demand, but we are trying to make the point here that we are focusing on electric power generation.

Mr. OTTINGER. Would the gentleman yield on that?

Mr. HARKIN. Yes.

Mr. OTTINGER. That conclusion particularly disturbs me in what I thought is really an excellent report. And I wondered whether you took into account the new developments in solar electric using concentrators where the figures we have been given on some of them produced by IBM Research indicate that solar electric could be economic at the present time. In fact, the figures that have been put out by ERDA have not reflected the accurate state of the art or indeed the knowledge they had at the time.

If in fact using concentrators solar electric can be economically competitive with the existing fossil fuels at the present time, shouldn't your overall projections be quite different?

Mr. GARWIN. Yes, they should be quite different if that were true. Of course, I am not speaking here as from IBM. I am an individual. But the problem with solar electric is that the Sun does not shine all the time and you need electricity when the Sun is not shining. But you pay the capital cost when the Sun isn't shining also. It isn't the cost of the semiconductors or whatever you put into the concentrated sunlight. It is the cost of the mirrors and the tracking and the environmental protection and the storage, even if the solar energy generation were free. I will find out what those particular numbers were and report to you. There has already been information available for the last couple of years on 20-percent efficient concentrated solar electric and I know that particular organization, Varian, is not pursuing this intensively because of the cost of the mirrors and tracking.

Mr. OTTINGER. I am speaking of the photovoltaic work.

Mr. GARWIN. I understand, and that was Varian also. We must put this in context. Our study, of which I think we are most proud, is how to look at the energy problems and when we get to any one of these questions like solar energy or breeder reactors, that is a fallout of the general competition among various potential energy sources to fill the demand which exists at any price.

The problem with solar energy now is not that it won't work. The problem is that we have low cost and truly low cost electrical power available from coal and from nuclear power. If we did not have those, you would see a lot more solar energy. First of all, you would see solar heating and water heating that is highly economical now in new construction but not in retrofit to old housing. We are not building enough housing or enough commercial enterprises to make a big dent, maybe a couple of percent in the next 10 or 20 years.

The problem with the breeder reactor is that it competes with light water reactors and even if light water reactors were not available because of uranium shortage, which is a possibility, there is coal, a large amount of coal in this country that sets a lid on the price people are willing to pay for breeder reactors in the near future.

In the distant future, especially if we have better breeder reactors because we have done more work, the breeder reactor will come in sooner and the same with solar energy. As to your question, Mr. Ottinger, I will find out and report to you on the solar photovoltaic with concentrators.

Mr. HARKIN. I guess, perhaps, when you said that may be the key that it is in terms of scale, I was interested in a comment on page 44, that the concepts and methods in economics are sufficiently flexible to accommodate most of the unusual features of energy. That depends on what kind of economics you are talking about.

If we use the classical types of economics that we have operated under in this country and in the world for the last few years, perhaps that may be so. But perhaps we ought to be thinking in terms of new or novel intellectual approaches, as you have said, in analytical devices.

If in fact electrical demand does in fact triple by the end of the century—I am not convinced it will, but let's say it does, and we do have to build all of these other electrical generating facilities, whether nuclear, coal, or whatever, it is going to require a lot of cooling water, for example, unless we develop some type of dry cooling towers or something. That will have a severe environmental impact in terms of what happens to the temperature of our runoff water in this country. What about even the source of water? Do we have enough cooling water to take care of all of these facilities? Then it comes full circle back to what Mr. Ottinger was talking about, when you use a photovoltaic system with a concentrator, perhaps you don't face that problem in that magnitude. So I'm wondering if perhaps we are not locked into thinking about our energy on economic terms based upon economics of scale of doing things on large central power stations, generating the power out to other remote places and perhaps we ought to be thinking of a different scale of economics, a scale of smaller economics, intermediate economics, rather than the large-scale economics.

I'm wondering if perhaps we shouldn't take a step back and analyze it from a different perspective.

Mr. GARWIN. We did look at some of those questions and we did not say that one ought to generate power only centrally. In many cases—for instance, as with cogeneration where a shopping center or industry or commercial building burns oil or other fuel in order to get space heating or cooling, they can also generate electricity and this would be distributed generation in rather small plants which would reduce the cost of energy and reduce the consumption of fuel. We are not trying to say in this study what should happen. We are not even saying what will happen. We are saying what could happen. And unless restrictions are placed in the way, that could happen and will happen. But unless you keep people from gathering together in cities for other reasons, they are going to need central supply of electrical energy and maybe even central supply of heat, district heating, from the byproduct of electrical energy generation, and that will happen. That is included in the kind of economic analysis one uses.

If one forbids the electrical generation by some means, then the analysis is sufficiently flexible to tell you what is the cost to society from reducing generation by arbitrary constraints. It doesn't mean you shouldn't do it. You should realize what it is costing.

Mr. HARKIN. One last question and you could even write me a letter and give me the answer. One question that I asked when I visited all the labs—when I was out visiting Dr. Panofsky last month I received some fine answers from people out there, but it is a question I have been asking of scientists. I make one basic assumption and that is that we have both a short-term and a long-term energy problem. I don't know how to define short-term, but I consider short-term my lifetime and whatever is beyond that is long-term, I guess, assuming I live to a ripe old age.

And if we don't solve the short-term, we might as well forget about the long-term, because we won't make it there. We will freeze to death or the economic downturn will be such that we won't make it to the long-term. I use that as an assumption. Therefore, if you had a limited resource, a limited amount of money for resource development and demonstration, which is what this committee is all about, let us assume you had in the neighborhood of $5 million per year to spend for the next 10 years, and your problem was not only to meet the problems of that 10 years but the problems, of let us say, 15 or 20 years beyond, to the turn of the next century, how would you spend that money?

Mr. KEENY. This committee did not try to answer that specific question. We did not in fact come up with detailed——

Mrs. LLOYD. I was wondering if it would be agreeable to Mr. Harkin for you to answer this later?

Mr. HARKIN. What I would like you to do is, if you could——

Mr. KEENY. I think I can answer it quite briefly. We did not come up, as a group, with a specific split breakdown as to how any particular pot of funds should be spent on R. & D. in the short-term. Our assessment of short-term is really the next few years as opposed to longer-term.

But one point we did make, and I think it is a key point, is that we are not concerned about the long-term availability of energy as our society needs it. But we assume in saying that that there is going to be an aggressive, effective R. & D. program to bring the breeder along, to bring solar energy and to bring fusion and to work on geothermal. We are assuming that our society will apply significant funds to those programs, and we point out that it is going to be a very difficult challenge how to do that, because we are talking about programs that may be 30, 50, or more years into the future. This is a very challenging proposition and we do not present the specific formula of how this should be done or how it should be split up.

Mrs. LLOYD. Thank you very much.

Mr. Lujan?

Mr. LUJAN. Very quickly, because of the time, when Mitre went out to do this study, did you have any specific instructions such as go out and get the best people you can and come up with an objective study?

Mr. KEENY. That is correct.

Mr. LUJAN. And you did, you went out and got people who have been involved in the business for a number of years and that leads me to the question of what has happened in the last 8 or 10 years—I remember when the breeder was made the highest priority of the Nixon administration and they said that is the thing that will get us where we want to go and every one of these people, I imagine, were around in those days and at least by their silence probably agreed with that conclusion at that time, that that would be the highest priority. And I am just wondering, because I can see nothing that has happened that would turn us around. Do you oppose it on the basis of cost and proliferation? Well, looking at cost, oil isn't any cheaper, or gas or coal. We don't need power less because we are not conserving, we are not doing any better job than we were, the alternate sources, fusion, solar and all of those, are not any more at hand than they were in 1968. What has happened to turn us around?

Mr. KEENY. I think the principal thing that happened with this group was that we were asked by the Ford Foundation and Mitre to undertake this independent study. While some of the individuals of this group may have had positions earlier or they may not have—I don't know—I think we have all looked at the problem in broader perspective than any of us had earlier.

So I think that is what affected our thinking the most. We have gotten a little closer to the problem. I suppose there are one or two things that have happened which seem fair to mention and that is that general projections of the rate and extent of the growth of electric demand have fallen considerably—I am thinking of Government projections as well as those of outsiders—they have fallen considerably from when the breeder program was considered in earlier years. I think that the possibility that uranium may in fact—there is certainly enough uranium available to see us through the intermediate period.

Mr. LUJAN. We have found more since 1968 or 1969, more in relation to what we would use?

Mr. KEENY. The answer is yes we have, but I think basically this group in looking at it has concluded that given the current range of demand there is enough available to see us through an intermediate period when it will be possible to, in fact, confirm that there may be substantially more material available for the longer range future.

Considering the fact, which I do not think has been emphasized clearly enough, that light water reactors will remain competitive even if the price of uranium goes up well above $30 a pound, simply because the cost of the fuel is such a small proportion of the total cost of nuclear generated electricity.

But, I don't believe any members of the group had been deeply involved personally or in any committee activities in the last decade or so, relating specifically to the breeder program. So really the main new thing that has happened is that we as a group have looked at the problem in some detail.

Mr. LUJAN. When you say the breeder program, are you referring just to liquid metal, or are you referring to all breeders? Are you speaking of just the liquid metal breeder reactor or all breeder research?

Mr. KEENY. Our feeling is that an insurance program looking at a longer time scale should be broader. We should certainly continue the existing program and should look at a broader range of potential breeder reactors and not prematurely close the books on other options that may in the long term prove more desirable or equally desirable.

Mr. LUJAN. The basic reason for that conclusion—two reasons, one being cost and the other proliferation.

Mr. KEENY. Yes.

Mr. LUJAN. You found that if the costs were all right in the year 2000 or 2025, then that would remove that objection.

But getting on to the proliferation issue, the chairman, Mr. Flowers, discussed that to quite an extent. Don't you think that the best way to prevent proliferation would be for us not to build just a 1,500-ton reprocessing facility but maybe build a 5,000 or 6,000 one and make it attractive for the whole world to come to us for their reprocessing? Then we could really—put 50 fences if you want with land mines in between, 50 guards at each door and then we would really have a handle on the thing rather than saying don't anybody do it, because you are not going to ever convince Japan that they should not reprocess the fuel.

Mr. KEENY. I think that is a legitimate alternative that should be considered. We did consider the desirability of multinational facilities of one kind or another. We felt after having looked at the economics critically, which none of us had done, I believe, before we undertook this study that the economic utility was so marginal, if any, that it was premature to cross that bridge yet, and that while there was no assurance restraint on our part would be decisive in all other countries' decisions, clearly if we go ahead with it, other countries will be driven in this direction: Since we have been the leaders in nuclear energy. If plutonium reprocessing and recycling become standard, it would be very difficult for us to insist or control how all other countries are going to do it. The countries we are most concerned about might be the ones that would be least likely to take advantage of any large national or multinational facilities that we might develop.

Mr. LUJAN. Madam Chairman, in the interest of time, there is a discussion on the old proliferation issue and some of the solutions as viewed by the chairman of the Armed Services Committee, Mr. Price, and I would like at this time to enter it into the record.

Mrs. LLOYD. If there is no objection, it will be inserted in the record at this point.

[The letter follows:]

U.S. HOUSE OF REPRESENTATIVES,
COMMITTEE ON ARMED SERVICES,
Washington, D.C., February 22, 1977.

Mr. JOSEPH S. NYE,
Deputy to the Under Secretary of State for Security Assistance,
Washington, D.C.

DEAR MR. NYE: This is in reply to your letter of February 7 asking for my suggestions and ideas regarding the problem of proliferating nuclear weapon capability.

As part of my congressional duties, I have been associated with this country's nuclear energy programs and activities for over 30 years. My experience embraces the entire historical span of the development, use and control of atomic energy for both military and civilian purposes, including the regulatory side inherited by the Nuclear Regulatory Commission under the Energy Reorganization Act of 1974.

I want to give you the gist of my thoughts in as few words as I can manage, so I will proceed directly with a brief candid account of the high points of my views:

(1) The proliferation dilemma involves complex considerations. It must not be dealt with as a one-dimensional problem.

Among thinkers, only those who want to halt civilian nuclear power understandably argue that the proliferation situation can be easily solved. They describe the problem as an immediate stark peril of catastrophic magnitude.

The solution, they say, would be an embargo on all exports related to nuclear power. Alternatively, they advocate the interposition of a governmental regime of proliferating procedures and export approval hurdles calculated to discourage knowledgeable foreign customers at the very outset, and the less wary at one of the many despair points in the time-wasting system for securing final official sanction. That the cessation of U.S. exports would not alleviate the proliferation problem, and indeed would worsen it, is not a deterring factor because the underlying intention of our nuclear opponents is to utilize every problem in a way that best serves their primary aim of weakening our domestic nuclear power industry and capabilities.

(2) Proliferation is a chronic illness. The best and most extensively applied treatment that can be arranged will not effect a complete cure. It will only gain time and a large measure of relative protection and peace of mind.

For two decades following the baptism of the peaceful atom, while the development and use of nuclear energy for medical, agricultural, industrial and other purposes flourished at home and abroad, nuclear weapon capability spread very slowly. During that period, two unique accomplishments were attained: The International Atomic Energy Agency was established in 1957; the Treaty on the Non-Proliferation of Nuclear Weapons went into force in 1970. It is a great source of pride to me that U.S. initiative (including my hand and mind) played a large role in the creation of these major multinational structures for safeguarding the peaceful atom. The magnitude and value of these accomplishments are immense. In regard to the NPT, consider that to date 101 countries—98 of them nonweapon states—have agreed to limit their sovereign prerogatives in the most sensitive of areas; 13 additional nations have signed but not yet ratified this extraordinary treaty.

Worry about weapon proliferation suddenly intensified in 1974 when India exploded a nuclear device labeled peaceful but indistinguishable from a non-peaceful detonation. Then West Germany agreed to supply Brazil with a complete fuel cycle capability, and South Korea, Pakistan and Iran tried to buy reprocessing technology. Proliferation concern was further stimulated by developments involving Egypt, Israel, Taiwan, Argentina and other countries. South Africa's nuclear potential is very much in the news these days. These international events within the past three years were preceded by a suddenly imposed awareness that the availability and price of oil were no longer dependable, and that alternative energy sources were imperative. The result is that today's greater potential for weapon proliferation coincides with, and will be aggravated by, an enlarging worldwide market for nuclear power.

(3) The U.S. is still a leader among the have-and-can-sell countries, and, as an active international participant, can exert a fair degree of influence toward common agreement on a reasonable system of safeguard standards and requirements as a condition of the sale of nuclear power plants and fuels.

The U.S. is not in a position to dictate to other supplier countries that they require, as conditions of their sales, that buyers agree to the safeguard measures we would prescribe. Nor can we unilaterally alleviate the proliferation problem by attempting to impose our own set of safeguard conditions on prospective buyers without regard to the sorts of conditions employed by other supplier nations. Customers can choose suppliers.

This situation extends to enrichment technology, reprocessing, and the development and use of breeder reactors. The U.S. simply does not have monopolistic control. If we want to be in a strong position to influence and attain general acceptance of improved antiproliferation safeguards we will have to remain a leader and an active international participant in all of these areas.

Historically, the U.S. never had a monopoly on nuclear technology. We were the first to develop nuclear weapons and for many years were the only supplier of enrichment services for civilian reactors. Though our enrichment technology has essentially remained classified, inevitably other countries have developed the means for commercial enrichment (the U.S.S.R., France, and all partners, the United Kingdom, the Netherlands and West Germany); within the next several years at least five additional countries will be in the field.

The U.S. has not yet decided whether to permit commercial reprocessing, but France has an operating facility for such purpose. The United Kingdom has temporarily closed down a large commercial plant for upgrading. Eleven other countries have laboratory, pilot, or near commercial reprocessing facilities.

Five countries are now exporting light water reactors, and in several years they will probably be joined by suppliers in six more countries. Canada exports the heavy water reactor. France is presently the world leader in the development of the fast breeder.

There's no need to go on with the details. The general picture and outlook are clear.

(4) The need for an improved international antiproliferation program is real. But apparently events in the last 3 years which have highlighted this need are viewed with much greater unease by opinion makers in this country than in other nations. The U.S. hue and cry has not been strongly echoed abroad. Additionally, the hyperbole in some of the U.S. expressions of alarm, the contents of several of the legislative measures proposed in the Congress, and the delays and confusion in nuclear export licensing have undermined confidence in U.S. judgment and in in its role as a reliable supplier; combined with out failure to assure enrichment capacity for foreign customers, the total adverse effect has been considerable. Consequently, the U. S. antiproliferation position, to be persuasive to both suppliers and customers, must be completely sound and practical.

(5) In my judgment, a sound and practical antiproliferation program should take advantage of and build upon the protective structures and measures already in place. They are familiar and have unquestioned value.

The IAEA, for example, should be strengthened, not interfered with. The spirit of the NPT should be vigorously promoted, and a renewed effort mounted to fulfill the compensating pledges of the weapon states to the nonweapon parties.

The protective features of the Atomic Energy Act should be maintained and reexamined for possible strengthening. I refer to such features as the Restricted Data system and the Section 123 export bridge. The President's Constitutional prerogatives should not be encroached upon nor his role as Executive leader diminished.

The Nuclear Regulatory Commissions ambiguous position should be clarified; a careful review of the legislative history of the Energy Reorganization Act of 1974 will disclose that the NRC was not intended to have any greater licensing and related regulatory jurisdiction in relation to the export area than the AEC's regulatory side was responsible for when it was elevated to independent agency status. Before, activities outside of the geographical bounds of the U.S. (as defined in the Atomic Energy Act) were with few exceptions, beyond the grasp of the regulatory regime; the developmental side of the AEC (now in ERDA), and, depending on the situation involved, the President, the State Department, and the DOD, controlled the decision making process, subject in some instances to congressional review. Regulation was applicable only to such aspects of exports as involved radiological health and safety, security, and environmental considerations affecting U.S. territory—but not proliferation and other problems abroad. In the confusion of rebirth during the period of raising U.S. concern over the proliferation problem, it became politically expedient for NRC to inject itself in this troublesome area and to attempt to acquire related knowledge and competence already possessed by other U.S. agencies.

(6) As important as the proliferation problem is, in any sensible ranking of priorities the formulation and execution of our domestic energy program must be placed well in advance of the proliferation concern, and treated as a discrete as well as first-rank objective. Separately, we should consider what impact on the proliferation problem related exports might have, but no judgements in this separate area should interfere with decisions and actions discretely addressed to our domestic needs. These propositions are too obvious to mention, but I restate the basic law of self-preservation because I have detected a tendency in some quarters to assume that all domestic policy decisions that would support the development or use of nuclear power-related materials, facilities or processes, in light of this country's own energy situation, must be contemporaneously evaluated and adjusted in relation to te antiproliferation objective. Too often, for example, I read statements these days by officials or "experts" to the effect that the U.S. cannot risk developing the breeder or licensing reprocessing because of the international proliferation problem. Such Alice-In-Wonderland thinking is dead wrong. Not only does it interfere with our own critical energy quest, but, as I have pointed out above, it so happens that our best hope of alleviating the proliferation problem may well rest with the magnitude of our international influence, which in turn depends on the extent of our technological capabilities as well as our willingness to participate in the have-and-can sell area.

It is possible that the means of carrying out a particular domestic energy decision may sometimes appropriately be selected in conjunction with antiproliferation considerations. For example, it is possible that a domestically oriented decision to build a reprocessing facility may, for antiproliferation policy reasons, be implemented in conjunction with a national decision that such a facility be built and utilized under a multinational arrangement. But in such case—and this is the point I emphasize—the principle of discrete consideration, ranking priority, and separate judgment in relation to our own energy needs must not be compromised, not even in regard to the means to be employed; only where the means of gaining our domestic objectives happen to be consistent with a preferred method for dealing with the proliferation question should the marriage of convenience take place.

Finally, it is possible that for anti-proliferation reasons alone our national policy might support the development or use of certain facilities or services. In such case the principle of the predominating importance of our domestic energy program must be maintained.

(7) I must say a word about the desire for nuclear power throughout the world because if it could be extinguished the proliferation problem could stabilize. The key difficulty confronting nuclear power foes is the formidable task of trying to convince a majority of the people, or the totalitarian rulers, in the various countries that their reasonable hope for an assured supply of safe, reliable energy can be satisfied without nuclear power. Is it realistic to expect that this proposition can be sold? The world is in an energy crunch right now and people everywhere are very concerned about it. The high cost of oil is creating massive balance of payments problems and other serious discomfit for most nations. The developing countries have been very severely affected. Most foreign countries do not have extensive coal reserves like the United States or possess hydro or geothermal resources that can supply a portion of their energy requirements. For many countries the choice must be imported oil at whatever price or lower-cost nuclear power. Can they be beguiled by nuclear opponents into waiting for promised breakthroughs in solar energy, fusion, and other new or advanced energy forms? I think not, though I hasten to add that when it comes to the search for new energy sources my long record fully testifies to my unflagging support of all promising R&D missions. But pending the great improvements that I hope and pray the future will bring, I, and I think most of the people in the world, know the difference between something in hand and promises, promises.

With nuclear power comes reprocessing. For most foreign countries the energy content of uranium and plutonium represents a significant addition to their domestic energy resources. They may well tend to view the value of this recoverable energy in terms of its credit benefit in the allocation of scarce foreign exchange for imports, rather than as a percent of the total cost of power. In any event the economic impact is important. In an energy starved world where conservation is imperative, we should not expect that source of fuel will be wasted.

