ERDA'S ROLE IN THE DEVELOPMENT AND ACCEPTANCE OF LIGHT WATER REACTORS

by

LWR Study Group

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Preface

The MIT Light Water Reactor R&D Strategy Assessment project is a two-year effort to assess the institutional, regulatory, economic, and technical factors influencing the development and deployment of LWR technology. The Interim Report (1-4), of which this report is a summary, is a report of preliminary results and analysis. A final report will be submitted in September, 1978.

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Contents

1. Introduction

In 1976 nuclear power accounted for 9% of electricity generated in the United States. The technical and economic potential of this technology have in general been realized, although significant improvements are technically feasible. In spite of this, the domestic nuclear industry may grind to a halt.

We are studying this paradoxical state of affairs from both institutional and technological perspectives, paying careful attention to the interplay between the two. We have examined the attitudes and actions of many sectors - electric utilities, vendors, federal agencies, state agencies, architect-engineers, financial underwriters, public participation groups - all as much as possible from their own perspectives. Our approach is to combine acquisition and analysis of information on the issues as perceived by the various "players" with technical and economic analysis of the costs and benefits of changes to the technology and to the institutional and regulatory regime which influences its deployment.

Our analysis of the interest and perceptions of these various groups indicates not only that the public decision-making organizations have been unprepared to handle the breadth of issues involved and hence have been caught by surprise, but they also seem to persist in that state, not by stagnation, but by continually lagging. Surprising new developments will arise, as will new problems, until eventually one or more of the following alternatives occurs:

The pace of LWR orders and installations will slow down so much that the nuclear industry as presently constituted (or even modified) will be unable to survive, thus ending the U.S. participation in the nuclear power field pro tem; or

The Federal and State Governments will decide that increased nuclear power is in the public interest and will make effective opposition and intervention more difficult; or

The problems of public acceptance of nuclear power, being largely generational, will gradually evaporate, provided, of course, that the above alternatives do not intervene.

Whatever the ultimate outcome, our analysis to date suggests the following conclusions.

1. 'Institutional and technical aspects of the role of nuclear power cannot be fully separated.

2. The most pronounced problems are (mainly) institutional and social, and failure to solve them will be sufficient to eliminate the nuclear option.

3. We see substantial economic and social benefits from improvements in both technical and institutional aspects of nuclear power.

4. Many feedback paths exist where difficulties foster responses, which in turn reinforce the difficulties.

5. ERDA, or other Federal agencies, need to deal with a substantively broader range of societal and institutional issues than has hitherto been the custom; we have several suggestions, both general and specific.

6. Excessive uncertainty - in regard to policies, supply, standards, cost, future acceptability - has had a very corrosive effect on the LWR sector. (Irrational irresolution must here be distinguished from keeping rational options open.)

7. A substantial number of relatively non-disputable technical improvements can be made right now, but to fix on those as surrogates of the real problems would exacerbate institutional difficulties

In the remainder of this report we discuss the basis for these conclusions. The reader should note that the participants in the study all believe that nuclear electric power, if properly implemented, can contribute substantially to meeting U.S. and world energy needs. Our purpose in this study is not, however, to build a case for nuclear power. Rather we seek to improve understanding of the present circumstances influencing the development and deployment of this technology, and to analyze differing perspectives and the likely consequences of particular actions. We attempt neither to present our own social viewpoint, nor to judge the viewpoints expressed by others. As a result some readers may find in this study reasons to strengthen the LWR sector; others may find reasons to abandon it.

2. Institutional and Social Aspects

2.1 Summary of Approach

We have followed three general approaches in our analysis. The first approach involved interviewing nearly 60 organizations concerned with nuclear power, including 12 electric utility companies (public and private), 12 public interest groups, 12 state regulatory agencies, several vendors, architect-engineers, financial firms, and branches of the Federal Government (including the Congress (1)). In all these personal interviews, most of which were done by telephone, the basic format was as uniform as possible, viz.

1) What are the problems with the LWR program, if any?

2) What agencies or sectors should be addressing the problems mentioned in 1)? Do they have the proper incentives and means to do so?