(8) As apparent from the foregoing remarks, I recommend striving for an improved anti-proliferation program that includes the following elements:

(a) Realistic acceptance of the worldwide prospects for nuclear power growth.

(b) International participation by the U.S. in civilian nuclear power activities.

(c) Strengthening IAEA.

(d) Working out a safeguards system of standards and procedures commonly acceptable to supplier countries as a condition of sales, the agreement to address first the current situation, and within a few years the outlook at that time, with flexibility built in for periodic reappraisals and revisions.

(e) Inclusion in the cooperative understanding of practical restrictions on availability of enrichment capability and reprocessing facilities, on dissemination of information of a Restricted Data nature and on fabrication of fuel and shipment and storage of fuel and reactor-produced materials.

(f) Exploring the possibility of building and operating reprocessing and related facilities under multi-national auspices.

(g) In collaboration with other countries, conducting a continuing R&D program to seek improved chemical and other technological means of increasing the difficulty of diverting or stealing sensitive materials for weapon purposes.

(h) In collaboration with other countries, improving the means of storing and disposing of radioactive wastes, of protecting facilities against sabotage, and of minimizing the MUF problem.

(i) Inclusion in the cooperative understanding of the continuing general observation of activities in kindred fields (research reactors, etc.) so as to exclude from closer control activities and facilities that have no practical impact on the proliferation watch, and to include those that do.

(j) Reforming and simplifying the U.S. export approval route, including:

(1) Assuring consistency with the safeguards system agreed to multinationally.

(2) Adherence to the Restricted Data system and Section 123 requirements in the Atomic Energy Act, as they may be modified to enlarge the President's role or Congressional oversight.

(3) Eliminating any NRC role in relation to circumstances, implications or consequences outside U.S. territory, except possibly to render advice to Executive agencies on comparable safeguards in the U.S.

We are dealing with an issue that will not necessarily be diminished by dint of U.S. sincerity, alacrity, or high motivation. Gulliver meant well when he decided to use the only gusher available to him to extinguish the conflagration in the palace of the Lilliputian empress; he was sincerely convinced that the thimbles of water with which the Lilliputians were fighting the blaze would be ineffectual. Instead of the commendation he expected for extinguishing the fire in three minutes, he earned the empress' enmity because her quarters were permanently polluted and unusable. I have often thought of the good lesson in that tale.

Sincerely,

MELVIN PRICE, *Chairman.*

Mrs. LLOYD. Mr. Ottinger.

Mr. OTTINGER. Thank you, Madam Chairman.

I too would like to congratulate you on a very provocative and useful report to us. I share much of the same concerns about it as Mr. Harkin expressed. I think all of the work that has been done in the energy field, at least at times in particular by ERDA and the Government has been on a think-big basis. I think that has many bad consequences for society, aside from the estimated trillion dollars of capital it will require through the year 2000 and the various environmental dangers associated with most of the means of producing this. I would hope that if you are going to keep going—and I hope you will in your explorations in this field—that you would seriously take on the possibility of a much more decentralized configuration for satisfying the country's energy demands in the future. The idea that in cities that we are going to have to used centralized sources of power I think is subject to challenge as well. In New York City, for example, there has been a self-help project, a very small scale with people rehabilitating their own apartment houses. In part of that there was installed on these apartment houses a solar collector for hot water heating and a windmill to produce the electricity for the building. It seems to be doing just fine. You could say, well, it's not price competitive. On the basis of a one-shot operation of an experimental nature of course it is not price competitive. But when you think of a world that is going to be controlled by just a few huge energy companies and all the problems attendant with the use of natural resources necessary to produce power in a centralized fashion and all of the environmental risks that are attendant, it seems to me well worth our while to explore the outer limits of what could be done on a decentralized basis. Are you going to continue your explorations in this field?

Mr. KEENY. No, sir. This committee was a 1-year study, and essentially we completed our work in January of this year. The group really no longer exists. We were simply brought back together in response to your request.

Mr. OTTINGER. I am sorry to hear this. There are certainly going to be extensive future references to all of you in the future. Do any of you have a comment on this?

Mr. ARROW. The concept of centralization and decentralization are tricky concepts. What centralizes in one way may decentralize in another. I think the feeling that there has been some prejudice due to extrapolation of history in favor of larger and larger and that this frequently leads to very undesirable consequences is a fair statement, although its worst effects show up not so much in a country like the United States but rather in developing countries which echo and imitate the advanced countries in ways which are inappropriate to it. It is probably not easy—it may well be, for example—it certainly has been true in the past—the encouragement of central station electricity has been one of the most powerful decentralizing tools. The shift from "steam driven" mills has permitted small industry to compete more effectively than it would have under the previous arrangements. The do-it-yourself sort of thing at home, the man at home with the power tool is not a joke. A considerable fraction of our activity has shifted back in ways which would not have been possible under other kinds of systems.

Mr. OTTINGER. You don't have to produce his electricity in a central station.

Mr. ARROW. I think if you don't that you will find yourself more dependent on centralization in other ways.

Obviously the first thing that could be said is that research and development and even maybe encouragement should be given to alternatives. If in fact windmills do turn out to be a useful way, not necessarily only in a purely economic sense but also as to satisfaction giving, and if this permits people to take care of themselves, fine.

It is a little hard for me to visualize tens of thousands of windmills. You can see that totally apart from the economic considerations that esthetics and mutual interference might be worse in the sense of people impinging upon each other. It might, in fact, be worse than it would be with central stations quite far away. I don't think electric utilities have very great power over consumers particularly.

Now, you can argue that whenever there are concentrations of power there are abuses. But in general——

Mr. OTTINGER. I don't think you would get far with that argument in my constituency. One of the things that I think is attractive about the possibility of solar electric power is that it permits the potential for decentralization. The information that we get is that that is a factor. I think you are actually in error here in terms of your projections, that in fact now the technology is economical. If that is so, we ought to be pushing it a great deal harder.

Mr. Garwin, you wanted to say something?

Mr. GARWIN. You probably need no reminding that in 1974 the Congress passed a law which created ERDA and before that they said we should have a solar energy research institute. On October 22, 1975, I talked to a committee of the House as Chairman of the National Academy of Sciences Solar Research Committee, which had reported to ERDA. ERDA and the Office of Management and Budget in a previous administration did not proceed with those recommendations. They reduced the scope of the institute by a factor of four or five. The

Assistant Administrator of ERDA resigned in large part over the treatment of the Solar Research Energy Institute. It is my belief that in order to understand where we are in energy and the prospects of going forward that one should have a substantial effort in the agency of government charged with that understanding and with the research and development. A contract has recently been awarded to be placed in Golden, Colo., and I have not looked at it in great detail, but I doubt that it works on the scope which you would advocate or which our report recommended. One can always decide not to pursue a certain line but you cannot instaneously generate an alternative.

Mr. KEENY. I would like to say that our study did not really get into the details that Dr. Garwin suggested about how the solar energy program should be run. Another thing we did not get into and explicitly state is the question of the lifestyle of society. We did not make any judgment as to whether it was desirable to centralize or decentralize, but rather looked at it more as an economic question.

Mrs. LLOYD. We will stand in recess for 15 minutes.

[Recess.]

Mrs. LLOYD. The committee will now come to order.

I believe Mr. Ottinger will now proceed with his questions.

Mr. OTTINGER. Thank you, Madam Chairman. As we were leaving you said you did not take into account lifestyles, which was, I thought, a rather remarkable statement to make, because it seems certain to me that lifestyles enormously affect energy consumption and in fact we have had such enormous changes in lifestyle over the past couple of decades that to anticipate things are going to be static over the next 20 years or so is just not dealing with the real world.

Mr. KEENY. I think the point I wanted to make, sir, is that we did not feel that a desire to change basic lifestyles should be an input into our decision as to the form that energy development should take. We did not take that as a starting point in our analysis. I think the way we stated it is the availability of energy and the evolution of our energy program need not change our lifestyle compared with that which society should choose to pick, which is a social decision that we did not consider.

Mr. OTTINGER. You considered all kinds of impacts and hazards on society, environmental hazards and so forth, it seems to me that not to take into account the concentrations of power—and that is already a trend within our society, bigger and bigger companies, less and less competition, bringing in greater and greater centralized governmental control, it just seems to me that that is an important factor in considering how you are going to go. It looks as if you took the existing framework in which we generate energy and just said, you know, if we're going to be running out of oil how are we going to substitute for it and did not look at the alternatives of possible decentralization that I think at least ought to be looked at. In our informal discussions before, I understood that some of the decisions we could make would pay for decentralization as well.

Mr. KEENY. We did look at it, but we did not consider that we should decentralize. We did consider some of the options.

Mr. OTTINGER. Did you consider the proposition that we could get huge amounts of power from the existing dams that do exist and the small streams that presently are not being used?

Mr. GARWIN. We took an economic approach and those things that are economical ought to be done. On page 149, if you look at energy supply and demand in the United States in 1970, hydroelectric power is only about 1 percent of the total supply. Total electric generation used only about 20 percent of our total energy and the output was only about 6 or 7 percent. So if you focus on electrical energy, as our study did to some extent, because that was our problem, that is all nuclear energy is good for in the near-term, and so you see a large stress on electrical energy, but that does not give you the whole picture. There is a great need for process heat, space heating, industrial uses of energy, and for energy in transportation, for most of which nuclear energy is not now competitive. Whether one does this in a centralized or decentralized fashion, our analysis was that it would be done in an economically efficient fashion, and that took into account the decisions that a free market would make if a free market existed.

Now, sometimes the Government will help make those decisions and if it makes those same ones it does not matter so far as efficiency is concerned. There is no one on the committee who wants to see greater centralization of power or arbitrary actions by Government.

Mr. OTTINGER. Your focus on this study, that was on nuclear power. I suppose that is part of my problem. It was not on overall energy options. Perhaps, therefore, my concerns are somewhat misplaced.

Mr. KEENY. I really would like to emphasize that our study focused on the question of nuclear power and we went somewhat afield, because in making any decisions on nuclear power you do have to consider the alternatives of coal and other renewable resources. We also made an effort to try and understand how nuclear power affected the electrical economy and how electricity entered the overall national economy. What we were seeking to do is to put some perspective on just how important or how critical are some of the decisions to be faced. The focus was always on nuclear power.

Mr. OTTINGER. I think that explains a little bit because when I was considering this, I was thinking from our previous discussion that you were focusing on overall energy alternatives.

Dr. Panofsky, you were saying some interesting things to me that you thought you wanted to get into the record with respect to the breeder and particularly with respect to that fact that we are proceeding much faster in the hardware area than we are with respect to dealing with other problems in the fuel cycle.

Dr. PANOFSKY. I was making essentially two remarks. One is that at present the development program, to the extent we could determine, about the entire fuel cycle which goes with the breeder where the plutonium concentrations are very much higher than they are in the reprocessing technology which go with the LWR——

Mrs. LLOYD. Pardon me, Dr. Panofsky. Would you talk into the microphone?

Dr. PANOFSKY. The R. & D. program dealing with the fuel cycle for handling the fuel for the breeder so that the breeding loop can be closed, is in a very much lower developmental stage relative to the developmental stage of the hardware project.

Mr. OTTINGER. Don't we have a good deal of time to make those assessments?

Dr. PANOFSKY. The answer depends on the resolution of this debate that you have been hearing about the total amount of uranium we have. The debate is legitimate. Our knowledge of the uranium assessment is indeed poor. However, the program to deal with it, the NURE program is of relatively recent date, and we found several very limiting factors associated with the NURE program which we believe should be cured. So our point is that it may just possibly be true that the broad arguments which Mr. Landsberg made about future uranium supplies being much larger, may be too optimistic. But there is plenty of time to find out whether they are optimistic or pessimistic. I think it is simply not wise to take large risks in terms of the breeder, while demanding absolute certainty of assured supply now for an energy source which is supposed to go way into the next century, considering the fact that our systematic resource assessment has been of such recent date.

Mr. OTTINGER. You were saying something about the quantity of plutonium that would be floating around if ERDA's projections were carried out and it was kind of frightening.

Dr. PANOFSKY. What I was saying is the following. We are facing a balance of risks. We know that having a large amount of plutonium floating around involves risks. It involves risks of diversion and all of that. And the numbers which go with that are very large. For instance, if you take several hundred breeders, in that case the total amount of plutonium which has to be in the commercial circuit per year as a result of the refueling operation, would be several times the total present plutonium weapon stockpile. Presumably one can develop plans to deal with this, but I believe that it is essential that some time be bought to develop such plans.

Therefore, in balancing of the risk of that happening versus the risk of having insufficient uranium one should first find out how real the imminent shortage really is.

Mr. OTTINGER. But it is your feeling that the plans to deal with that much plutonium traveling around the country are not very well developed at this point?

Dr. PANOFSKY. They are not developed.

Mrs. LLOYD. Mr. Goldwater?

Mr. GOLDWATER. Thank you, Madam Chairwoman, and I thank you gentlemen for being here today. This has been an interesting discussion. I did not notice in your report what the assumption on energy growth was that you projected. Did I miss that somewhere?

Mr. GARWIN. We really did not project energy growth. We projected a growth in the gross national product and then the energy was associated with that in two ways. There was an income elasticity of demand. We said it goes along with the GNP for the most part, although we could use other assumptions and it changed with the price of energy, the cost of energy.

So we took a price elasticity of demand. So all that come out of a model which we used, for example, and we used that model to verify our judgment, which in fact it did, as to what was important. So we don't have a projection. We have an example.

Mr. KEENY. The intent of the example was to examine the sensitivity of the various assumptions and to examine what the impact of the various assumptions were on the total national economy. We made no independent projection of energy demand, but rather critiqued some that had already been made by others.

Mr. PANOFSKY. I think we explicitly felt that the usual approach which goes with energy studies where a demand projection is given from the outside and then you see how to live with that is not a good one.

We think that a much better approach is to look at the cross-elasticities between the supply and the demand and then find out how much losses to the economy and the income would be, if certain of the program options which are being faced by this country are followed.

Mr. GOLDWATER. Could you say that again?

Mr. PANOFSKY. We identified the loss to the economy, again, if certain alternate options are being followed in terms of choices between nuclear and coal and the breeder and not the breeder reprocessing and not reprocessing, how that would impact the per capita income of the average American.

So rather than saying we must have so much energy, we examined what would happen to the economy if alternate choices are being made among the various nuclear power alternatives.

Mr. GOLDWATER. But you did not consider what would happen economically, if we did not have enough energy to meet demand?

Mr. PANOFSKY. We did.

Mr. GOLDWATER. How could you do that if you did not project demand?

Mr. PANOFSKY. Demand depends on the cost of supply and, therefore, what we did do is we said the total gross national product is going to grow at approximately such and such a rate. Then we assumed that energy would have certain costs. If energy becomes too expensive, in that case the need to satisfy energy would have to come from other activities, and, therefore, there would be a loss to the economy from other sources.

We did not assume that demand is a fixed and varying thing which would be the same irrespective of the supply and the cost of the supply.

Mr. GOLDWATER. So you factored in the elasticity of energy?

Mr. PANOFSKY. Correct.

Mr. GOLDWATER. Do you have tables showing the various levels of demand and the impact upon that, the elasticity of the cost?

Mr. GARWIN. We do have some text on page 61 and then the assumptions which were used are on page 69. One example, for instance is that we chose rather arbitrarily to set a limit on the amount of coal which could be mined for one reason or another in the year 2000. We set about 50 quads, about two-thirds of our total energy consumption could be provided from coal. The result of that was that the price of coal rose very high because the supply was completely inelastic. So the coal prices were up to a couple or $3 per million Btu instead of the $1 cost. And that drove down the demand for coal to equal the supply as people moved to electrical energy generated from nuclear or to other alternatives. But that's an example—a rather arbitrary example of the effect of the constraint on this model.

Mr. GOLDWATER. Did you arrive at a conclusion that energy was in fact inelastic?

Mr. GARWIN. No; in the very long run energy can be supplied certainly from the breeder reactor at reasonable cost, not much bigger than current nuclear energy costs. It probably can be supplied from solar and geothermal energy at a few times our present cost. Those are affordable costs, but society has no reason to want to pay more than it has to pay for energy. And that was the origin of our conclusion that for the rest of this century and well into the next century most of the energy, especially electrical power, will come from a mixture of coal and nuclear power plants. Most of the nonelectrical energy will come from coal after the price of oil and gas rises.

Mr. GOLDWATER. But you found that demand was elastic?

Mr. GARWIN. We assumed that demand was elastic. There is no really good evidence in a period of rising real energy cost. We took some different estimates of the price elasticity of demand.

Mr. GOLDWATER. On page 22 on nuclear proliferation you make the statement there that expectations, knowledge, and trade in nuclear facilities and materials are so widespread that the United States is not in a position to stop the expansion of nuclear power. Moreover, advanced countries and some developing countries are not dependent upon nuclear power to produce nuclear weapons.

I was interested in your discussion earlier with chairman Flowers and his concern over leadership. Then again later Dr. Arrow said something about the fact that we can influence the rest of the world by demonstration. Well, that seems to me to contradict your statement in the book that in fact we are not in a position to stop the expansion of nuclear energy, in contrast to Dr. Arrow's statement that we are going to influence the rest of the world by demonstration.

What happens? The question I have in this regard is going, I guess, way back to the 1940's and 1950's where we have arrived at a national policy which has influenced the rest of the world in the area of leading to the breeder reactor. We are now—you are—recommending a major change in direction.

The thing that is hard to resolve in my mind—and I think what Chairman Flowers was driving at—is this major change going to influence the rest of the world? Do you really think so?

Mr. KEENY. I think that is a very good question. The view of our group was—and we gave a lot of thought to this—that it was clear that if you went ahead with these programs, even if they were not clearly economically needed at this time, it would be a strong influence on the rest of the world to move ahead on them too.

If we really reassessed their real economic utility and deferred our programs, it would probably have considerable influence with some countries and to some extent would influence all countries. We certainly are not saying in our report that we guarantee that if we defer reprocessing or if we defer early commercialization of the breeder that every other country will automatically follow our lead. But we think it will have a considerable influence on the rest of the world since we are still the leader in the nuclear field.

And the converse I think is clear, if we move rapidly with these programs, we can be sure they will take on accelerated development in other countries. I think this is really the core of our reasoning.

Mr. GOLDWATER. Obviously, all of this is speculation.

Mr. KEENY. Correct, sir.

Mr. GOLDWATER. In viewing the rest of the world's need for energy and that of emerging nations and looking at the fact that there are six nations that are deeply involved and either others that are planning, we have a heap of a lot of influencing to do to turn their necks. Again, we speculate that our grand demonstration is going to do that. And the question we have to ask is, is it worth that risk to bow out in the name of example or demonstration while the rest of the world proceeds in their own fashion, void of our influence?

Mr. GARWIN. We are certainly not proposing to bow out of nuclear energy or in any way to restrict the growth of nuclear power.

Mr. GOLDWATER. I am speaking of the breeder program.

Mr. GARWIN. One cannot worry about all of these things simultaneously. If the rest of the world proceeds with a breeder contrary to what we estimate is the best thing for us economically, then they will at some time have breeders which we could call upon for our energy problems if the uranium resources prove short.

If the rest of the world re-does the calculation as we have done and says that it is too soon and they will have better assurance of supply by relying on U.S. and other providers of enrichment for light water reactor fuel, we will endorse that and enthusiastically approve because they have done what is most efficent as we see it and it also helps in the problem of limiting proliferation of nuclear weapons. I do not see that there is a great risk of proliferation because we delay the breeder and because we delay reprocessing for light water reactors.

Whereas, in the other direction the influence is pretty clear. We will continue to do R. & D. on reprocessing because, of course, reprocessing is absolutely necessary for the breeder if the breeder is needed.

Mr. GOLDWATER. I would suggest the risk is that we no longer have influence over the size and shape and policies for the expansion of the breeder program. One of the great things about American technology and American programs is that—and I think you could relate this to the Clinch River program—is that we have been able to demonstrate and thus set a standard for the world in the area of safety and environment, economic issues, but now we are saying we are going to leave that up to the rest of the world to meet those kinds of standards, which I am not sure are as high or as tough as ours would be.

Mr. KEENY. I think those are good points about the history of our program. I think, that if various countries attempt to move ahead with the breeder and it proves really noneconomic, it is not clear that they are going to find any market in the rest of the world and particularly in the underdeveloped countries, compared with light water reactors, which we believe, will not only be competitive but will actually be economically favorable during this century.

It is not obvious that the breeder program for plutonium reprocessing holds much interest or promise for underdeveloped countries or developing countries. And in particular this is not the case if it proves to be more expensive and has a very heavy additional capital cost.

Mr. MYERS. Will the gentleman yield?

Mr. GOLDWATER. Certainly.

Mr. MYERS. I tend to agree that that probably is the case, but can it not also be said that if in fact the United States has a breeder program which is workable within their own economy that that would in fact free up the potential for more light water reactors being placed in the regions of underdeveloped countries. I don't think we have to argue the point whether or not the breeder will be placed in those countries, but I think the decision we make with respect to the breeder will certainly impact the availability of light water reactors over a long period of time in those areas. I think that is part of the balancing of decisionmaking that should be made.

I do not think we can argue that the developing countries won't want to build a breeder reactor but they may in fact want a light water reactor that won't be available because the fuel supply won't be available because we have not essentially guaranteed that we are going to extract fuels from the international sources.

Mr. KEENY. As you know, it is our conclusion that fuel will be available for a time period which will give plenty of opportunity to decide whether fuel will in any way be a future limitation on light water reactors. I think it is very unlikely that any limitation on fuel is going to be a limiting factor on the rate at which undeveloped countries can procure nuclear reactors of any type.

Mr. GOLDWATER. In your report did you take into consideration the limitation by reducing or eliminating the Clinch River program and thus the demonstration, the effects on the limitation of future choices on nuclear power?

Mr. GARWIN. Our whole intention was to expand the range of future choices in the breeder program and in nuclear power in general. And we do that by using limited funds on a broader and deeper basis, broader in looking at other kinds of reactors, ones which may not have such high breeding gain, bring back and put more emphasis on the thorium breeder, deeper, to look at the fuel cycle in advance, so we can be sure of having a more economical fuel reprocessing system when the time comes.

Mr. GOLDWATER. So in essence we would reduce ourselves to paper studies or laboratory scale?

Mr. GARWIN. No. We have a very major program with the fast flux test reactor facility and the separate function test and development programs where we can test pumps and molten sodium and things like that. We want more individual demonstrations and definitions of interface, so that these things can be put together in a major program.

Mr. MCCORMACK. Will the gentleman yield?

Mr. GOLDWATER. Yes.

Mr. MCCORMACK. Mr. Keeny, I was busy writing, but something in the side of my ear seemed to hear you say that you didn't think the availability of ordinary light water reactors to foreign nations was a function of the availability of uranium fuel. Is that what you said?

Mr. KEENY. What I actually said was I did not think the availability of uranium was going to be a limiting factor on the extent to which developing countries were going to be able to buy nuclear reactors. What I was getting at was that undeveloped countries or developing countries are going to have a major problem in purchasing these facilities.

Mr. MCCORMACK. What you are saying is that there would be other limiting factors that would be more restrictive than the availability of fuel?

Mr. KEENY. I think that is correct. I was focusing on the undeveloped countries in this century. It is true that a number of them are interested and a number of them will get these facilities but nuclear power with some exceptions is not the solution to the energy problems of most of the developing countries.

Mr. McCormack. As long as you put that response in context, I don't think I would care to argue with you. But obviously there are some nations that are so poor and the population is so small and they are so undeveloped that they could not use any large central power stations at this time. And for those nations any central power station would not have much applicability. I think we could agree with that.

Mr. Keeny. Particularly nuclear, because to be economical you need large plants.

Mr. McCormack. This makes a series of assumptions that I do not accept. I would not like to acquiesce in that perspective, because you obviously have not explored the potential for solving the problems you are talking about. You have only talked about the problems and why we can't solve them. I will get to that on my own time later on. But I think we just ought not to extrapolate by inference from the fact that some small nations are too small and have too little population to need any central power station to the inference that nations that do have central power systems and would use nuclear powerplants, if there were fuel available, would not have them.

Or let us say, they would not be limited because of unavailability of fuel. I think there is a consensus around the western world and among most professionals in this country that the restriction on nuclear power programs throughout the world is going to be the availability of fuel.

This is obviously why every major industrialized nation in the world is going for a breeder program. If they did not believe that, they would not be going for a breeder program. The proof of this is evident and I would not like to have the obvious fact that some nations are so small that they can't use any central power station extrapolated to the assumption that other nations could have plants, even when there is no fuel available.

Mr. Keeny. On a broader basis, as we have discussed in some detail earlier in this hearing, we do believe that there will be adequate uranium resources on a worldwide basis for the growth in nuclear power.

Mr. McCormack. On my own time I will discuss that with you.

Mr. Goldwater. The time of the gentleman has expired.

[Laughter.]

Mrs. Lloyd. Mr. Goldwater.

Mr. McCormack. I yield back the balance of my time to Mr. Goldwater.

[Laughter.]

Mr. Goldwater. Madam Chairperson, I would like to get into an area that I do not think we have talked about too much and that is the impact upon our industry, the industrial base, as well as the economics that you gentlemen have been talking about and which seems to be the basis for some of your analyses. Now the Clinch River Breeder program represents to my knowledge one of the largest utility sharing contribution programs that our Government has ever been involved in. It is my understanding that the utilities have committed over $250 million so far.

Now all of a sudden we terminate this program. What does this do to the cooperative spirit of utilities which tend to be pinched somewhat anyway for resources, their confidence in our Government? Here they have been pulled into these programs with assurance of a new energy supply that they are going to be a part of the evaluation on. In fact that was one of the reasons for including them, so that we could get real time evaluation.

What is that going to do for future cooperation, future involvement, and future enthusiasm of the utilities? Is that something you have looked at?

Mr. GARWIN. That is like any other money——

Mrs. LLOYD. Might we add one other thing—the brainpower.

Mr. GOLDWATER. I want to get to that. That is the next line.

Mr. GARWIN. Those are funds like any other funds and if the U.S. Government makes the decision that it is not in the national interest to have available a higher cost source of electrical energy—and that is all it is—electrical energy—the utilities like everybody else ought to applaud that decision. Utilities in more detail will include that in their financial statements. If they are assured of return on investment, that will be taken into account. It is always difficult for somebody to be in a program which does not pan out for one reason or another and this is just the instance at hand. There are many other things, water projects, people who have bought land nearby, people who have built housing districts near refinery sites which can no longer be built, many many hundreds of examples. This is only one of them.

Mr. GOLDWATER. We have committed over $2.7 billion into the breeder program so far and utilities have been a part of that program and increasingly so, to prove out the technology transfer, to bring into the decisionmaking process the real world. And you are willing, in essence, to push that aside, to disregard the importance of that kind of commitment and that involvement all without any regard at all for the consequences?

Mr. GARWIN. No; I think, Mr. Goldwater, that we have regarded all of the costs thus far as sunk. We have never asked how much will a breeder reactor cost, including research and development. We have asked, What will be the capital cost for these things after they have been developed and replicated and would anybody buy them. If the decision is that they will not be bought, then we think that that breeder reactor should not be built in a demonstration phase, as the CRBR is planned to be.

Mr. GOLDWATER. What does it do if we cut back on this program, what does this do to our industrial base? And the chairman has referred to brainpower, technical competence, and capability. It is my understanding that the Clinch River program alone, if you cut back, you are talking about $192 million in annual wages that are lost and a termination cost of $0.5 billion.

Money aside, how is this going to impact and did you consider this in your report? How will it impact upon our industrial capability in this area?

Mr. GARWIN. This is a detail to which one cannot descend in looking at the overall program. One cannot have it both ways. Either those termination costs of $0.5 billion are going to be paid and people are going to get that money, in which case we will not have a near-term employment problem, or if one looks carefully at the near-term costs, one will find that they don't have to be paid. And those people, like any others, will have to be looking for productive employment. And society will try to employ them.

We hope some of them will be employed on a more variegated breeder program. Some of them will be employed in improved light-water reactor safety. Some of them will be employed in improved coal or analysis or transportation systems.

Mr. GOLDWATER. You see no diminution in our technical base or capability by cutting back on this program?

Mr. GARWIN. No, Mr. Goldwater, I don't.

Mr. GOLDWATER. We have four major vendors in the area of nuclear energy and many, many subs that are involved and if we depend solely upon the light-water program, did you consider what impact this would have on our four major vendors as well as the subvendors involved in these programs?

Mr. GARWIN. I think a larger impact is probably from the reduction in demand more than a factor of 3 below demand projections for light-water reactors common a few years ago. And nobody is arguing that we should build that many reactors which would not be bought. This is a small effect compared with the reduction in demand for electricity.

Mr. GOLDWATER. Do you feel that this is going to force a reevaluation of corporate and utility commitments to nuclear power with the possibilities of potentially diversifying into lower risk markets or lower risk sources?

Mr. GARWIN. Well, we hope not. We believe that each utility makes the decision plant-by-plant between light-water reactors and coal now. It does that on the basis of all information available to it. I don't think it makes a nuclear commitment so that it is committed to buy breeders plus light-water reactors in a certain number of thousand megawatt lumps. It looks at them individually according to the demand and financing available, the relative cost, the transportation, and the environmental requirements.

I do not think anything we say here should lead a utility to defer nuclear in favor of coal or anything like that. In fact, we are quite favorable to nuclear power in that regard. We say it is acceptable from the point of view of safety. In many places it is cheaper than coal and I would think this would be encouraging both to the utilities and the vendors.

Mr. GOLDWATER. One of the weaknesses I see in your report is your failure to honestly and openly project demand, thus being able to bounce off your assumptions as to what the supply is going to actually be and where we are going to get that supply.

Now I understand we go to this London Supplier's Conference every once in a while to hash out the mutual problems and make determinations on supply of fuel and other important questions, and we play a very important part of that conference as we do in the rest of the world and yet you seem to wash aside the loss of industrial capability or the possible loss—we don't really know exactly what that may be—with the major change in direction of our program. You seem to minimize the uncertainty by the industry that is involved with the potential loss of leverage at these kinds of conferences, because of lack of industrial capability, lack of technical expertise and leadership.

I see a weakness in that. You seem to telescopically look at just one particular program without looking at the broad scale. How does it impact upon our utilities and their future involvement with our Government in bringing on line these very sophisticated, very complicated and expensive programs? We are not in the process of declining or reducing our industrial capability in energy. We are trying to expand it, and yet it appears to me from what you just got through saying that there is no problem with reducing our technical capability or our industrial potential in this area. I am just saying that if you have that sort of flippant attitude about it that the potential is that we are going to lose our leverage at the London supplier's conference and other meetings we have around the world. And I think we have to be concerned about that.

Mr. KEENY. As far as the markets are concerned for those countries, the light water reactor——

Mrs. LLOYD. Excuse me. Because of the call of the House we will be in recess for about 10 minutes. Mr. McCormack will be back and since we do have to vacate this room by about 20 after, he will be back shortly to proceed with the questioning.

[Recess.]

Mr. McCORMACK. The meeting will resume. Congresswoman Lloyd asked me to pick up with the questioning at this point because we have the room only for a short time longer and we are having to run relays on the votes in the House.

Gentlemen, I appreciate the opportunity to talk with you this morning. I must say that I'm sure it is no secret that I am deeply disturbed with your report. I have a host of questions that I will not have an opportunity to get answered. I have not really organized them in any particular orderly fashion, but I would simply like to review with you some of the problems I see. I recognize that some of these questions have been asked previously in one way or another and I hope they will be asked again.

My first area of questions runs to the availability of uranium as a fuel. Over the years that I have worked in this field and the years that I served on the Joint Committee on Atomic Energy, we have had a number of discussions about the availability of uranium and there have been a number of studies made.

All of these studies disagree with your conclusions. They disagree dramatically with your conclusions. I would like to explore this with you just a little bit. The most recent studies by the Energy Research and Development Administration, The National Academy of Sciences and other organizations indicate that this Nation has reserves of about 800 million short tons of uranium, U^{308}—800,000—not short tons—that probable resources run to 1.8 million.

Included in those probable resources is a lot of low grade material which surrounds high grade material, which high grade material has already been mined. And the low grade material has been damaged so it is difficult to mine.

Now the National Academy of Sciences Study talks about a prudent planning basis for the availability of uranium and they use the 1.8 million short tons of U^{308}.

Now with 1.8 million short tons, or thereabouts, it would be possible ultimately to put 328 nuclear powerplants on the line sometime. You could not put them all on at once because it would take a number of years to mine all that material and get it out of the ground. This would be a total of 328 1000-megawatt plants at 70-percent load capacity and giving us every bit of the benefit of the doubt, with no recycling, 328 plants, domestic and foreign. Do you disagree with this number, gentlemen? There are two numbers. Let us go through them backwards. Do you disagree with the 328 plants from 1.8 million tons?

Mr. KEENY. I think that is probably roughly the correct number. Of course, that is 30 years operation.

Mr. McCORMACK. Right, that is the only way we can plan for a plant and that's the only way any utility can order a plant and that's the only way any utility commission will grant a license is if the uranium for the lifetime of the plant is visible someplace. I think you will agree to that.

Now the ERDA and the National Academy of Sciences predicts a probable resources available of 1.8 million tons.

Mr. KEENY. I am not familiar with the National Academy of Sciences study.

Mr. GARWIN. Which one is that?

Mr. McCORMACK. It is the one available now.

Mr. GARWIN. It is not available to us and we could not comment on it. When that report is published, we will read it with great interest.

Mr. McCORMACK. The report is undergoing peer review now. It is, shall we say, well circulated at the present time.

Mr. PANOFSKY. I am a member of the Academy and I discussed this situation. This particular report, I believe, the one you are referring to, is being written by a subpanel of the current CONAES study which is a broad energy study of the Academy which hopefully will be available sometime in midyear. My understanding is that this study is yet to undergo several major reviews. I don't have it, obviously, nor does anybody else. But the leadership of the academy is quite concerned about the fact that other reviews are indeed in the works.

Mr. McCORMACK. If you don't wish to refer to the Academy study or the figures they work with, let me then just go to the report of June 15, 1976, put out by the Council on Environmental Quality, Department of Commerce, Department of Interior, U.S. Geological Survey, the Energy Research and Development Administration, et cetera, which calls for 1.84 million probable resources of uranium. It is a prudent resource and planning base by definition from all of these sources in a published Federal report.

Mr. GARWIN. In our book on page 76 we have U.S. uranium resources in thousands of tons. These are not our data. It is the same statistical data from ERDA. If one adds up, at $30 per pound cutoff, one adds the reserves of 640,000 to the probable of 1,060, one gets 1.7 million tons which is close to the number you are quoting. Plus the byproduct would be another 100. But the question is whether this is the prudent planning number and whether it is right, even if it is prudent and whether $30 per pound should be the cutoff. Because $20 per pound additional uranium cost is only 2 mills per kilowatt hour under your assumptions on the reactors.

Mr. McCormack. Let me ask you about that $20 extra. I assume you are speaking of another increment of uranium.

Mr. Garwin. We have gone into this in great detail. We don't know where that uranium is or whether it is there, because it is not included in the base which is accumulated by the Government, a base provided from information obtained from private industry which was looking for low cost $8 per pound uranium.

In some cases, as Dr. Landsberg pointed out, quoting from industry some 2 years ago, they know they have deposits but they have not drilled them up enough to put them into any of these categories. So there is a lot of uranium whose location is known but it has not been sufficiently well explored to quantify it. We are very emphatically associated with expanding and strengthening the national uranium resource evaluation program so that we will know in relatively few years how much uranium there is and at what forward cost.

Mr. McCormack. I agree. As a matter of fact, I was one of the sponsors who created the program. Now, let's talk about it for a second. How much do you think that program is going to go about 1.84 in our projections?

Let me say that in all charity I think your report—one of the unfortunate aspects of it is that it has been made by too many economic considerations inside instead of a closed room. One of the things we recognized early on was that price was not going to control the availability of uranium. If one assumes it can be controlled exclusively by price, I think it is a naive approach. Quite obviously it is physically possible to take uranium from Tennessee shale or strip the granite from New England, or maybe even go out to Greenland and take the granite out there.

But did you consider at all the environmental reaction in this country to mining these ultralow quantity materials, quite aside from the physical price?

Mr. Garwin. No; we never had to go so far in uranium grade.

Mr. Keeny. I think the central point we tried to make in the report was that—and we don't differ with the numbers you have quoted. These are in fact the numbers that have been used. But these numbers were developed in an environment when uranium was bringing a very small price. There was very little incentive for industry at that time.

Mr. McCormack. It was not the perspective at that time. That is our perspective in retrospect. At that time $30 or $50 looked extremely attractive, when those original studies were made.

Mr. Keeny. There was very little economic incentive for people to look for $30, $50, or $70 uranium if they could not even get $8 per pound. There was no market. The uranium industry was a depressed industry for most of its history. We barred foreign imports.

Our general conclusion is we don't know how much uranium there is. It is possible there may prove to be a very sharp cutoff. It would surprise us very much, by analogy with any other resource.

Mr. McCormack. If I may paraphrase what you are saying, you are saying you don't know how much uranium there is, but you will ignore the report of the Federal Government and use some other planning base which is much higher?

Mr. Keeny. Our report has no estimates. We report the estimate you indicated there. We report some higher ERDA projections. We make no projection of our own. We simply suggest that it seems very probable that as the price of uranium rises in an expanding market we will see a very different uranium picture and it is our belief that we will probably find much larger reserves and resources developing over the next decade or so as the whole market for uranium changes.

And it is part of this, but given the fact that even now there is not as much private incentive as one might like, we are strongly suggesting that the NURE program be accelerated to give a better map of the possible future of uranium.

But from this we go on to say that given the present apparent rate of growth of the nuclear electric industry, both here and abroad, there is enough uranium even with what we believe are conservative projections to cover those requirements and to give us time to come up with a more sophisticated view of what uranium requirements may really be in the longer term future when much higher cost material will be acceptable.

Mr. McCormack. What you have said is essentially you believe that somehow there must be more uranium out there.

Mr. Panofsky. We are not saying that there is more out there. We are saying that the resource assessment is in relatively bad shape and we talked about risks in going into some of the programs of reprocessing and the breeder there is time to improve the assessment. We are willing to accept the fact that if the assessment shows there is no more out there then in that case indeed one should tremendously accelerate the breeder. But there is decision time available, considering the revised demand figures a more deliberate job can be done.

We have been impressed by the ignorance on uranium resources, as you have also, and we see no reason why an uncritical acceptance of any data base is satisfactory.

Mr. McCormack. You are saying you are not sure of the data base and, therefore, we should abandon one of our major research programs to give us an option?

Mr. Panofsky. No, we are not saying that breeder research should be stopped.

Mr. McCormack. You are saying we should stop the LMFBR and Clinch River.

Mr. Panofsky. One thing I would like to clarify, Mr. Chairman, is that we have not redefined the LMFBR program specifically according to our recommendations. We do not even know whether it would be smaller or larger than the present one. We are not saying that LMFBR work should be stopped.

We do believe that its concurrency as a technical program is not warranted, considering the time scale in which it could be economically attractive.

Mr. McCormack. Let us analyze that for a second. The 1.8 million probable resources gives us a total of 328 nuclear plants with no recycling. Now at the present time we estimate we could have about 140 plants on the line by 1985 and 240 by the year 1990. So far, unfortunately, we have lost 100 plants up to 1985—I am sorry—I have been advised that we are virtually out of time.

Mr. Goldwater, would you proceed with your line of questioning and I will have to submit mine in writing.

Mr. Goldwater. I am awfully amazed at the enthusiasm with which our chairman becomes involved in this subject and certainly he should because of his background and knowledge. I think we are fortunate to have that kind of expertise to bring these real questions out on the table to be discussed. I think it has been very beneficial.

I just wanted to follow up with the thought that I left when the bell rang. We were discussing the impact upon industry and upon utilities, the impact upon our industrial and technical base and manpower capabilities. I guess after the discussion the thing that it is difficult for me to understand about your report is how you could have dismissed the impact on our utilities, our industries, our technical base, the economic considerations and impact on the economics, the banking community and what have you, business, all of these recommendations, predicated upon reliance on a light water reactor program, greatly expanded, on the assumption of available uranium supply, which according to all this discussion is uncertain. That is the thing I cannot really comprehend, how you arrive at your conclusions without making those kinds of considerations.

Mr. KEENY. Our view about the utilities was that their decisions will be made on economic grounds and if, as we think they will be, light water reactors are competitive, and in many areas preferable, utilities will in fact buy them and we hope some of our comments might create some confidence in their acceptability.

As far as the manufacturers are concerned, they will be manufacturing an article that is for sale and that presumably someone wants. If light water reactors are bought and wanted, that deals with the vendor's problem. I think we would admit there is a problem with the momentum in a research program and this is a serious problem. It troubles us and Dr. Panofsky may want to comment more on that. But from the long-term view of technical competence, we emphasize that we want to keep the breeder program going and have good people working in it on a variety of possible paths to future application.

We do not make the argument—and I think it is a debating point—but you could say if all of your capability is tied up in one program that may prove noncompetitive, you may find you are in a poorer position in the long-term than if you have good people working on a variety of longer-term programs. That may be more effective in the long run. But whether that is true or not, I would see a lot of people involved in working on breeders in a continuing program.

So I am not sure that——

Mr. GOLDWATER. The point is in your report you did not consider those factors before making your recommendation that we should eliminate the Clinch River program and greatly reduce, or as you say, expand the breeder program. There is a great commitment, over $2.7 billion so far and 250 million by utilities.

There is, as you say, a great momentum going forward which you are recommending that we greatly reduce. Now that is going to impact across the spectrum. And the thing that I could not understand is how you could arrive at your recommendation without making note of the impact. It is all based and predicated on what, an uncertain supply of uranium.

Mr. MCCORMACK. You have about 30 seconds for response. Gentlemen, go ahead.

Mr. PANOFSKY. Admittedly, a weakness of this report is the fact that we analyzed the economics of the breeder program but we did not redesign the breeder program. We cannot even tell you whether the breeder program which would fit our recommendations best would be smaller or larger than the present one. But you must recognize that we do believe that the FFTF should continue. It should produce data to feed the program. We do recognize the fact that the facilities' investment was $250 million. But as the rest of the program increased, the rest of the commitment to Clinch River had to all come from the Federal Government rather than the utilities, because already at that time the utilities found it difficult to increase their commitment. But it is true we have not redesigned the program which we feel fits the present resource and economic situations. But—it is our conviction that we would be doing a service by having recommended that the program be reoriented not to lead toward just one technology at an early date, because we believe that at that date utilities will not buy the product. Therefore, the Federal Government's commitment will, in fact, be considerably larger than the $12 billion total because of the fact that at that time the private sector will not be in a position to pick it up.

Mr. McCormack. Dr. Panofsky, I thank you.

I want to say that there will be many written questions submitted to you. I trust you gentlemen are prepared to try to answer them. Is that acceptable that you respond to written questions?

Mr. Panofsky. Sure.

Mr. Garwin. To some extent, those that we can answer from the report. But we do not still exist as a group.

Mr. Keeny. We do have somewhat of a problem. We will be helpful in any way we can, but our study group was a 1-year study and it is now terminated. So we do have a problem getting off into new problem areas.

All of the individuals here I am sure are available to Congress to help in any way they can.

Mr. McCormack. Are there individuals responsible for various sections or chapters?

Mr. Keeny. The whole group was responsible for the entire report. Obviously, various individuals worked more on certain parts.

Mr. McCormack. Was there a peer review of this report before it was published?

Mr. Keeny. No.

Mr. McCormack. It was not sent out for critique?

Mr. Keeny. This group—and I should emphasize that these findings are not the positions of the Ford Foundation nor the Mitre Corp.—is an independent group. When it was set up, it was agreed—that it would be the sole judge of its report and its product.

Mr. McCormack. Gentlemen, I thank you, and I cannot resist saying that I not only appreciate what the report did about recognizing the validity and the safety aspects of the nuclear program, but obviously I am appalled at the conclusions about reprocessing, about the availability of uranium, about whether or not foreign nations will follow our lead. I can assure you from my conversations with them that they are equally involved and will not follow our lead.

I want to put this on the record and I am sorry there is not time for you to respond to this. But thank you very much for coming.

[Whereupon, at 1:25 p.m., the report was concluded.]

REPORT OF THE NUCLEAR ENERGY POLICY STUDY GROUP

NUCLEAR POWER ISSUES AND CHOICES

Foreword by McGeorge Bundy

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Overview

The debate over the future of nuclear power has become increasingly dominated by dedicated advocates and opponents of this source of energy. While polemics may focus attention on the problem, they do not provide a sound basis for public understanding of the issues or for national decision-making. In this study we have tried to take a fresh and independent look at the role that nuclear power should play in the United States and the rest of the world in this century. We have sought to develop a framework for assessing the difficult problems relating to nuclear power now before the U.S. government. Imminent decisions with far-reaching domestic and international consequences must be made on the following issues: (1) the reprocessing and recycle of plutonium, (2) the breeder reactor program, (3) the management of nuclear wastes, (4) the expansion of uranium enrichment capacity, and (5) the export of nuclear technology and materials.

In assessing the role of nuclear power, we have examined a broad range of difficult and controversial questions, including:

- How important is nuclear power to the economic growth and prosperity of the United States, of our major allies and other advanced countries, and of developing countries?
- How do the economics of nuclear power compare with those of coal and other alternatives?
- What are the extent and distribution of the world's uranium resources, and how do they affect the future of nuclear power?
- What are the economic prospects and developmental time scales of energy sources such as solar and fusion energy that may be alternatives to nuclear and fossil energy?

- What are the effects of nuclear power on the environment and human health as compared with those of coal and other alternatives?
- How safe is nuclear power, and how does the possibility of accidents affect the comparisons between coal and nuclear power?
- Can nuclear wastes be disposed of in an acceptable manner?
- How serious are the possibilities of sabotage to nuclear facilities, or of the diversion of materials to make nuclear weapons?
- What is the relationship between the worldwide growth of nuclear power and the proliferation of nuclear weapons, and how can the decisions of the United States affect the likelihood of proliferation?

While such questions are now being debated most actively in the United States, they are relevant to the rest of the world as well. Even in this country these questions have until recently been largely ignored by the public and, to a disturbing extent, have been treated complacently by the government itself. For more than twenty years, it has been the clear and almost unchallenged policy of the government to promote the development of peaceful nuclear energy at home and abroad.

The intense debate of recent years between those who emphasize the promise of nuclear energy and those who fear its consequences has identified but generally failed to clarify the underlying issues. Many critics attack nuclear power as an unacceptably dangerous source of energy that is being forced on the public despite unfavorable economic prospects. They question its economic benefits by pointing to escalating costs of nuclear construction and fuel, poor reactor performance, and hidden subsidies. They emphasize the gravity of the health hazard inherent in the nuclear fuel cycle, pointing to the possibility of catastrophic accidents and to a persistent threat from nuclear wastes, which may endanger civilizations thousands of years in the future. Finally, they assert that nuclear power will lead inevitably to the proliferation of nuclear weapons throughout the world and that every reactor and fuel cycle facility is a potential target for terrorists interested in sabotage or materials for bombs. Some critics conclude that the only solution to these dangers is a moratorium on further construction of nuclear plants.

Its proponents advocate nuclear power as a safe, clean source of energy that is indispensable to the future U.S. and world economies. They assert that it can generate base-load electricity at significantly lower cost than any fossil fuel alternative and that without it the rising demand for electricity cannot be met. They argue that it is demonstrably less dangerous to the environment and to human health than fossil fuel alternatives. They point to the excellent safety record of reactors and calculate that, while an accident could be serious, the probability of its occurrence is vanishingly small. Nuclear wastes, they assert, can be handled in ways that essentially eliminate the possibility of future accidents. They emphasize that nuclear power is an essential component of energy independence. Finally, they maintain that the hazard of nuclear weapons proliferation exists independently of American nuclear power and warn that restrictions on programs or exports would simply turn potential markets over to foreign competitors and reduce U.S. influence over nuclear power developments abroad. Some advocates conclude that future energy demands can only be met by a massive government-supported program to accelerate nuclear power, including early introduction of plutonium reprocessing and recycle and the plutonium breeder.

The "energy crisis" arising from the oil embargo of 1973 and the subsequent large increase in OPEC oil prices introduced a new and confusing element into the debate. Although these events did call attention to the limits of oil resources, they did not themselves define—much less determine—the much larger and more complex issues of long-range energy policy.

In our study, we have found merit in many of the points raised by both the advocates and the critics of nuclear power, but we have not been persuaded by their conclusions as to the future role of nuclear power. We have also been concerned about broader economic and security issues raised by the current "energy crisis," but we believe that great care must be taken to relate these issues properly to the question of nuclear power.

To put nuclear power in some perspective, it must be recognized that the world is not running out of energy. Although the relative contribution that oil and gas make to the world's energy supplies will diminish before the end of the century, substantial amounts of these fossil fuels remain. Coal resources are vast, and uranium resources are probably much larger than currently estimated. Further in the future, solar energy, probably fusion energy, and possibly geothermal energy can provide essentially unlimited sources of power. If these options are successfully pursued, the world can have plenty of energy in the future, although probably at costs significantly higher than those of 1976. Thus, the long-range energy problem is one of higher costs rather than one of absolute limitations on energy availability.

Over a reasonable period of time, the impact of increased energy costs on the world's economy in general, and the U.S. economy in particular, will not be as great as is often assumed. Sudden sharp increases in the price of energy can cause serious temporary hardships and dislocations, as was demonstrated by the post-1973 quadrupling of oil prices. Permanently higher real energy costs will reduce the economic resources available for other needs—an effect of particular importance in developing countries. The cost of energy, however, is a small enough factor in the overall economy that long-term cost increases of the magnitude we foresee will not cause major changes in the economic or social future. Economic growth can be sustained even with large increases in the price of energy. In any case, higher future energy costs, which are probably inevitable, are largely independent of the rate at which nuclear power is developed and deployed over the next twenty-five years.

Our analysis indicates that nuclear power has and will probably continue to

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have a small economic advantage on the average over coal, the closest alternative for the generation of electricity in the United States. Regional and other variations in the cost of electricity from nuclear power and coal, however, are sufficiently large that coal is and will continue to be a competitive source of energy in many areas. Moreover, the ranges of possible social costs, such as health and environmental impacts, associated with coal and nuclear power also overlap to such an extent that neither has a clear advantage. We find such large uncertainties and unknowns in both the economic and social costs that the average comparative advantage could shift either way in the future.

In these circumstances, we believe that there is time for a broad and sustained approach to energy problems. While nuclear power is one of the options that should be pursued, it is not as critical to future economic development as its advocates claim. There is time therefore to assess carefully the potential risks as well as the benefits of nuclear power and to avoid hasty and uncritical decisions.

At present, the range of uncertainties in the comparative costs of coal and nuclear power is such that a mix provides a useful hedge against uncertainties. Since there is considerable overlap in the present costs of coal and nuclear power, economic forces may be expected to produce such a mix of coal and nuclear plants. For the longer term, a balanced research and development program should develop additional options based on improved use of coal and nuclear power as well as solar, geothermal, and fusion energy. These energy sources should play a role in the future when and where they can compete economically.

In general, this analysis also applies to the role of nuclear power in other advanced nations. However, countries that lack domestic supplies of coal, as well as oil and gas, face a more difficult problem than the United States in obtaining assured, diversified energy sources and in dealing with balance of payments problems. While complete dependence on nuclear power is not a solution for such countries, they may have, or may think they have, a special interest in nuclear power.

Nuclear power, with its large, complex, capital-intensive plants poses special problems for developing economies. The higher capital costs per unit of generating capacity of small nuclear plants, suitable for small power grids and limited demands, would tend to eliminate the economic advantage of nuclear power even against imported fossil fuels. Nevertheless, some fifteen to twenty developing countries may find economic justification for nuclear power in this century.

By far the most serious danger associated with nuclear power is that it provides additional countries a path for access to equipment, materials, and technology necessary for the manufacture of nuclear weapons. We believe the consequences of the proliferation of nuclear weapons are so serious compared to the limited economic benefits of nuclear energy that we would be prepared to recommend stopping nuclear power in the United States if we thought this would prevent further proliferation. However, there are direct routes to nuclear weapons in the absence of nuclear power, and the future of nuclear power is not under the unilateral control of the United States. Most advanced countries are now actively developing and utilizing nuclear power, while less developed countries count it among their expectations. In fact, abandonment of nuclear power by the United States could increase the likelihood of proliferation, since the United States would lose influence over the nature of nuclear power development abroad. With continued nuclear power development, however, the U.S. government must give greater weight to the proliferation problem in its decisions on nuclear matters and its relations with other nations.

Nuclear energy is now a fact of international life and will provide a significant portion of the world's electricity by the end of the century. At the same time, nuclear power is only one of several energy options, and decisions about it should be made on the basis of sound national and international economic considerations, realistic accounting of social costs, and a paramount concern to avoid further proliferation of nuclear weapons.

THE CURRENT STATUS OF NUCLEAR POWER

Nuclear power is a present reality, not a future prospect. In mid-1976, nuclear power plants in the United States accounted for about 40,000 megawatts of electric capacity (MWe), or about 8 percent of total national capacity. Abroad, nuclear power totaled about 35,000 MWe. In the United States, some 170,000 MWe of additional nuclear capacity are under construction or on order and scheduled to begin operation by the mid-1980s; abroad, construction and orders are reported to amount to about 130,000 MWe. While there has been a substantial cutback in plans for both U.S. and foreign nuclear power plants in the past two years, this reduction appears to be primarily the result of economic recession and reduced projections of electricity demand rather than a rejection of nuclear power.

Projections of U.S. nuclear power capacity for the year 2000 vary greatly, and have been sharply reduced recently. In 1975 the Energy Research and Development Administration (ERDA) estimated that nuclear power capacity could be as high as 1,250,000 MWe by the year 2000. These estimates were revised downward by ERDA in July 1976, to range from 450,000 to 800,000 MWe, and in September 1976, were further reduced to range from 380,000 to 620,000 MWe.

Measured against the total use of energy, the present contribution of nuclear power is still small, amounting to about 2 percent in the United States. For the foreseeable future, nuclear power will only be used for generation of electric power, which currently consumes some 28 percent of the primary energy used in this country. In contrast, fossil fuels can be used not only for electric power but also for transportation, industry, residential heating, and petrochemicals. It is generally expected, however, that the use of electric power will grow more rapidly than overall energy consumption. Moreover, in producing electricity, nuclear power releases some oil for other purposes. In the future, it could also release coal for other uses such as the production of synthetic oil and gas if there are constraints on the utilization of coal.

Nuclear power has become international. Thirty countries, in addition to the five nuclear weapon states, have nuclear power plants in operation, under construction, or on order. There is now highly competitive international commerce in reactors, uranium (natural and enriched), and supporting equipment. The principal suppliers in addition to the United States are West Germany, France, the United Kingdom, Canada, Japan, South Africa, and the Soviet Union.

The principal motive for this interest in nuclear power is the desire for a cheaper source of energy. Although the original promise of abundant nuclear electric power at a fraction of the cost of other sources has faded, the more modest belief persists that economic benefits will accrue over the lifetime of current plants. Buying into nuclear technology is widely believed necessary to share in future economic payoff. This economic rationale, which is central to the nuclear power debate, is examined in detail in the following section.

Considerations other than economic have also undoubtedly influenced some nations' interest in nuclear power. One of these is the desire to develop a diversified energy base to increase the security of supply. While a reliable energy supply is an objective to which most nations must give attention, only a few countries have the resources for total independence or self-sufficiency. Since much of the present world economy relies on oil and gas and since nuclear power cannot directly substitute for oil in such areas as transportation and petrochemicals, an assured supply of nuclear power would not eliminate the need for other fuels. Substitution of electricity for other energy uses would be a lengthy and gradual process involving major changes in capital equipment. In the next few decades, nuclear power can do little to reduce the impacts of sudden changes in energy supplies such as oil. Principal reliance during this period must be placed on stockpiles, resource sharing, and other measures. However, concern about the long-term security of energy supplies, particularly of oil, will probably lead to a preference for nuclear power, particularly in Japan and Western Europe.

In the longer term, nuclear power may present advantages in guarding against interruption in supply since uranium stockpiles are more manageable and less costly than comparable stockpiles of oil or coal. Some countries may see breeder reactors as providing greater independence from external fuel supplies for electricity. Countries seeking independence through the breeder, however, would have to be able to reprocess plutonium and fabricate new fuel within their own borders, and, aside from Japan and Western Europe, would still be dependent on a few outside suppliers for reactors and critical equipment. The level of economic and political cost individual nations may be prepared to bear in pursuit of energy independence is a hard choice each will have to make for itself.

Another motive for acquiring nuclear power is prestige. The status accorded nuclear power as a high technology industry was initially stimulated in large part by U.S. promotion of the Atoms for Peace program, beginning in 1955. Today, even in less developed nations for whom the investment may be disproportionately large and the benefits questionable, nuclear power may be politically attractive for its perceived glamour.

A final motive for the development of nuclear power is to acquire a technical base for a nuclear weapons option. Even if a country has no present plans to manufacture weapons, it may want to be in a better position to acquire a nuclear weapons capability in response to a future threat. That a shortened lead time toward a potential nuclear weapons capability may be a motive for acquiring nuclear power indicates the close tie between energy policy and foreign policy.

ECONOMIC CONSIDERATIONS

The principal argument for nuclear power has been that it would produce cheaper electricity than alternative energy sources. The present worldwide level of investment in nuclear power may suggest that nuclear power has achieved a clear economic advantage. The charge is frequently made, however, that if costs were properly accounted for and subsidies stripped away, nuclear power would not be competitive. To clarify this fundamental issue, we have examined the economics of nuclear power as compared with coal, the closest competitor, and with other alternative energy sources. We have also considered the broader significance of the differences in cost between nuclear power and alternative sources to general economic growth and prosperity.

Comparison of Coal and Nuclear Power

Like so much else in the nuclear debate, the comparative economics of nuclear power and other energy sources for electric power has become shrouded in controversy. The comparative economics of coal and nuclear power is a genuinely complex problem about which there can be honest differences of opinion. Plants committed today will not begin operation until 1986 and are intended to have a useful life of thirty years. On such a time scale, the projection of lifetime costs is a very speculative business. Not only have construction costs of both coal and nuclear power plants escalated substantially in recent years but so too have the prices for uranium and coal. Moreover, stricter environmental controls on nuclear power and fossil fuels could have far-reaching economic effects. Finally, new scientific information on long-range environmental effects or events relating to safety or nuclear proliferation could lead to decisions that would have major economic effects. In such an uncertain environment, projections must be made with considerable caution.

Despite these large uncertainties, our analysis leads us to the conclusion that nuclear power will on the average probably be somewhat less costly than coal-generated power in the United States. However, coal will continue to be competi-

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tive or preferable in many regions since there are large regional cost differences and wide variations even within a region. The advantage for nuclear power is likely to be most significant in New England and in parts of the South. In large areas of the West, containing a small fraction of the country's population, coal-generated power is likely to be less costly than nuclear power. In much of the country, however, the choice is so close and the uncertainties sufficiently large that the balance could easily shift either to increase or to eliminate the small average advantage that nuclear power presently enjoys.

Conclusions on the comparative economics of coal and nuclear power depend on estimates of future capital charges, which include construction costs and interest, and the cost of uranium and coal. Each of these cost factors involves special problems that contribute to the uncertainty and possibility of different interpretations.

Capital Charges. The cost of electricity from nuclear plants is dominated by the capital charges for the plant.[a] At present, more than 70 percent of the cost of electricity from a light-water reactor (LWR) is attributable to capital charges. Over the past decade, construction costs of nuclear power plants have risen markedly faster than the rate of inflation. In addition, as a result of outages and reduced operation, the average capacity factor[b] for nuclear plants has been less than expected, particularly for the large new 1,000 MWe plants. Reductions in the capacity factor have the same effect on power cost as increases in capital charges.

Analysis of capital charges of nuclear power is complicated by the surprisingly wide range in the construction costs of plants of similar design, depending on the location, the builder, and the method of doing business. If one starts with high-cost examples and assumes that costs will continue to rise as they have in the past, it is indeed possible to conclude that nuclear power will become economically noncompetitive. Our analysis indicates, however, that construction costs (in constant dollars) will tend to level off in the future. Costs of labor and materials have escalated more rapidly than the general rate of inflation. The regulatory process has lengthened the construction period and necessitated numerous design changes and retrofits. The rate of escalation in costs should not continue to diverge from the regular rate of inflation, and the construction and licensing period (now typically ten years) should not continue to lengthen and may be shortened. With experience and standardization, design changes and retrofits should be brought under progressively better control. Finally, although aging factors not yet encountered might further reduce the capacity factor, it seems more likely that the somewhat disappointing operating experience to date

[a]Costs are for electricity at the point of generation; distribution costs add 50 to 200 percent to the price to the consumer.

[b]The "capacity factor" of a plant is the ratio of electric energy actually delivered during the year to that which would have been delivered if the plant operated 100 percent of the time at full capacity.

is part of the shakedown experience typical of a new technology and that capacity factors will improve in the future.

Capital charges are a smaller fraction of the total cost of electricity from coal than from nuclear power plants. Nevertheless, these charges still represent a substantial portion of the cost of coal-generated electricity (35 to 65 percent depending on location). Construction costs of coal plants have also increased in recent years for some of the same reasons as for nuclear plants. In addition, the use of new equipment (scrubbers) to reduce sulfur emissions may increase construction costs as much as 20 to 25 percent. In view of evolving pollution standards and technical responses, the uncertainties in construction costs of coal plants are probably as great as for nuclear plants. Nevertheless, with experience, the construction costs of coal plants should also level off and capacity factors should improve.

Uranium. At present, uranium accounts for only 5 to 10 percent of the cost of electricity at the power plant. The recent rapid rise in the price of uranium from around $6 per pound in the early 1970s to spot prices reportedly as high as $40 per pound has further clouded the economic picture. Although the increase from $8 to $40 per pound (if sustained) would only increase the cost of electricity by around 20 percent, such a rapid advance in prices raises basic questions about the future price and availability of uranium. If uranium is indeed in short supply and becomes very expensive, the current generation of light-water reactors (LWRs) will have difficulty competing with coal plants. This asserted future shortage of uranium is the principal argument advanced for early introduction of breeder reactors, which in theory might expand the power produced by a given supply of uranium by a factor of as much as 100.

Our review convinces us that current official estimates of uranium reserves and resources substantially underestimate the amounts of uranium that will be available at competitive costs. We believe that there will be enough uranium at costs of $40 (1976 dollars) per pound to fuel light-water reactors through this century and, at costs of $40 to $70 per pound, well into the next century.

While mineral reserves are commonly understood to be identified resources (i.e., known in location, quantity, characteristics, and economically recoverable with current technology), uranium reserves are specified over a range of estimated costs, which at the higher end will only become of commercial interest in the future. Indeed, early estimates of uranium reserves reflected industry judgment on how much uranium could be produced profitably at the government-set price of $8 per pound. Consequently, there was little commercial interest in more expensive uranium, and presently identified higher cost deposits represent principally the by-product of exploration for low-cost reserves. In the past two years, uranium prices have risen sharply in response to an anticipated expansion in demand, present low production levels and doubts about the pace of expansion, and the increase in oil prices. It is difficult to estimate the increased supplies that will become available at higher prices. This is not unusual, since mineral reserves estimates almost always lag when prices rise and markets expand.

It is not enough to wait for market forces to press firming up of potential resource estimates and the discovery of these "new" reserves, since more reliable estimates are needed for long-range decisions on future energy policy and technical programs. Although the National Uranium Resource Evaluation (NURE) program has been established for this purpose, we do not believe it will produce better estimates soon enough, since it is almost entirely dependent on private efforts to locate, define, and report reserves. This program should be reoriented with higher priority assigned to improving estimates of uranium reserves and resources.

Coal. In a coal-fired electric power plant, the cost of mining and transporting the coal accounts for 30 to 60 percent of the total cost of the electricity. This wide spread in fuel charges reflects differences in costs of transportation, of the sulfur content of coal, and of mining methods. The price of coal increased in response to OPEC's increase in the price of oil and is now about twice the preembargo level. The real cost of coal mining, however, has not increased very much in spite of increased labor and environmental charges.

Unlike uranium, U.S. coal reserves are definitely known to be very large. Reserves are estimated at more than 400 billion tons in place with 50 to 80 percent recoverable, compared with an annual production in 1975 of just over 600 million tons. Total coal resources are estimated at some 4 trillion tons, most of which would be available only at higher costs since it is contained in seams too thin or deep to qualify as reserves. In view of the enormous coal reserve, the real cost of mining coal should not increase substantially until well into the next century. Cost increases due to increased mining safety standards, environmental controls, or more difficult deposits should be at least partly offset by technological improvements in mining and transportation.

Recent official policy has projected a doubling of coal production by 1985. Although production has not expanded significantly in the past three years, we believe that it should be possible to achieve this production by the 1985-90 period and to double it again by the turn of the century if the demand appears. Doing so would require an increase in production of some 6 percent annually, a rate we judge achievable if basic problems are resolved. Large investments will be required to open new mines and to improve transportation. Public conflicts will have to be resolved on environmental and land use issues before adequate commitments will be made by private investors.

Three years after the Arab embargo, the coal industry is still not operating at full capacity; and, in the absence of new demand, coal prices have fallen from their peak. Nevertheless, the prospects for coal should not be underestimated since coal will be generally competitive with nuclear power for a long time to come and will in all probability become the material from which synthetic gas and oil will be manufactured. A larger role for coal exports in the international energy trade is also foreseeable and desirable. In these circumstances, the priority and expectations for coal should not be less than for nuclear energy. Both government and the private sector should demonstrate this priority by increased efforts to develop more efficient mining technology, improved transportation systems, better control of sulfur oxides and other emissions, radically improved long-distance electrical transmission, and development of more efficient, lower cost synthetic gas and oil conversion. Equally important is a climate of confidence with regard to land use regulation, public energy policy, and federal-state regulatory relations.

Comparative Economics in Other Countries

The foregoing comparison of coal and nuclear electric power is based on expectations in the United States. Most other countries have fewer resources and less access to technology and investment capital. Nevertheless, the arguments concerning the comparative costs are similar in all countries, as long as fossil fuels and uranium can be relied on as items of international commerce.

Considerable emphasis on nuclear power has developed in Western Europe and Japan. These countries have experienced a gradual reduction of coal reserves and persistent difficulties with their coal industries. As a result, following World War II they turned to low-cost Middle East oil, which, together with natural gas, became their principal energy source. These countries are now planning extensive nuclear power programs to reduce their reliance on oil, which is no longer cheap and constitutes a far larger share of imports for them than for the United States. For most of them, a shift to heavy reliance on coal would require increasing dependence on imports from the United States and Eastern Europe. The political acceptability of such dependence is not clear. There is also a question as to how large a foreign market this country could supply and still meet its own growing domestic demand. For these reasons, a greater preference for nuclear power should be expected in these countries than in the United States. While official pronouncements affirm this preference, there are also indications of increasing public opposition to nuclear power in these countries. On balance, a diversified energy program appears to be the best choice for Western Europe and Japan both economically and politically.

In less developed countries, the share of future energy demands that will be supplied by nuclear power is very uncertain. Nuclear power may be competitive in some twenty developing countries by the year 2000, and others may install it for noneconomic reasons. As a practical matter, the large 1,000 MWe nuclear power plants now being built to achieve economies of scale are not matched to the small power grids of most developing countries. More suitable, smaller plants (less than 600 MWe) would have significantly higher capital costs per kilowatt and, in the absence of demand, are no longer being built. For these reasons, nuclear power may be ruled out as an economic energy option for many developing nations.

Alternative Sources of Energy

It is frequently argued that solar, geothermal, or fusion energy would be viable alternatives to nuclear power if they received a fair share of the research and development funds. It is our judgment that these forms of energy cannot compete with nuclear, coal, or other fossil fuels as major sources of electric power until well into the next century. We believe, however, that vigorous research and development should be carried out in these fields to develop the long-range options and to provide a hedge against possible unforeseen problems with fossil or nuclear power.

For the long run, solar energy is especially interesting, since it is essentially unlimited. It takes many forms, from direct radiation to energy stored in the ocean, waves, winds, and vegetation. Applications such as house heating will be practical in the near future in favorable situations and, in conjunction with improved insulation and other conservation measures, can reduce the growth in demand for electricity. However, solar electric power will become competitive only after considerable research and development and a large increase in the cost of electricity. While we favor a continuing effort to develop solar electric power, we see little prospect, given the state of the technology and the high capital costs, that solar electricity can compete with nuclear and coal plants in this century.

Geothermal energy, which is being exploited on a very limited scale at a few unique locations, constitutes a huge potential resource. Most of this energy, however, will be very difficult to exploit. We see little prospect therefore that geothermal energy will prove competitive for electric power on a large scale in this century.

Fusion, like solar energy, offers the promise of practically unlimited energy. Important scientific progress has been made recently in this extremely sophisticated technology. Although it is still premature to predict success, we believe that fusion reactors will probably demonstrate a useful energy output by the year 2000. There is little prospect, however, that fusion will supply electricity on a competitive basis in the next fifty years. Fusion reactors will involve large capital costs and complex systems with unknown capacity factors, and it remains for future generations to see when they will become competitive.

Despite our pessimistic assessment of the near-term prospects of these alternative energy sources, they support our optimistic assessment that in the longer view of human affairs, adequate energy will be available—at a price.

In the search for new sources of energy, a variety of proposals have been advanced that make use of the energy in nuclear explosives. The proposed applications of Peaceful Nuclear Explosives (PNEs) range from the stimulation of gas and oil and "in-situ" retorting of oil shales to the direct heating of steam for power plants. The economic merit of these proposals ranges from highly dubious to clearly noncompetitive. All of the proposals that could have any serious impact on the energy situation would require a frequency of nuclear explosions and the production and transportation of nuclear devices on a scale that would dwarf nuclear weapons activities. For example, two 50 kiloton explosions per day would be required for a single hypothetical 1,000 MWe power plant. The security implications are staggering since PNEs are fundamentally indistinguishable from military explosives. We believe, therefore, that the now dormant U.S. PNE program should not be revived even as a research and development effort and that the United States should discourage interest in PNEs abroad, since they provide a convenient cover for weapons development.

Long and expensive research and development efforts will be required before advanced technologies can be commercially competitive. With such time horizons, there is little prospect that the private sector will support these activities. Energy research and development is currently funded by the government at over $3 billion per year, about 4 percent of the current value of the energy output. Further development of nuclear power, particularly breeders, and improved utilization of fossil fuels, compete for these funds. While these more developed technologies deserve a large share of the government effort, we believe that a serious effort should continue on advanced technologies to provide assurance of long-range energy supplies and to provide a hedge against the possibility that limitations may have to be placed on either fossil or nuclear energy for some reason.

The research and development chain includes the following steps: fundamental research, basic applicable research, applied research, development, and finally commercialization. Costs increase dramatically as one moves from fundamental research to commercialization. Since the advanced technologies aim at targets as far as fifty years away, the decision to go forward with full-scale development should be taken with great care. The transition from federally supported programs to unsubsidized commercial use can be achieved only if the private sector finds investment in plants economically attractive. Thus there is little value in demonstrating clearly noncompetitive technology unless the demonstration substantially advances the engineering of the technology at a cost commensurate with the value of the advance. If the demonstration takes place before it is economically justified, the government may have to subsidize the program at a high level for a long time after demonstration, and the ultimate product may also be inferior to that which would have resulted from continued development. In addition, premature commitment to expensive demonstration programs can distort the balance of the federal energy program. We believe that the government must exercise greater care in the future before moving into the very costly phases of the development chain.

The Economic Significance of Nuclear Power

Whatever is done about nuclear power over the next few decades, real energy costs will continue to increase into the next century. We have considered the likely effects of this overall cost increase on growth, income and employment, and have estimated the differences that would result from possible variations in the timing and character of the U.S. nuclear future. We find that nuclear power choices have limited bearing on these larger social and economic conditions.

Energy is an important factor in an economy, and any unexpected interruption in supply, such as an oil embargo, will have serious disruptive effects. But the cost of energy is less critical than assured supply. Even after OPEC quadrupled oil prices, primary energy costs are only about 5 percent of the U.S. GNP. Another doubling in real energy costs would result in the shifting of up to 5 percent of the economy from the production of final products to the production of energy or of goods to pay for imports. If such a shift occurred rapidly, it could be accompanied by serious, short-term dislocations in the economy, including increased unemployment, loss in output, and a reduction in growth. The rate of investment might have to be increased permanently from 10 percent to 12 or 13 percent of GNP to provide the larger amounts of capital needed, and current consumption expenditures would be reduced by 2 or 3 percent. In the long run, however, the economy should be able to absorb higher energy costs with little effect on growth or employment.

In actual practice, the impact of higher energy costs on income and capital needs will probably be reduced significantly by the market response to the higher prices and by other energy conservation actions. Energy-saving industrial processes such as the cogeneration of electricity with process heat, energy-efficient building designs and transportation systems, and less energy-intensive consumption habits are widespread in other developed economies where higher energy prices have long prevailed. Now that even higher energy costs are expected everywhere, new conservation opportunities will be developed and exploited as an alternative to expansion of supply. Market forces will produce most of these conservation measures, but the government must play an important role by helping market forces to operate, by providing information and leadership, and by modifying policies which may uneconomically encourage greater energy use.

Although we anticipate that the market response will significantly reduce the growth of energy use, there are hazards in formulating long-range energy policy on specific predictions based on such inherently uncertain factors. Projections of U.S. energy demand in the year 2000 differ by a factor of 2. For example, the Institute for Energy Analysis has estimated that U.S. energy demand, which was about 70 quads (one quad is 10^{15} BTU) in 1975, would grow to 101-124 quads by the year 2000, while the Edison Electric Institute has estimated a demand of as much as 194 quads by then. Because of the large uncertainties in demand determination, we attach little credence to long-term projections that rely on extrapolations from historical experience. Although there has been historical correlation between energy and economic growth, there is no reason to believe that the same relationship will hold under conditions of rising rather than falling energy prices. Fundamental energy policy decisions should therefore be designed to meet a broad range of possible future conditions.

Whatever the income loss due to higher energy costs, nuclear power can do little to reduce it in this century since nuclear power will at best have only a small cost advantage over coal. To understand the ranges of the economic benefits associated with nuclear power, we have used a simple computer model of the U.S. economy to explore the effects of various economic assumptions and program decisions. Even with assumptions favorable to nuclear power, the benefits from the continued growth of light-water reactors (LWRs) and the early introduction of the breeder are very small in this century (a small fraction of 1 percent of GNP), and only 1 or 2 percent in the next century. Relatively conservative assumptions for the reduction in demand in response to higher energy prices were used in the calculations. If, as we anticipate, demand reduction turns out to be easier than assumed in this formal analysis, the income effect of higher energy costs will be even less. Even though it will not affect the long-range economic growth of the country, 1 or 2 percent of the large GNP anticipated for the next century is a large absolute dollar amount of income and should be given up only if there are strong noneconomic reasons for doing so.

The desirability of maintaining or changing any particular style of life has not entered into our analysis. Some critics of nuclear power include among their arguments disapproval of industrial society and of continued economic growth. The broad range of issues relating to the style of life of our society is not, however, central to nuclear power. These issues should be addressed directly on their merits. The style of life that evolves in the future will depend on many factors other than the existence of nuclear power or central power stations or the price of energy. Increases in the price of energy may gradually modify attitudes toward specific energy-intensive activities relative to other activities. But in themselves, higher prices for energy need have relatively little effect on the evolution of the basic style of life of the future.

We have analyzed the impact of energy on the economy from a long-range perspective that smooths out short-term effects. While substantial changes in energy prices can be accommodated in the long run, sudden stoppages or sharp increases can indeed force severe temporary cutbacks in industrial operations with attendant unemployment and hardship. The level of economic activity will be affected since individual and institutional plans and attitudes take time to adjust. The amount of nuclear power available will have little to do with the cause, severity, or duration of such events. The choice made between coal and nuclear power will have little or no effect in insulating the United States from the short-term effects of sudden changes in oil prices and availability. The response to these situations must be by other means.

Although our analysis has focused on the U.S. economy, the same conclusions are broadly applicable in other industrialized countries willing to rely on world markets for fuel supplies and to assume the associated foreign exchange costs. The situation in less developed countries is more serious. In these countries, economic growth is more dependent on expansion of the industrial base, which requires capital and energy, particularly for industry and transportation. Higher energy costs may therefore have a more serious effect on their economic growth. Moreover, the already stringent balance of payments problem of many less developed countries will be further aggravated by the necessity of importing fuel at higher costs. This constraint immediately affects their prospects for economic growth. Nuclear power, however, is not well suited to the needs of many of these countries, since it is capital-intensive and limited to the production of large amounts of electricity. Moreover, the need for increased energy for transportation, industry, and agriculture implies the use of nonelectrical energy that cannot be supplied by nuclear power. The extent to which nuclear power is an economic response to high world oil prices will therefore depend on the circumstances of individual countries.

This assessment of the economic impact of nuclear power has been dominated by market considerations. Responsible policy decisions must also consider the external social costs of risks to public health and the environment and the implications for national security and world peace. In the following section, we consider the social costs that are not included in ordinary market calculations.

HEALTH, ENVIRONMENT, AND SAFETY

Nuclear power has been widely attacked as a threat to human health. Critics are primarily concerned about the possibility of catastrophic reactor accidents and the health and environmental problems associated with nuclear wastes and plutonium. These risks are real and must be considered in any assessment of nuclear power.

As with market economics, the risks and social costs of nuclear power should be compared with those of coal, which is the principal energy alternative for electric power in this century. This comparison is not an easy task. The possible social costs of coal and nuclear power involve such diverse health effects as prompt and delayed deaths, genetic diseases, illness, and discomfort; the environmental effects range from land use problems to the possible modification of the atmosphere leading to worldwide climatic changes. Some of these social costs (such as the costs of improving the safety of reactors, reducing pollution from coal, and payments to miners with black lung disease) are reflected in the market economic comparisons between coal and nuclear power since they are included in the cost of electricity. However, the general effects of emissions from coal and nuclear power plants are not included in such cost comparisons.

Analysis of social costs raises difficult and controversial methodological problems in valuing human life and health now and in the future. The greatest difficulty, however, is the uncertain state of knowledge regarding the effects on health and the environment of low levels of chemical and radioactive pollution and regarding the probability of nuclear accidents. Since there is little operating experience with nuclear power, it is impossible to estimate accident probabilities with any precision. Some risks may be unknown. In the case of coal, several hundred years of experience have not produced quantitative understanding of the health consequences and even less understanding of the possible effects on the world's climate of the carbon dioxide and particulates released during coal combustion.

The range of uncertainty in social costs is so great that the balance between coal and nuclear power could be tipped in either direction with resolution of the uncertainties. It is unlikely, however, that the principal uncertainties will be resolved in the near future. We do not believe therefore that consideration of social costs provides a basis for overriding our conclusions, based on economic analysis, of the comparative attractiveness of the two technologies and the desirability of maintaining a mix.

Public Health—Normal Operations and Accidents

In principle, one can compare the impact on public health of coal and nuclear power directly in terms of the deaths and illness they cause. In normal operations, a 1,000 MWe nuclear power plant has been estimated to produce roughly one fatality per year from occupational accidents and radiation risks to workers and to the public. A comparable new coal plant, meeting current new source standards, has been estimated to produce from two to twenty-five fatalities per year. Accidents in coal mining and transportation account for roughly two fatalities per year, and the rest of the range is attributed to the health effects of sulfur-related pollutants. This wide range results from the very large uncertainties in the actual effects on human health of the pollution chains resulting from sulfur oxides and from significant differences resulting from plant location with respect to population. The analysis of the risk at specific locations is complicated by uncertainties in meteorology, chemistry, synergistic effects involving other pollutants, and existing backgrounds. In addition to fatalities, pollution from coal plants contributes to large-scale nonfatal illnesses and discomfort for which there is no nuclear counterpart. There may also be significant effects from nitrogen oxides, carcinogenic hydrocarbons, and heavy metals for which a quantitative basis has not yet been established.

Thus, in a comparison of normal operations, nuclear power has smaller adverse health costs than coal. However, in an overall comparison of health effects, the possibility of accidents must also be taken into account. The possibility that nuclear accidents could have very serious consequences for public health has long been recognized as a unique problem associated with nuclear power. It is difficult to compare such rare but extremely severe events with the continuous health burden due to fossil fuels, but some perspective is gained from averaging the consequences of estimated accidents over an extended period. This requires knowledge of the probabilities and consequences of a spectrum of possible nuclear accidents.

To date, the safety record of nuclear power reactors in the United States has been excellent, at least as far as public health is concerned. However, the experience of some 200 reactor years of commercial nuclear power does not provide an adequate statistical basis for risk predictions covering the 5,000 reactor years expected during the rest of this century. Probabilistic judgments must be made on related technical experience and theoretical computations. Such an analysis of the current light-water reactors was undertaken in The Reactor Safety Study (WASH-1400, frequently referred to as the Rasmussen Report), published by the Nuclear Regulatory Commission (NRC) in October 1975. This report examined in a systematic fashion a large number of possible paths that could lead to an accident, estimated the overall probability of a nuclear core meltdown and breach of containment, and developed a probabilistic assessment of the consequences of such an accident, averaged over location and weather. Although WASH-1400 is a valuable resource for the study of the safety problem, we believe that it seriously underestimates uncertainties and has methodological flaws that are discussed in our report.

Without attempting to duplicate the massive analysis of WASH-1400 but taking its uncertainties into account, we have attempted to gain some perspective on the possible social costs of reactor accidents by considering the following questions:

- How does the predicted rate of reactor accidents affect the average rate-of-loss comparison between nuclear power and coal?
- How serious might the consequences of a reactor accident be?
- How likely might an extremely serious nuclear accident be if the associated uncertainties are all viewed pessimistically?

The average rate-of-loss due to reactor accidents calculated in WASH-1400 is only about 0.02 fatalities per year for a 1,000 MWe nuclear power plant. This rate is very low compared with the one fatality per year predicted for normal nuclear operations or the two to twenty-five fatalities per year attributed to a comparable new coal plant. Although we have not made an independent estimate of this average value, for losses due to nuclear accidents, our analysis indicates that with extremely pessimistic assumptions the WASH-1400 estimate might be low by a factor of as much as 500. On the other hand, it could be on the high side as well. In the most pessimistic case, which we consider very unlikely, the average rate-of-loss could be as high as ten fatalities per year for a 1,000 MWe nuclear power plant. However, even in this extremely unlikely situation, the average fatalities would not exceed the pessimistic end of the range of estimated fatalities caused by coal. Thus, on an average rate-of-loss basis, nuclear power compares favorably with coal even when the possibility of accidents is included.

An extremely serious accident under very adverse conditions is estimated by WASH-1400 to kill as many as three or four thousand people over a few weeks, cause tens of thousands of cancer deaths over thirty years, and cause a comparable number of genetic defects in the next generation, as well as more than \$10 billion in property losses. Despite large uncertainties in biological effects, this appears to be a reasonable assessment of the potential consequences. While such an accident would clearly be a major disaster, the consequences would not be out of line with other peacetime disasters that our society has been able to meet without long-term social impact. For example, the United States has experienced a number of hurricanes that have taken over a thousand lives, produced physical damage in the billions of dollars, and required massive evacuation. In such a nuclear accident, the delayed deaths from cancer would not be an immediate effect but might result in a 10 percent increase in the incidence of cancer in the exposed population over a period of thirty years. It must be emphasized that a nuclear accident would probably have much less severe consequences than those estimated for this extremely serious accident and that most nuclear accidents would result in few, if any, fatalities.

The most serious accident considered in WASH-1400 is assigned an exceedingly low probability of occurrence (only one chance in 200 million years of reactor operation). This calculation is based on the combination of a number of low probability estimates for a series of events, most of which are extremely uncertain. When the uncertain factors are viewed in the most pessimistic light, there is a significant chance that such an event might occur during this century if the nuclear program grows at the projected rate. While it is very unlikely that this pessimistic assessment correctly describes the probability of such accidents, it does place an upper bound on the problem.

Having examined nuclear accidents from each of the above perspectives with very pessimistic assumptions, we have concluded that, even when the possibility of reactor accidents is included, the adverse health effects of nuclear power are less than or within the range of health effects from coal. At the same time, this analysis underscores the importance of continuing efforts to reduce the probability and consequences of accidents by improved safety designs and siting policies.

A foreign reactor accident would not necessarily be evidence of risk in this country, since some foreign reactors may be less safely constructed or operated than those in the United States. Nevertheless, a foreign nuclear accident could have a major psychological impact in this and other countries. A high premium should be put on reducing the probability and consequences of reactor accidents wherever they might occur.

Nuclear Wastes

The potential health hazards of radioactive wastes and plutonium produced during reactor operation are unique to nuclear power. Plutonium and other waste components present special problems since they decay very slowly and remain dangerous for hundreds of thousands of years. Critics of nuclear power question the morality of creating this threat to future generations or even to future civilizations.

We are convinced that nuclear wastes and plutonium can be disposed of permanently in a safe manner. If properly buried deep underground in geologically stable formations, there is little chance that these materials will reenter the environment in dangerous quantities. Even if material were somehow to escape eventually in larger quantities than seems possible, it would not constitute a major catastrophe, or even a major health risk, for future civilizations.

Despite our confidence in the feasibility of permanent disposal, nuclear wastes remain a very serious potential health problem until isolated from the environment. We are, therefore, more concerned about the current worldwide management of nuclear wastes before they are sequestered permanently than we are about the unlikely prospect that they will affect society subsequently. Inadequate management of wastes from the nuclear weapons and earlier civilian power programs here and abroad has already created potential contamination problems that can only be overcome at considerable cost.

Until very recently, all decisions on waste disposal were deferred apparently in anticipation that the problem would be resolved as a by-product of the assumed early introduction of plutonium reprocessing and recycle. As a consequence, it is widely believed that reprocessing is a necessary stage in waste management and disposal, when in fact it may simply complicate the process. If spent fuel is reprocessed to recover plutonium, the possibilities of waste management failure increase because of the additional steps involved. The risks in permanent waste disposal, however, appear to depend little on whether reprocessing has occurred. The impact of reprocessing on waste management is that it substitutes a larger immediate contamination risk for a small reduction in the long-term hazard from permanent disposal.

Environmental Effects

In addition to direct effects on human health, the generation of electricity by either nuclear power or coal has environmental effects on air, land, and water, and potentially on global climate as well. On balance, however, nuclear power has significantly less adverse environmental impact than coal.

Local thermal pollution is common to both sources, although somewhat more severe for nuclear power. In other respects, however, the coal cycle presents the more serious problems. Coal mining has a more disruptive effect on the land than uranium mining and milling, although this difference will diminish as lower grades of uranium ore are mined. Coal mining results in acid runoff that pollutes waterways, and combustion of coal leads to acid rain that damages land and crops.

The most serious potential environmental impacts from greatly increased power generation are changes in global climate. The thermal output of both coal and nuclear power plants contributes directly to the long-term heating of the atmosphere. A much more immediate atmospheric heating problem, however, results from the carbon dioxide produced when coal is burned. The carbon dioxide, which probably cannot be prevented from entering the atmosphere, heats the earth by the so-called greenhouse effect since it is transparent to incident solar radiation but absorbs some of the heat that the earth reradiates. It has been estimated that the carbon dioxide from fossil fuels burned in the last two centuries has increased the mean temperature about 0.3° C above what it would otherwise have been. However, the extent of the actual heating is complicated by the uncertain, possibly compensating, effects of particulates and other pollutants that are also emitted by coal combustion. More fundamentally, the current unpredictability of natural climate variations, which can be significant over relatively short periods, makes an empirical assessment of the actual impact of increased use of fossil fuels very difficult. Moreover, since short-term fluctuations would generally mask any trend for a number of years, these questions are not likely to be resolved for some time.

Despite these uncertainties, major increases in the use of fossil fuels could have a significant effect on climate. Whether the impacts of carbon dioxide will combine with natural changes in climate to the net disadvantage or advantage of mankind or to particular regions such as the United States cannot be judged at this time. On the basis of greater knowledge, however, this effect could take on overriding significance in a comparison of coal and nuclear power. This factor argues against putting complete reliance on coal power at this time.

Risk Reduction

Much better information is needed for the comparative assessment of the social costs of coal and nuclear power. There is little prospect, however, that this information will be available soon. While it is being developed, much can be done to reduce the risks of both coal and nuclear power.

For nuclear power, we have been particularly impressed by the variability of risk with location in case of accident. The predicted consequences of accidents at different sites can vary a hundredfold depending upon the distribution of population and prevailing weather. A more restrictive siting policy would increase somewhat the costs of nuclear power in some locations, but we believe it is warranted by the uncertainties in the probabilities of accidents and by the large risk reductions that are possible. Special measures such as underground siting should be considered if nuclear power is to be sited at high risk locations.

We believe that in research and development more emphasis should be placed on actually improving safety as compared with proving that reactors are "safe enough." The present government safety program, which is oriented toward the latter confirmatory approach, will ultimately narrow the range of uncertainty, but it is unlikely to reduce the probability of accidents. Steps should also be taken to ensure that the regulatory process does not inadvertently create disincentives to improvements in safety design.

For coal, stricter regulations have greatly reduced occupational hazards in mining and substantially reduced the levels of pollutants. Improvements in current technology such as scrubbers and new combustion technologies such as fluidized-bed combustion can further greatly reduce the health hazards to the public. With scrubbers, for example, the health effects from sulfur-related pollutants could be reduced by as much as a factor of 10 below present levels for new plants if low-sulfur coal were also used. The land damage from strip mining can be largely eliminated with only a small increase in the cost of coal. With these and other measures being taken on their own merit, the comparison between the social costs of nuclear power and coal will present a constantly evolving picture.

NUCLEAR PROLIFERATION

In our view, the most serious risk associated with nuclear power is the attendant increase in the number of countries that have access to technology, materials, and facilities leading to a nuclear weapons capability. The growth and diffusion of nuclear power thus inevitably enhance the potential for the proliferation of nuclear weapons. If widespread proliferation actually occurs, it will prove an extremely serious danger to U.S. security and to world peace and stability in general. By 1985, most advanced and many industrializing countries will have nuclear power plants in operation and be only a few steps from a weapons capability.

Expectations, knowledge, and trade in nuclear facilities and materials are so widespread that the United States is not in a position to stop the expansion of nuclear power. Moreover, advanced countries, and some developing countries, are not dependent on nuclear power to produce nuclear weapons. None of the present nuclear weapon states developed its weapons through nuclear power. Each followed the direct path of producing the fissionable materials for its weapons in facilities designed specifically for the purpose.

Despite this somber appraisal of the technical situation, nuclear weapons are not an inevitable consequence simply because the technical capability has been achieved, as West Germany, Japan, Canada, and Sweden demonstrate. The perils of proliferation are recognized by most countries. For most, nuclear weapons offer little advantage and considerable risk. There is widespread though not complete support for the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) and the international safeguards on peaceful nuclear programs administered by the International Atomic Energy Agency (IAEA). These institutions, which reflect an international consensus against the acquisition of nuclear weapons by additional states, provide a framework for a nonproliferation policy and legitimize bilateral and multilateral restraints on nuclear trade.

Not all nonweapon states have foresworn nuclear weapons, and some may seek a nuclear weapons capability. Their possible motives are understandable if questionable: achieving prestige and status for some; overcoming isolation and insecurity for others. The response to these motivations is to give such countries confidence and standing, internationally and regionally, without recourse to nuclear weapons, and to limit the desires for nuclear weapons by regional settlements and easing of tensions and by security alliances and support for insecure states.

The motivations and responses to states seeking weapons capability underscore the essentially political nature of the nuclear proliferation problem. A strategy to constrain proliferation must be complex and comprehensive. U.S. nuclear power policies and programs can be shaped to support such a strategy, but they can be only partially effective unless they are meshed with broader political actions and international arrangements.

Some of the elements of a U.S. nonproliferation strategy that are broader than nuclear power are: a foreign policy in support of international security, peace, and stability; security commitments to reduce the perceived need for nuclear weapons; use of influence to discourage apparent preparatory moves for a nuclear capability; arms limitation agreements (e.g., a comprehensive test ban) to build additional barriers to proliferation; deemphasis of nuclear weapons in military policy, particularly doctrines that present nuclear weapons as acceptable and necessary armaments for limited application or political pressure; and cooperation in international development of the full range of energy resources.

Other measures more specifically related to nonproliferation include: support of the NPT and encouragement of present nonparties to adhere, and increased financial and technical support of the IAEA as it undertakes the increased burden of applying safeguards to a rapidly expanding, worldwide nuclear power industry. IAEA safeguards play a limited, but important, role in the effort to control proliferation. These safeguards cannot prevent proliferation but can discourage it by providing a system for warning that material has been diverted from proper peaceful uses. Such a system, while not foolproof, is a valuable deterrent. It would not be an attractive choice, for most states, to base a nuclear weapons program on clandestine diversions in violation of a formal international treaty.

There are also actions and policies that relate directly to nuclear power and the nuclear fuel cycle that would help to control nuclear proliferation in important ways. The nonproliferation system will inevitably be flawed and unstable if plutonium and highly enriched uranium, materials suitable for nuclear weapons, and the facilities to produce them become increasingly widespread. The time required for achieving a nuclear weapons capability would be greatly reduced and the temptation to make an irreversible decision to fabricate, and even use, nuclear weapons might be difficult to resist in a crisis. Facilities for plutonium separation and enrichment of uranium are thus particularly sensitive.

Fortunately, current reactors do not require plutonium or highly enriched uranium and instead use slightly enriched or natural uranium that cannot be used directly for weapons. These reactors do generate plutonium as part of normal operation, but it is mixed with highly radioactive fission products in the spent fuel and requires separation before it can be used in weapons. If this plutonium is chemically separated (reprocessing), it can be used again (recycled) in current reactors. The plutonium breeder reactor, which produces more plutonium than it consumes, requires reprocessing and recycle of plutonium for

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fuel. The potential danger of these technologies to proliferation is abundantly clear.

Current uranium enrichment facilities, located in the five weapon states, use gaseous diffusion technology, which inherently requires large capital investment and consumes large amounts of electricity. New methods that can be applied on a smaller scale are in various stages of development. Centrifuge plants, suitable for smaller programs and easily modified to produce highly enriched material, are beginning operation in Western Europe; most other countries would need to import the main equipment. Laser separation, which could prove successful in the 1980s, may permit production of highly enriched uranium on a small scale for relatively little capital investment and very small amounts of electricity. If not controlled, these new technologies will further complicate the proliferation problem.

International arrangements to control the nuclear fuel cycle are imperative to buttress the NPT and its safeguards system. Continued adherence by the United States to its long-standing policy of banning export of reprocessing and enrichment facilities is one contributing measure. Coordination with other suppliers of nuclear technology and materials is also essential. A few suppliers, however, cannot impose an enduring fuel cycle arrangement on the rest of the world. There must be developed a significant consensus among buyers as well as suppliers that it would be in their common interest to control the nuclear fuel cycle and thus establish physical constraints against a chain reaction of proliferation that could undermine international stability. Within the framework of such a common appreciation, it should be possible to develop effective constraints on the export of sensitive technologies.

The early introduction of plutonium recycle and plutonium breeders has been widely believed to be critical to the economic use of uranium and nuclear power. These beliefs have been encouraged by the emphasis on these programs in the nuclear development activities of the United States and the other principal nuclear suppliers. If the nuclear fuel cycle is to be controlled internationally, other countries will have to be convinced that there are no significant economic penalties in deferring these technologies. This will be hard to do if the United States is proceeding with reprocessing and breeder commercialization. While deferral of these programs would not necessarily convince all others that they should foreswear trading or acquisition of such facilities, it probably would convince some and would seriously influence the thinking of all countries. Deferral would also remove the appearance of discrimination in asking developing countries to forego these technologies and in achieving common supplier action to ban the export of such technology. Conversely, a decision by the United States to proceed with plutonium reprocessing and recycle would probably ensure worldwide movement to incorporate plutonium in the fuel cycle.

Postponing plutonium recycle and the plutonium breeder will increase concern about the availability of slightly enriched fuel for the present generation of light-water reactors. Conversely, assured supplies of such fuel from the United States and other suppliers will reduce the pressure for the new technologies directed at extending fuel supplies. Assured supplies of slightly enriched uranium at reasonable prices will also greatly reduce the economic rationale for other countries to build indigenous enrichment plants. The fact that a number of countries will be able to furnish enrichment services should provide further confidence of assured supplies.

Within such a framework of national and international constraints on the nuclear fuel cycle, we believe that, with concerted efforts by the United States and the international community to meet national security concerns and to reduce international tensions, the risk that nuclear power will lead to proliferation can be substantially reduced. The specific nuclear power decisions that the United States will have to take to accomplish this objective are considered below under "Issues for Decision."

Terrorism

A particularly disturbing aspect of nuclear proliferation is that it could extend to subnational terrorist groups. While a completed nuclear weapon would be a more convenient target, a highly organized terrorist group might have the capability to fabricate a crude nuclear weapon from stolen plutonium or highly enriched uranium. Since neither of these materials is available in the present fuel cycle, this threat will only emerge if plutonium is reprocessed and recycled or if reactors requiring highly enriched uranium are introduced.

The difficulty and danger of designing, planning, and constructing a crude weapon from reactor-grade plutonium should not be underestimated. Although it would not prove as easy as sometimes suggested, it is conceivable that a well-organized group supported by knowledgeable individuals could construct a device that might have a yield equivalent to a few hundred tons of TNT. When one considers that the largest conventional bombs of World War II contained only a few tons of TNT, the destructive potential of such a weapon is apparent.

A terrorist group might sabotage a nuclear facility in an attempt to inflict damage or threaten sabotage of a seized facility to blackmail authorities. The most serious target would be an operating nuclear reactor, where trained and knowledgeable saboteurs could cause a major accident. This threat cannot be quantified, but it clearly adds to the probability of an accident. Whatever that additional probability is, it can be reduced by measures designed to prevent or deter sabotage.

We believe that additional measures should be taken to reduce the possibility of terrorist acts to divert materials or sabotage facilities. Physical and personnel security should be improved at nuclear power plants and fuel cycle facilities. At present, the responsibilities of federal, state, and local agencies with respect to jurisdiction over crimes involving nuclear facilities are ill-defined, a situation that could lead to an inappropriate response to an emergency. The federal government should lead in developing improved security practices, coordinating procedures for law enforcement, and making expertise available.

We are convinced that measures to improve security substantially can be taken without infringing on the civil liberties of employees of the nuclear industry and the general public. Overzealous and ill-conceived measures, however, could endanger civil liberties and set dangerous precedents. The government should, therefore, be particularly sensitive to the broader legal implications of measures undertaken to improve security against, or the ability to respond to, terrorist activities.

Nuclear terrorism is international in scope. Terrorist acts in the United States could result from materials or devices seized abroad and smuggled into this country. The United States thus has a critical interest in the improvement of nuclear security and should encourage the development and implementation of effective physical security measures in all countries.

INSTITUTIONAL FRAMEWORK

Formulation of policy on nuclear power is affected by the institutional framework within which decisions must be made and implemented. Nuclear power interacts with public health and safety, the environment, foreign policy and national security as well as the economy. At the same time, nuclear power is, or should be, part of overall national energy policy, which in turn should be part of broader national economic policy. As a result, the complex issues have increasingly cut across institutional lines within the Executive Branch, regulatory agencies, Congress, state and local government, and the private sector.

In some respects, this institutional complexity is characteristic of energy in general. In other respects, nuclear power presents unique institutional problems arising from the original government monopoly in nuclear energy, the special risks of accidents and theft, the risks of nuclear proliferation, and the complex of treaties and agreements that have developed in the field. Until 1974, the government's role in nuclear power was largely the monopoly of the Atomic Energy Commission (AEC), which served as both promoter and regulator of the industry. This arrangement, while effective in developing nuclear power as an energy alternative, tended to make nuclear energy an end in itself, isolated from broader energy policy and potentially out of balance with other domestic and international considerations.

In a major organizational reform, the AEC was abolished in 1974 and the Nuclear Regulatory Commission (NRC) was created to deal with the regulatory aspects of nuclear power. The Energy Research and Development Administration (ERDA) was given responsibility for all research and development in energy including nuclear power. This action eliminated the anomalous situation where the same institution was both promoter and regulator, and placed the development of nuclear power in a common framework with all energy development activities. Although these institutional reforms have corrected some of the obvious problems with the AEC, the decision process remains fragmented. Despite its new charter, ERDA has to some extent continued to place emphasis on nuclear energy, in part because it inherited the substantial organization and facilities of the AEC.

Despite the extensive reorganization of energy institutions and the intense interest and activity in the field since the 1973 embargo, the government has not formulated a clear national energy policy. We believe that such a policy is necessary to provide a basis on which the various agencies concerned with energy can establish priorities and make and implement specific decisions. Such a policy need not, and we believe should not, be a highly structured long-range plan but rather a strategy for developing choices for the future. The policy should establish consistent and achievable objectives and priorities in areas such as the development of new energy supplies, conservation, energy independence, emergency supplies, and the weight to be given to nonproliferation.

We are convinced, after a year's exposure to the range of problems involved, that the President must be directly involved in the formulation of both overall energy and nuclear energy policy. There is no lower level that can have the authority to resolve the diverse domestic, foreign policy, and security interests. While not attempting to advise the President on how to organize the Executive Office, we believe that some arrangement should be devised to assist him directly in this area. Although this approach can be criticized as establishing a pattern that would break down if extended, as will be suggested by some, to many other complex areas such as resources and food, we believe the energy problem does merit priority attention.

Even where energy policy has been established, there is no clear mechanism for implementing it within the Executive Branch, and agencies are often left to interpret government policy independently. The Executive Office must play a stronger role in seeing that policy is understood and carried out responsibly by each lead agency and coordinated with other agencies having responsibilities for various aspects of the nuclear power problem.

With the demise of the AEC, the Joint Committee on Atomic Energy lost its unique position and has now been abolished. Other Congressional committees have acquired increased responsibilities for separate aspects of nuclear power. This has been a useful process in developing broader Congressional and public understanding of the issues. However, Congressional responsibility for nuclear power has become too diffuse, and there should be some consolidation so that Congress can deal effectively with nuclear power in the broader perspective of overall energy and foreign policy. In the final analysis, the ability of Congress to contribute to the policy-making process and produce constructive legislation will depend on the presentation of an overall energy plan to Congress by the President.

In a narrower sense, there are important institutional problems affecting nuclear power in the relations of the federal government with state and local governments. Regulatory authority over nuclear energy facilities is widely dispersed among federal, state, and local authorities. The licensing of a power plant requires dozens of separate permits and approvals. Each authority considers the question not only in a limited geographical setting, but also from a narrow functional perspective—economic, safety, environmental, or aesthetic. The licensing process can become an obstacle course, resulting in delays and increased costs and frustrating sound decision-making.

Under the Constitution, Congress could pass legislation establishing federal control over the whole licensing process, but the variety and intensity of local and regional interests argue strongly against wholesale displacement of their authority. Short of this, it would be desirable to act at the federal level to simplify and rationalize this process by reducing the number of separate hearings and proceedings required before final approval. Federal statute could provide for a single consolidated proceeding at which all aspects of the problem could be covered with all interested parties having an opportunity to appear and present evidence. This would produce a consolidated record on which local, state, and federal authorities could make decisions which could be reviewable in a single appeal to a Federal Court of Appeals.

From the perspective of a rational overall energy policy, one might argue that provision should be made for federal preemption over decisions by state or local authorities. However, in keeping with our conclusion that economic factors and appraisals of social costs should lead to an appropriate mix of coal and nuclear power plants, we believe that it is desirable to allow considerable leeway for local preferences. If it should develop that the cumulative effect of local preferences would endanger a reasonable national mix of coal and nuclear power plants, the case for federal preemption would be stronger.

Government-industry relations in the nuclear power area are currently in some disarray. The government has historically taken the leading role in nuclear development, originally a government monopoly. Private firms were initially contractors or chosen instruments. Even today, nuclear power is not really a private industry in the normal sense, since the government retains a dominant role in such areas as uranium enrichment, waste management, and research and development.

It is in the interest of a sound U.S. energy economy to let the market establish the rate of nuclear power growth. This does not mean, however, complete private ownership of the fuel cycle in view of the large capital requirements, technical and economic uncertainties, and security sensitivity of facilities such as those for uranium enrichment, plutonium reprocessing, or permanent waste disposal. Siting policy is also an appropriate area of government responsibility in view of the strong dependence of accident risks, affecting large and widely dispersed populations, on the specific location of power plants. Working out a government-industry relationship that is economically and managerially sound and provides a clear basis for planning is an important national objective; doctrinaire assignment of proper roles for government and the private sector is not warranted.

In sum, we do not believe nuclear power can be treated as just another industry. Utility choices between coal and nuclear plants should be based on market considerations, within a regulatory framework that deals adequately with social costs external to the industry. At the same time, the special security implications of nuclear power demand continued close government control and participation in critical stages of the nuclear fuel cycle.

ISSUES FOR DECISION

The United States faces a number of early decisions having an important bearing on the future of nuclear power and on the worldwide risks in the nuclear fuel cycle. These decisions, which are closely interrelated, must be considered in the context of the economic, energy supply, social costs, and international security issues discussed above. From this broader perspective we have examined the pending decisions: whether to proceed with plutonium reprocessing and recycle; how to conduct a breeder program most appropriate to long-term energy needs; how to manage and dispose of nuclear waste; when and how to expand enrichment capacity; and how to develop a nuclear export policy which minimizes threats to international peace and stability.

The significant common thread in these decisions is the question of whether plutonium should be introduced into the nuclear fuel cycle. We have concluded that there is no compelling reason at this time to introduce plutonium or to anticipate its introduction in this century. Plutonium could do little to improve nuclear fuel economics or assurance here or abroad. This conclusion rests on our analysis of uranium supply, the economics of plutonium recycle in current reactors, and the prospects of breeder reactors. In the longer term, beginning in the next century, there is at least a possibility that the world can bypass substantial reliance on plutonium. If this is not the case, the time bought by delay may permit political and technical developments that will reduce the nuclear proliferation risks involved in the introduction of plutonium.

Plutonium Reprocessing and Recycle

The principal immediate issue affecting nuclear power is whether the United States should proceed with the reprocessing and recycle of plutonium. Until recently, it was generally assumed that spent fuel from light-water reactors (LWRs) would be reprocessed to recover the plutonium produced during operation and that the plutonium and any unused uranium-235 would be recycled as fuel in LWRs. The expectation was that this process would take place on a commercial scale as soon as the nuclear power industry had expanded to the point to justify the large facilities needed for economic operation. The decision whether to license this activity is now before the NRC. Statements by both candidates during the 1976 Presidential campaign indicated, however, that these assumptions are being challenged on a bipartisan basis and that a consensus is emerging not to proceed at this time with reprocessing.

In a major statement on nuclear policy on October 28, 1976, President Ford announced that "reprocessing and recycling of plutonium should not proceed unless there is sound reason to conclude that the world community can overcome effectively the associated risks of proliferation." This does not, however, constitute a decision on reprocessing but rather an identification of the issue. Although the Administrator of ERDA was directed not to assume that reprocessing would proceed, he was also directed "to define a reprocessing and recycle program consistent with our international objectives." During his campaign, President Carter stated in San Diego on September 25 that he would "seek to withhold authority for domestic commercial reprocessing until the need for, the economics, and the safety of this technology is clearly demonstrated."

The risks associated with reprocessing and recycle of plutonium weigh strongly against their introduction. The use of plutonium in the commercial fuel cycle would expose to diversion and theft material directly usable for weapons. With widespread adoption of the plutonium fuel cycle, there would be increased pressures for independent national reprocessing facilities. The proliferation of such facilities would reduce the time necessary for a national decision to develop weapons.

Despite these widely recognized problems, it has been argued that the economics of reprocessing and recycle of plutonium in LWRs is so compelling as to make their introduction inevitable. Although plutonium and unburned enriched uranium have substantial value, the recovery of these materials from the highly radioactive wastes in spent fuel has proven to be much more difficult and expensive than anticipated. As reprocessing and recycle have moved closer to commercial practice, cost estimates have escalated rapidly. The first two U.S. commercial reprocessing ventures failed, one for economic and the other for technical reasons. The Allied Chemical plant at Barnwell, South Carolina, the only remaining U.S. commercial venture in this field, is likely to incur substantial losses and is seeking government support. European ventures are not yet operating on a commercial basis and are unwilling to contract except on a cost-plue-fee basis.

The most recent government analysis of reprocessing and recycle shows at best a 1 or 2 percent reduction in the cost of electricity in the latter part of the century. These estimates, however, are based on assumptions that appear to underestimate some elements of plutonium fuel cycle costs. Our own analysis of the costs indicates that any net economic benefit during this century is questionable.

Even if plutonium recycle proves of little economic importance, some countries may consider the plutonium inventory in spent fuel reassuring in view of the uncertainties in future uranium supply. In the case of the U.S. program, however, recovery of plutonium and unburned enriched uranium from spent fuel would only reduce uranium fuel requirements by some 20 percent. The incremental value of recycle would be largely irrelevant if access to reasonably priced supplies of fuel can be assured. Specific measures to accomplish this are discussed below.

It has been argued that early reprocessing of LWR fuels is important to build up plutonium inventories for future breeders. Our analysis indicates that the time when breeders may be economically competitive is sufficiently distant that the present value of establishing plutonium inventories now for future breeders is very small and thus recovery of plutonium is not economically justified for many years. Furthermore, spent fuel can be stored retrievably, so that the plutonium could be recovered if plutonium breeder reactors are actually deployed in the futrue.

An incentive to defer reprocessing and recycle also comes from the complexity it introduces into the waste management problem. Wastes are converted in these operations from relatively easy to manage spent fuel to a number of new forms–high level waste, acidic liquid waste, cladding hulls, process trash contaminated by plutonium, and others. As experience with reprocessed military and civilian wastes has shown, these operations introduce opportunities for waste management failures. While it has been commonly believed, particularly abroad, that reprocessing to remove plutonium decreases the long-term hazards of waste, we have concluded that any reduction in long-term risk is small in comparison with the more immediate risks potentially arising in reprocessing and in the use of plutonium in the active fuel cycle.

On the basis of our analysis of plutonium reprocessing and recycle, we have concluded that the international and social costs far outweigh economic benefits, which are very small even under optimistic assumptions. We believe therefore that a clear-cut decision should be made by the U.S. government to defer indefinitely commercial reprocessing of plutonium. Although the question of plutonium reprocessing and recycle is now before the NRC, we believe that, in view of the important international implications, the President should make the decision to defer plutonium reprocessing. If a decision to postpone this technology indefinitely is articulated and carried out effectively, it can have a major influence on the assessment of costs and benefits of reprocessing and recycle by other countries that are, or soon will be, facing similar decisions. Conversely, a U.S. decision to go ahead with reprocessing or actions that appeared to foreshadow such a decision would accelerate worldwide interest in the plutonium fuel cycle and undercut efforts to limit nuclear weapons proliferation. For this reason, we conclude that the government should not take over or subsidize the completion and operation of the Barnwell facility.

The Breeder Reactor Program

The priority and timing of the plutonium breeder is inevitably a central budget and policy issue since the commitment to this program currently dominates federal energy research and development activities. The plutonium breeder, which produces more plutonium than it consumes in operation, can in principle improve the utilization of uranium by a factor of as much as 100. When used in light-water reactors (LWRs), current estimated uranium reserves would provide only one-tenth the energy of coal reserves; in breeders, these same uranium reserves could in principle provide ten times the energy of coal reserves. The breeder thus opens up a vast additional energy resource and answers the criticism that nuclear power will price itself out of the market as soon as low-cost uranium is exhausted.

The Liquid Metal Fast Breeder Reactor (LMFBR) has become the centerpiece in the U.S. energy research and development program. The LMFBR program is focused on the early commercialization of a power plant to compete with the current generation of LWRs. ERDA has estimated that this program will cost at least $12 billion to complete, assuming utilities will be able and willing to start buying breeders within ten years without government subsidies.

The plutonium breeder involves a full commitment to the plutonium fuel cycle and would introduce tremendous quantities of plutonium into national and international commerce. In these circumstances, the pressure for indigenous plutonium reprocessing facilities would grow rapidly and be difficult to oppose. The breeder would thus greatly complicate the proliferation problem and increase the possibility of theft or diversion of material suitable for weapons. The economics of the breeder have generally been considered so persuasive that this serious disadvantage has until recently been largely dismissed in government planning.

Past government policy on the LMFBR has been predicated on a belief that nuclear power would exhaust reserves of low-priced uranium in a few decades, making breeder introduction economically attractive by the early 1990s. Our analysis, however, indicates that the early economic potential of the breeder has been significantly overstated. The LMFBR, as presently envisaged, will have higher capital costs than the LWR and must therefore operate at a significantly lower fuel cycle cost to be economically competitive. There appears to be little prospect that these fuel cycle costs can be reduced to a point that would give the LMFBR a significant economic advantage over the LWR in this century or the early decades of the next century. The current assessment of uranium reserves probably substantially understates the supplies that will become available; uranium, at prices making light-water reactors competitive with breeders, will be available for a considerably longer time than previously estimated. New enrichment technologies may also extend these supplies. Moreover, coal available at roughly current costs will look increasingly attractive if the costs of nuclear power rise. Finally, demand projections on which breeder economic assessments have been made in the past were unrealistically high and have already been substantially reduced. These considerations lead us to the conclusion that the economic incentive to introduce breeders will develop much more slowly than previously assumed in government planning.

This conclusion applies to other countries, as well, provided that they have access to low-enriched uranium to meet their nuclear fuel requirements. Moreover, the contribution of breeders to energy independence is questionable for most countries since the complexity and scale of the breeder fuel cycle would make an autonomous breeder system too costly for all but the largest industrial economies. Therefore, the prospect of a large export market for breeders in this century is illusory.

Despite this negative assessment, we believe that a breeder program with restructured goals should be pursued as insurance against very high energy costs in the future. This situation could develop if additional uranium reserves do not become available, environmental problems place limits on the utilization of coal, and other alternative energy sources do not become commercially viable at reasonable prices in the first decades of the next century. The present U.S. program, directed at the early commercialization of the LMFBR, is not necessary to the development of the breeder as insurance. The ultimate success of the breeder may even be compromised by telescoping development stages to meet an early deadline, freezing technology prematurely. We believe therefore that the breeder program should deemphasize early commercialization and emphasize a more flexible approach to basic technology. In such a program, with a longer time horizon, the Clinch River project, a prototype demonstration reactor costing $2 billion, is unnecessary and could be canceled without harming the long-term prospects of breeders. In fact, premature demonstration of a clearly noncompetitive breeder could be detrimental to its ultimate prospects.

Although long lead times are required for a project as complex as the breeder, we believe that the decision on commercialization, now set for 1986, can safely be postponed beyond the end of the century. The cost, if any, of such postponement will be small, and there is a strong possibility that postponement will help in restraining large-scale, worldwide commerce in plutonium and buy time to develop institutions to deal with this problem. The option of bypassing the plutonium breeder altogether should not be prematurely foreclosed since there is at least a possibility that the plutonium breeder may never become necessary, or even economically competitive, compared to other energy sources that may become available in the next century.

Nuclear Waste Management

The United States must greatly improve the management of its rapidly growing accumulation of nuclear wastes and decide soon on the strategy for its disposal. This long-deferred action is closely related to decisions on plutonium reprocessing and the timing of the breeder program. The need for action on this problem was recognized by President Ford in his directive on October 28, 1976, calling on ERDA to undertake an accelerated program to demonstrate all components of waste management technology by 1978 and a complete disposal repository by 1985. However, the question as to what strategy should actually be followed in managing and disposing of wastes has yet to be resolved.

As indicated in the earlier discussion, we are persuaded that nuclear wastes can be disposed of permanently with acceptable safety by deep burial in salt and other stable geological formations that are isolated from ground water intrusion. This conclusion holds equally whether the nuclear wastes are contained in spent fuel or in processed form. Until they are securely isolated from the environment, however, nuclear wastes are potentially extremely dangerous.

In the past, the waste disposal problem has generally been approached on the assumption that spent fuel would be reprocessed to recover plutonium for recycle. Decisions on disposal were continually deferred pending successful introduction of plutonium recycle. As a consequence, it is widely believed that reprocessing is a necessary stage in the waste disposal process. However, if plutonium is not recycled in light-water reactors or used eventually in breeders, there is no reason to reprocess spent reactor fuel. In fact, reprocessing potentially increases short-term risks associated with management of nuclear wastes and does not significantly reduce long-term risks after disposal. Spent fuel can be disposed of directly, and probably at costs comparable to those for reprocessed wastes. Therefore, if plutonium reprocessing for recycle in LWRs is deferred indefinitely as we recommend, waste disposal is made no more difficult.

The breeder, which we believe should continue as insurance against the uncertainty of future energy needs, presents a more difficult problem since large inventories of plutonium (or highly enriched uranium) would be required to start a commercial breeder program. The time scale of commercially competitive breeders is sufficiently distant, however, that separation of plutonium for this purpose will not be justified economically for some time. Nevertheless, as part of the breeder insurance program, some portion of the spent fuel should be retrievable and not disposed of permanently. The retrievable fraction should depend on the evolving time schedule of breeder development.

In the immediate future, spent fuel can be kept in the cooling ponds at nuclear power plants where it is presently stored. These facilities can easily be expanded when necessary. While this arrangement is acceptable as a temporary measure, it is not satisfactory for extended storage of large quantities of material that can be anticipated with the growth of the nuclear power industry. Therefore, we believe that the waste management and disposal program should develop both permanent and retrievable and irretrievable storage for spent fuel in stable geological formations. While security of storage will have to be balanced against ease of retrieval, the emphasis should be placed on security since retrieval may be long delayed or perhaps unnecessary.

We believe that liquid wastes accumulated from the military program and the abandoned West Valley commercial plant should be disposed of permanently to eliminate a potential safety hazard and to demonstrate the seriousness of the government's concern about the waste management problem. Experience gained in this activity could be applied to handling and disposal of wastes from future reprocessing plants if a decision is made eventually to use breeder reactors.

Our confidence in the ability to manage spent fuel is sufficiently high that we believe the United States should be willing to take back spent fuel from countries lacking waste facilities for retrievable storage or disposal if this will reduce risks to international health or of proliferation of nuclear weapons.

Expansion of Uranium Enrichment Capacity

The United States must have a clear policy on its long-term role in providing enriched uranium fuel to both domestic and foreign nuclear power programs. If future requirements are to be met, present facilities will eventually have to be expanded. The timing and magnitude of this expansion depend not only on the anticipated growth of domestic demand for enriched uranium fuel but also on the extent to which this country wishes to be able to assure fuel for others. The issue has become entangled in the question whether expansion would best be carried out by the private sector or the government. At present all enrichment facilities are owned by the government but operated under contract by private firms.

An assured supply of uranium fuel is a major factor in limiting worldwide proliferation capabilities. The assured availability of fuel at reasonable prices limits the pressure on other countries to seek indigenous enrichment facilities that would provide a capability leading to weapons. An assured fuel supply also reduces the incentive to recycle plutonium or to develop breeders in an attempt to stretch available fuel supplies.

In 1974, when projected demand appeared to call for more enriched uranium than the United States could supply, this country stopped entering into long-term commitments to supply fuel for new reactors abroad. This unwillingness to guarantee supply (even when the purchaser was willing to supply natural uranium for "toll" enrichment) is reportedly the main reason for Brazil's 1975 agreement with West Germany that provides for Brazil's eventual purchase of both enrichment and plutonium reprocessing facilities.

Present U.S. plans for new enrichment capacity are still based on earlier demand projections that are now being revised sharply downward. Cutbacks in nuclear construction plans here and abroad have delayed the time when additional fuel facilities will be required. Requirements recently estimated for the mid-1980s now seem unlikely to be reached before 1990. The ongoing program to upgrade existing U.S. enrichment plants will increase capacity by more than 50 percent in the mid-1980s. By the mid-1980s, Eurodif, in France, and URENCO, a West German/British/Dutch consortium, plan to have a combined capacity approaching, and possibly greater than, present U.S. capacity. The new private and government facilities proposed in legislation submitted to Congress in 1976 would be equal to or greater than the total present U.S. capacity. This would bring the total free world capacity in the mid-1980s to three or four times present levels, well beyond currently projected needs. The Soviet Union also has excess capacity and is selling toll enrichment services on the world market. In short, no shortage of enriched uranium need occur in the 1980s, and there is ample time to meet the needs beyond 1990.

The rapid pace of technological development further complicates decisions on expansion of uranium enrichment since new separation techniques may significantly reduce the cost of enrichment. While two of the proposed U.S. plants would employ the same gaseous diffusion technology as existing plants, three others would employ the centrifuge technology which may prove less expensive. More significant is the prospect that laser isotope separation will reduce drastically the cost of enrichment. If, as we anticipate, this new technique proves commercially feasible, both the construction and operating costs of an enrichment plant will probably be much less than those of either the new gaseous diffusion or centrifuge plants. Laser separation may also stretch uranium supplies and reduce costs by making the extraction of a larger portion of available uranium-235 economically feasible. In these circumstances, it would appear to be prudent to let the technology of centrifuges and lasers evolve further before making major new commitments unless they are urgently required.

While centrifuge and laser technology may support nonproliferation objectives by making enriched fuel available at lower costs, they also create proliferation problems since they make possible much smaller plants that can be converted to the production of weapons-grade enriched uranium. This could prove to be a particularly serious problem with laser enrichment plants, although it may be somewhat compensated by the very high technology and special lasers associated with some of the approaches to laser isotope separation. The inherent size and capital cost of gaseous diffusion plants have provided something of a natural barrier to the spread of indigenous enrichment facilities.

We believe the United States should maintain adequate uranium enrichment capacity to meet worldwide nuclear power requirements. However, in view of rapidly changing demand projections and the possibility of radical technological developments, decisions in this area should not be taken hastily. Nor should the United States attempt to monopolize the world market, since availability of alternative suppliers of safeguarded fuel will enhance confidence in fuel supply. Decisions on expansion should therefore take account of worldwide enrichment capabilities, which should be looked on as an added resource.

The present argument for private ownership of new capacity is not persuasive. Proposals involve extensive government guarantees and few of the advantages of a competitive market. Although we favor the principle that nuclear energy should be judged by unsubsidized competition with other energy sources, we believe that the government should at this time retain control of both enrichment facilities and new enrichment technologies. If this is done, the U.S. government will be in a stronger position to use this resource in support of its nonproliferation policy and in dealing with the security problems that may be created by new enrichment technologies.

Export Policy

Most countries have access to nuclear facilities and fuel only through imports from a small number of supplier states. The terms of such trade can contribute significantly to nonproliferation objectives. The United States cannot, however, unilaterally determine international nuclear trade policy since a growing number of countries are competing for the nuclear export market. Attempts to restrict trade in nuclear fuel cycle facilities must take into account the U.S. commitment in the NPT to facilitate the peaceful use of nuclear energy in exchange for the commitment of other states to forego nuclear weapons. Moreover, attention must be given to the impact of export policies on the political concerns of the few key countries that must reach their own decisions not to develop nuclear weapons.

Despite these limitations and complications, U.S. export policy can significantly support its nonproliferation objectives. As the long-time leader in the field, the United States has considerable influence with other suppliers, most of whom are allies. Although the ultimate response to proliferation is political, important actions can be taken in the export field in conjunction with a broader diplomatic effort to develop a consensus on the merits of a nuclear fuel cycle without plutonium.

From the nonproliferation standpoint, the focus of concern must be on exports of facilities that can separate plutonium or produce highly enriched uranium. Such facilities provide a capability for all but the final steps in the production of weapons. This capability might significantly influence a nation's political decision to develop nuclear weapons in a time of crisis. Such facilities also greatly increase the threat that material suitable for weapons might be stolen by terrorists.

Fortunately, at the end of 1976, other major nuclear suppliers seemed to be moving in the direction of U.S. policy, which has always refused to license exports of these sensitive facilities. The United States should build on these emerging attitudes to develop a consensus among supplier and consumer nations alike against the spread of national plutonium separation and uranium enrichment facilities. This agreement should be built upon a common recognition that it is more in the interests of both suppliers and consumers to reduce the possibility of nuclear proliferation than to pursue marginal economic gains or status from the sale or acquisition of these sensitive facilities. The success of such an effort will depend largely on the extent to which it is widely recognized as a major U.S. priority with strong Presidential support.

A U.S. proposal for international reexamination of the economics of plutonium recycle and breeders will hardly be credible unless the United States is itself prepared to defer its own plutonium recycle and breeder commercialization programs on valid economic and energy supply grounds. Such action will not necessarily convince all countries but will certainly influence their thinking and will preempt charges of discrimination or of failure to honor NPT commitments.

If plutonium reprocessing and recycle and attempts to commercialize breeders are postponed, there will be increased concern about the future availability of enriched fuel for light-water reactors. U.S. export licensing procedures should permit the United States to make credible guarantees of fuel supply to countries that are in compliance with the NPT or other agreements in the operation of their nuclear programs.

Although safeguards cannot prevent a nation from developing a nuclear weapons capability, they can help to deter it and provide assurances to others that it has not done so. The value of safeguards is obviously greatly weakened if they do not apply to all of the nuclear facilities in a country and, in particular, to any indigenous facilities for reprocessing plutonium or enriching uranium. While the NPT obligates nonnuclear weapon states that are members to place all their nuclear facilities under safeguards, the United States and other suppliers have interpreted their treaty obligations on exports to nonNPT members as requiring that the nonmembers place under safeguards only the exported facilities or materials and not *all* their nuclear facilities. To strengthen safeguards, the United States should seek in future agreements with nonNPT members to have all nuclear facilities placed under IAEA safeguards. An effort should also be made to renegotiate existing agreements to include this provision and to persuade other suppliers to adhere to a similar policy. To emphasize that inspection is not intended to serve a discriminatory purpose, the United States should move promptly to implement its offer made in late 1967 in connection with the negotiation of the NPT to put all U.S. peaceful nuclear facilities under IAEA safeguards. The United States should give generous financial and technical assistance to the IAEA so that it will be in a position to handle its rapidly growing responsibility for safeguards.

Above all, in approaching the energy problem, the United States should discard the promotional approach to nuclear energy that has characterized so much of its program since the initiation of the original "Atoms for Peace" program. In all countries, but particularly in developing countries, the United States should encourage realistic assessments of energy needs and options and not press the nuclear option.

In this overview, we have endeavored to put nuclear power in realistic perspective relative to broader economic, social, and security objectives and to develop a framework for considering the current policy decisions on nuclear power. In the body of the report, we examine the elements of the nuclear power problem in greater detail. The report is divided into four parts: Part I deals with the economics of energy, energy supplies, comparative costs of nuclear power, and potential alternative energy sources; Part II deals with the impact of nuclear power on human health and the environment in normal operations and the potential effects of reactor accidents and nuclear waste; Part III examines the relationship of nuclear power to the proliferation of nuclear weapons and nuclear terrorism; and Part IV presents a more detailed analysis of the specific policy decisions currently facing the U.S. government.

Questions to the Nuclear Energy Policy Study Group

The questions which follow were given to the Ford/Mitre panel members for written responses. At the time of publication of this print, those answers had not been received.

GENERAL

What should be our long term energy posture? (a) Continued imports? (b) Energy independence? (c) Energy exporting?

For each of the above, what are the implications with respect to: (a) National Security? (b) Domestic Economy (Balance of Payments, Unemployment, etc.)? (c) International Equity?

Should such a potentially important policy document as this one be issued without adequate peer review, as has been the criticism of the Rasmussen report?

Do you regard your decision that development of the breeder option can be delayed for many years as one which truly balances overall risks? Your arguments for delay depend upon the positive outcome of many shaky hypotheses: high uranium availability, non-economic competitive production of large quantities of coal, and oil from shale. Would it be fair to observe that there is a serious asymetry of risks in your picture of future energy needs? What if the breeder is needed in 20 years and it is not available for commercial deployment? What value do you place on having an assured breeder option?

Could you describe how your Group of 12 learned men could unanimously agree on the Conclusions of this report? Usually there is substantial disagreement or at least alternatives which are preferred by some of those in a group as large as this.

RESOURCE (Supply)

Your report states that you believe the Government's estimates of uranium reserves is very conservative. I'm sure you are familiar with the work of the group of uranium experts that have compiled estimates as a part of the energy study of the National Academy of Sciences. Could you tell me why you believe they have concluded that ERDA is, in fact, overly optimistic in their estimates?

The report deplores the lack of communication by ERDA with the U.S. Geological Survey (p. 83), because the USGS has established through many years an improved methodology of resource estimation, and the USGS possesses regional specialists whose knowledge would be especially valuable to the ERDA program.

The report says that ERDA's uranium estimates "are now conceptually incompatible with those of other resources." Does that statement refer to all other resources, to all mineral and fuel resources, or just to all mineral resources? What is the problem with this conceptual compatibility?

The report hints that "ERDA's narrow sandstone focus" would likely be broader if the USGS played a major role in preparing uranium estimates. While this is undoubtedly true because of the broader perspective of the USGS, is it not true that in the early days (1950's) of the domestic uranium exploration the USGS and AEC program was a joint one, and thus the narrow sandstone focus could be chargeable to both agencies?

The report suggests the advisability (p.83) of the government doing the search for "the necessary information" on uranium in unconventional environments, or to provide exploration incentives for industry to invest in such activity. Are these mutually exclusive, or how could a mix be accommodated?

Two typographical errors occur, one of which appears to be serious. In table 2-3, the world total for reasonably assured resources of $30 uranium should be 2310, not 3310, should it not? The African country is Niger, not Nigeria, as correctly stated in Table 2-3 but incorrectly printed in the last paragraph on page 80.

As discussed in the text (p. 81), there are "undoubtedly large amounts of uranium in the Soviet Bloc and China," however, it continues, "there is no reliable information available on Soviet reserves and resources." How about the Soviet Bloc and China reserves and resources? What evidence is there that "large amounts of uranium" occur in the Soviet Bloc and China?

There seems to be reasonable agreement upon the amount of uranium known to exist as defined by drillings and other evidence. But when it comes to estimating undiscovered uranium, estimates vary. Economists follow the traditional assumption that demand for uranium will produce supply. On the other hand, geologists are less optimistic and note that uranium often is not where logic would suggest it to be. In arriving at its assessment that adequate supplies of uranium eixst, how did the Study Group take into account and balance the widely different views of how much uranium there is in the U.S. and where it is?

In discussing the "vicious circle" that would result from purchase commitments, the report says (p.87) that "there is no comparable desire to have assured contracts for coal, oil, and gas." This statement is contradicted by the practice of the electric utility consuming sector in the past several years to arrange long-term (20-30 years) purchase contracts for coal, for a large part of the projected life of the coal-burning power plant. Canada's decision to decree a 30-year set-aside of domestic uranium reserves for each domestic reactor (p.87) was probably not reached without consideration of the "vicious circle." Therefore, is not the concern expressed in the report somewhat of an overstatement?

The report states (p. 77, Para.3) that it is wrong to conclude from available data that low-cost uranium reserves are nearing exhaustion, because "there is too little knowledge of uranium resources over the whole country." Because many explorationists and developers of any mineral habitually claim that the data are inadequate, how can one assess the credibility of this statement? Assuming that it is correct, what kind of knowledge must be acquired, how, and in what time frame?

The report correctly notes the increase in uranium exploratory activity in the past couple of years, and wisely comments that investment is needed in development drilling, in manpower, and in new mills to process the ore -- if the projected increase in demand is to be met (p. 84). The report then expresses seeming complacency that a uranium shortage can be handled if our attention were turned toward limitations on processing, and states, "Fortunately, society has better means of dealing with industrial constraints than with a lack of natural resources." Please supply examples to justify the quoted statement, which seems to reduce a complex issue into a single positive statement.

If one adopts a "prudent planning" estimate of 2.0×10^6 tons U_3O_8, is there a greater urgency for the breeder.

INTERNATIONAL/PROLIFERATION

With the exception of concern for nuclear weapons proliferation, the breeder reactor could be the most direct and viable path to stable energy costs and a position of being a reliable net exporter of energy -- coal, oil or enriched uranium. The report considers only the undesirable and destabilizing aspects of nuclear weapons proliferation. How does the report help us consider the destabilizing consequences of non-nuclear weapons proliferation? How can the non-nuclear weapons trade, which currently is one of the principal means used by industrial nations for recycling petrol dollars, be diminished if we pursue a path of increasing reliance upon oil imports? Can we allow this condition to persist 25 to 50 years longer than necessary because of a delay in our breeder development?

A recent item in the Economist (March 19, 1977, pp. 12-13) notes that nuclear power is expanding in controlled societies without the opposition now seen in the democracies. What is your assessment of this observation? If true, what are its implications for future proliferation? If true, what are its implications for future world energy policy and for national security of the United States to the extent that the latter depends upon the amount of fuels and energy we import?

What do you think will be the likely response to other countries to the proposition that they are not trustworthy to possess and use plutonium, and to have and operate nuclear fuel reprocessing plants, but that the United States is trustworthy to continue to operate large reprocessing plants at Hanford and Savannah River and to ship plutonium from point to point for industrial processing and fabrication? (Refers to U.S. weapons program which produces plutonium and makes it into nuclear warheads.)

The report (at page 327) bases much of its conclusion about economics of foreign reprocessing upon use of a large reprocessing plant, arguing the economy of scale. To what extent did the Group consider whether foreign analysts agree with our concept of the effect of the economy of scale? To what extent did the group consider the effect upon economy of scale analysis of other factors such as national security, costs of importing uranium, or willingness to use a labor intensive process?

The Study Group observes (p.279) that preventing construction of small reprocessing plants dedicated to weapons production is an urgent task. To what extent did the Study Group consider how such plants could be detected if built and operated secretly? What is the considered opinion of the Group as to present U.S. capability to detect such plants?

The Study Group emphasizes the dire potential consequences of a successful theft of dangerous nuclear materials by a terrorist organization. To what extent did the Group consider the desirability of assigning protection of nuclear materials and facilities to the Department of Defense? Can a private or other public protective force be as credible a deterrent as the armed forces?

If, despite domestic banning of plutonium, other nations proceed to use plutonium as a fuel, how much different will the risk of terrorist use of plutonium within the United States be than if plutonium were permitted to be used in the United States?

If the U.S. is to import uranium, to what extent will nonproliferation controls imposed on such uranium by the exporters limit its use here? For example, Canada apparently would like to require safeguards inspection within U.S. enrichment plants, but the U.S. does not like this idea. If this is not resolved, Canada might decline to export uranium to the United States.

If laser separation of isotopes will "reduce drastically the cost of enrichment" and "prove commercially feasible" as the report anticipates, what is there to prevent or discourage any ambitious country from establishing its own enrichment and weapons capability?

TIMING FOR BREEDER TECHNOLOGY

Your report recommends that a "breeder program with restructured goals should be pursued as insurance against very high energy costs in the future." While you state that restructuring the breeder program was beyond the scope of your study, you did not lcearly define your proposed goals but you did make some strong recommendations relative to elements of the program structure. With respect to your proposed goal of "insurance against very high energy costs in the future:

What are the conditions or events under which the insurance policy must "pay off?" (a) Problems with coal? (b) No more LWR fuel? (c) Breeders are more economical?

How do we know when we have reached "this point?" (a) Utilities can't build coal plants? (b) Utilities won't buy LWR's(*)? (c) ?

When we have reached "this point," how must the insurance pay off? (a) Restart the sequence of plant scaleup, public acceptance, utility training, etc., on some form of breeder? (b) Replace LWR's that are scheduled for decommissioning with LMFBR's. (c) Supply all new and replacement electrical demands with LMFBR's? (d) ?

If the breeder option is to be maintained as insurance, how do the authors propose keeping enough of the present highly skilled breeder team together?

During the interim between now and the "pay off point," what can we expect to have been achieved towards resolution of the plutonium economy problem?

Is it reasonable to expect that resolution of such a complex problem can be achieved through a "base technology" program?

Should we depend on the existence of a "more favorable climate" in which to resolve the problem?

Is it fair to future generations to "force" the resolution of such a complex problem in a crisis situation?

How can the regulating agencies function in a meaningful manner under these conditions?

If we adopt the "insurance" goal, don't we need the pay off to be: The Ability to deploy, when required, a high confidence breeder system complete with its fuel supply?

If we assume that the signal for the insurance policy to pay off is the refusal of utilities to buy more non-breeder reactors based on the fact that we have committed all of the economical and environmentally acceptable uranium, we may have about 20 years of nuclear power capability left. At this point, don't we have to be in a position to deploy full size breeders that we are sure will work in every respect (technical, economics, licensing, fabrication, construction, maintenance, etc.) on the first try? If we try to bring several concepts to this status (e.g., molten salt, HTGR, GCFR, etc.), how much will that cost?

How does one draw a meaningful parallel to the breeder development program in view of the fact that all of the major industrial nations including the U.S.S.R. are proceeding with the sodium cooled fast breeder? Are the differences between loop and pool designs such that one type or another will become economically unattractive? Even if such were the case, how could such a determination be assisted by a delayed U.S. program?

(*) Based on p. 2-30, the last plant is ordered in 1990 and the last plant shuts down in 2030.

Assuming the early commercialization is not justified, is termination of CRBR the proper action simply because its stated goals are premature? What is there to preclude CRBR from satisfying valid restated goals associated with the "insurance policy" or contributing to an orderly progression to a commercial plant? In other words, is not a delay in PLBR the more appropriate action along with a delay in the 1986 decision on commercialization?

You state that the Clinch River Demonstration Plant is not necessary in a restructured program and "could be cancelled without harm to the long term prospects of breeders." Yet you also state that the restructured program should emphasize base technology. Have you investigated, and with whom, the relationship between a base technology program and a demonstration plant which embodies the base technology? Do you believe that an effective base technology program can be carried on indefinitely without integral demonstration of the technology?

You write that a premature demonstration of a noncompetitive breeder could be detrimental to its ultimate prospects. This implies that it will some day be possible to build a fast breeder demonstration plant which will be competitive when built. Do you believe that? Does the idea of looking at many different breeder cycles but not putting any of them into demonstration plants leave one on solid ground relative to deployment?

With respect to your views on "telescoping development stages" and "freezing technology prematurely," did you consult with any individuals engaged in the breeder program to obtain their views on these matters?

Argonne National Laboratory has been operating an experimental breeder reactor for 13 years -- did you discuss with them your views on "freezing technology prematurely?"

The report contends that a more relaxed timetable would allow a stretch-out of the prototype sequence and hence more opportunity to integrate important new research efforts into the reactor development process. The essential ingredient of continuity of technical expertise seems to be minimized to the point of insignificance. How do the logistics of such a program make sense in view of the fact that there may be up to ten year intervals between common points in a delayed sequential design-construct-operate cycle? The French program was not sequential.

What are the major variables leading to your conclusion that a breeder technology can be safely deferred, which might alter this conclusion?

(a) rate of economic growth?
(b) rate of energy growth?
(c) rate of electric energy growth?
(d) success of conservation or price related reduced energy demand?
(e) availability of uranium?
(f) capability to utilize coal?
(g) cost and availability of oil and gas?
(h) cost and availability of synfuel and shale oil?
(i) cost and timing of advanced energy technologies?

Have you tested the sensitivity of any or all of these variables to your conclusion? If so, at what point would your conclusion be reversed?

The Ford Foundation report implies that the Clinch River Plant is obsolete by saying that "is about to be superseded by the new ERDA/EPRI cooperative design studies for the PLBR." The report also suggests an undefined approach to basic technology rather than proceeding with Clinch River. Would you please clarify your conclusions in this regard?

If we decide to defer the present FBR program, what measures should we use to determine if and when to start it up again?

Why do other analyses with the ETA model used by your group show positive and substantial benefits for the breeder?

If competitiveness is to be demonstrated for the breeder, can this be done without proceeding with demonstration-scale breeders and fuel cycle pilot plants? Can we delay these demonstrations of the breeder option if a prudent view of a more constrained uranium ore availability is taken?

REPROCESSING

While the Study Group makes a case for not reprocessing spent fuel and using plutonium as a nuclear fuel for the near future, the Study Group appears to concede that use of plutonium may be necessary later one. During a moratorium, what Federal development of reprocessing and plutonium fuel technology should be carried on? How can the nuclear industry and the government plan ahead so that if and when reprocessing is begun, the decision and subsequent steps will not be taken so hastily that risks to proliferation and to public health and safety then will be greater than if reprocessing had not been suspended?

A principal element in the Study Group's assessment is that the economic and conservation values of reprocessing and plutonium recycle are marginal at best and so it does not matter much if use of plutonium for nuclear fuel is banned in the United States. A recent analysis by S.M. Stoller Corporation estimates that the money savings from a plutonium-recycle economy through the year 2065 would amount to some $180 billion, with 85% of this benefit realized by 2025 (Nuclear Fuel, March 21, 1977, p.18+). What is the Committee to conclude when equally eminent groups arrive at such widely divergent findings? To what extent did the Study Group consider the views of analysts such as Stoller?

ERDA feels it must have commitments for new enrichment capacity in order to provide enrichment services at reasonable tails assays (thus conserving natural uranium) and to "open the order book" for new enrichment services. The centrifuge process is nearing commercial application. However, for the laser process neither the technical production feasibility, let alone commercial feasibility, have yet been demonstrated. Page 69 of the Report suggests that it would "be prudent to let the technology of centrifuges and lasers evolve further before making major new commitments unless they are urgently required." What are your comments?

DEMAND

Experts differ by factors of 4 to 5 on demand and uranium supply; the GAO and others have estimated that the LMFBR program will result in only 4 to 5 power plants by 2000 compared to the 30 projected by ERDA. Would you please give us the range of expert estimates that were considered by your Group on the critical issues of U.S. growth in demand for electric energy, U.S. supply capability for uranium feed, and time required for commercialization of the breeder?

If a 1 to 2% shift in the GNP is an acceptable cost to bear, what is not acceptable: 3%, 5%, 10%?

Other than by the shift in GNP from non-energy to energy purchases, are there measures of the cost to consumers of the question above? For example, what ahppens to the price of electricity, all energy forms?

Discounting future benefits at 10% for a period of 50 years for a system whose major benefits are accrued in the last 20 years seems to be an inappropriate basis for determining comparative economics. Do you think that discounted benefits are underestimated because of timing and a high discount rate? Is the method appropriate? Is the discount rate too high? What if a 5% or 3% discount rate were used?

Your conclusions and recommendations concerning a plutonium economy and the breeder reactor depend heavily on certain assumptions about uranium supply, coal production and the consequent results obtained from your economic model. How convinced are you that the other available energy-econometric models would have given you the same kinds of ranges on energy supply and demand and the effect of energy growth on GNP?

The Committee on Nuclear and Alternative Energy Systems (CONAES) energy modelling group, of which Alan Manne is a member, is examining various models by using the same inputs. The reports indicate that the outputs vary as much as 50%. How can you justify such a critical decision about our energy future on a technique that has such dubious predictive power?

Given the uncertainties of our energy supplies as well as the energy models, it seems that prudent energy supply planning must aim for a larger capacity than what is needed. Did you take this into account in making your recommendations to reduce the breeder program to a research effort?

IMPORT POLICY

U.S. uranium import commitments in the past two years have quadrupled, and the U.S. can greatly expand its imports "before falling into the kind of dependency that it is trying to avoid in the case of oil" (p.92). Recent national awareness of the seriousness of our continuing energy-supply situation should cause government policy analysts to reexamine this import issue and particularly to be careful of complacent statements like the report's statement regarding U.S. imports. Can you document or otherwise justify your optimism about the low-risk nature of such imports?

In the summary (p.94), reference is made to "the slow schedule for full removal of import restrictions" on uranium, but we cannot find documentation or discussion of that statement elsewhere in the report. Please furnish this information.

COAL MINING AND TRANSPORTATION

In discussing the reserve base for coal in the U.S., the report states (p.100-101) that a large-scale, comprehensive R&D program to develop entirely new mining methods has been initiated by the Federal Government -- and that the coal-mining industry "should be able to supplement this government-sponsored program and accelerate the introduction of new technology." What are the elements of this government program? What research areas is the coal-mining industry actively pursuing today, and where is industry's future mining R&D effort likely to be concentrated?

Regarding the structure of the coal industry, the report says (p.102) that "attempts to restrict ownership of coal companies could have an adverse effect on future coal development," with the implication that the large investments needed to open up new mines will cause even the largest companies some difficulty. Please supply documentation for this significant statement.

Regarding coal transportation, two questions arise:

The report rightly says (p.103) that the contemplated expansion of coal production to meet increased demand goals by 1985 "could be constrained by transportation's" inadequacies, citing particularly the deterioration of railroad equipment and limited lock capacity on the Mississippi River for barge transport. Please expand on these statements on the inadequacies of rail and barge transportation.

In the discussion of coal-slurry pipelines, the report correctly points out (p.103) the local opposition in water-short areas such as the Northern Great Plains, and concludes that "a return pipeline to recycle water would reduce water requirements by 70-85 percent and eliminate water-cleaning problems, since the returned water would be used to reslurry." However, the report overlooks the energy required to pump this water, deadhead the long distance back to the originating region -- and to lift it the 2000-3000 feet in altitude lost during its original trek eastward. Discuss the net-energy significance of the slurry pipeline for transporting coal out of the originating region.

ENVIRONMENT, HEALTH AND SAFETY

The study includes as a rather significant portion of the health and safety effect of coal-fired plants, accidents involving train transportation of coal. No consideration seems to be given to the potential reductions in loss of life or accidents which could be accomplished by such changes as mine site location of power plants or the proposed use of pipeline transport of coal. What would be the effect on estimates of health and safety if calculations were changed to postulate greater emphasis on these technological changes in the transport of coal?

As already noted, the data used from the CHESS studies have been demonstrated to be in substantial technical error and identified as essentially useless for predictive determinations. Further, there are inadequate comparisons of the long-term impact on populations of the burden of radioactive waste-handling and storage (which also might be postulated as having a greater risk from train transport accident than has been included, particularly as volumes increase and also because a castastrophe in transporting radiowastes would have greater implication than a collision or track jump with a coal train) as compared with the potentially great possibility of technological control of stack gases from coal-fired plants. It would appear that health and safety could be controlled for coal-fired plants more effectively than for nuclear plants, particularly when time factors, (beyond our ken in the case of storage of radioactive wastes) are factored into total effect. Please comment -- e.g. hazards from coal are technologically controllable and the immediate risk thus controllable; nuclear risks are continuous regardless of the high technology for containment since the risk persists so long and depends upon a continuous monitoring and dependence upon no risk from natural catastrophes.

How can the long-term genetic risks to populations from radiation, which all studies agree will occur although there is disagreement as to the extent of these risks, be compared with the short-term potential respiratory risks from SO_2 at high levels, which is a short-term risk affecting specific individuals and not future generations?

With regard to the coal energy cycle risk estimates, the data from the CHESS report were used as one source to estimate health effects of effluents. In view of the recent finding of the Subcommittee on the Environment and Atmosphere that the CHESS report findings are highly questionable, was it prudent to use these data in the context of this report?

The report concludes that estimated risks to health for the coal energy cycle are much higher than for the nuclear energy cycle. Have comparisons between the nuclear energy cycle and other energy cycles (oil, gas, geothermal, solar) been made with respect to health effects? Could these data be presented to the Committee in tabular form? In fact, would it be possible to better summarize the comparative health risk data in this report in tabular form? If possible, please tabulate the data by category on the basis of the highest and lowest risk estimate.

The report, at page 326, would have so-called low-level wastes containing plutonium and fission products accorded the same treatment as high-level wastes. Does this mean that the Group would eliminate the classification of low-level wastes and require any wastes containing plutonium and fission products, no matter how small the amount, be treated as high-level wastes?

O