3) How do you see the role of your organization in addressing those problems?

4) What is the process by which your organization reaches decisions with regard to your involvement in the LWR program, and which are the most important factors which determine those decisions? (When addressed to utilities this question meant decisions to build LWRs instead of coal plants, or perhaps nothing. When addressed to the public interest groups it meant the decision to intervene in the license process, etc.)

5) Is there proper balance between nuclear power and alternative energy sources with regard to public acceptance, regulation, promotion, R&D, information about safety and environmental impacts?

Variations and elaborations were designed for each group, and topics that each group thought especially important were explored. Typical interview times were one to two hours.

The second approach (see (2)) involved questionnaires, sent principally to selected electric utility companies and regulatory agencies, designed to elicit information on the effect of regulatory procedures - on planning, construction schedules, costs, and productivity. The results of this survey (now being analyzed) will be combined with results from a parallel study we are presently (August 1977) carrying out in Europe in hopes of making some insightful comparisons.

The third approach has been focused on preparation of topical essays, each dealing with a facet of the problem we thought important <u>ab initio</u> (see (1)). Examples are: how balance can be upset between promotional and regulatory forces, the role of public information, and the (in)adequacies of existing institutions to deal with LWR issues.

In this synopsis, the three approaches have been integrated as much as possible so as to highlight several over-riding topics which have emerged to date. Many topics of interest but lesser importance are here mentioned hardly more than by their titles. (See (1) for more details.)

2.2 The Role of Uncertainty

Although each sector perceived this problem far differently, almost all gave it high priority. For example, the electric utility industry has traditionally operated in an atmosphere in which the technical challenges were substantial but not overwhelming, and where regulation permitted them to exchange the chance of high profits and the risk of financial failure for a relatively guaranteed but moderate rate of return on investment. Their time perspective was long, because of owning and operating equipment with expected lifetimes of about 40 years. For a long period preceding the 1970's utilities grew accustomed to decreasing real costs of both fuel and capital equipment (mainly through increases in size and generating efficiency). Because electric energy rates were generally set on the basis of past performance, the companies could usually take advantage of improving circumstances between rate reviews. Additionally, electric power plants were small enough in size and number so that siting was a tractable problem. Fuel supply was simpler; to be sure, the price ten years hence might not have been predictable, but the supply was predictable, and therefore some price explainable to rate commissions surely existed. Environmental degradation had not emerged as a large issue, and alternative low-energy lifestyles had not been discovered

All that has changed; the electric utility companies see the following problems being posed within the electric utility sector, but they cannot be solved within it:

- A time limit on resources may now exist which falls within the time limit of new plant obsolescence.
- The utilities must change their technological base for power generation within one technological obsolescence time (on which there is more below)
- Environmental constraints restricting and delaying siting of new plants and requiring new control equipment.
- In the LWR area especially, what seems like the possibility of endless backfits, and bad estimates of their cost.
- Perception by the utilities that governmental attitudes are illogical, uncertain, and unpredictable with respect to nuclear power. An example of this is what to do with spent fuel; are the electric utilities liable to be stuck with it?
- The virtual guarantee that various groups will intervene, much more so for nuclear plants than for other types.

More problems of this non-internalizable sort could be listed. One that may soon arise is a court finding that the Price-Anderson Act is unconstitutional (in limiting the right to sue, not in the matter of government guarantees). Then electric utility companies, without an adequate national consortium arrangement or a government guarantee of support, will feel themselves unable to answer demands for fiscal responsibility at the levels demanded by critics.

The electric utility sector's rewards are not based on building nuclear reactors, but in large part on providing reliable service at low cost. Escalation of uncertainty escalates doubts about future reliability and future cost. Thus the electric utility sector finds reasons

- at least in the short run - not to "think nuclear," but rather to opt for solutions defensible at state levels in the short term: these include installing oil-coal convertible plants, burning oil today and recording for future defense the Federal government's optimistic remarks about future coal acceptability and availability. Alternatively, the electric utility company may install nothing, waiting until public demand forces them to install turbines on a short lead time. Clearly, this strategy does not deal with long-term problems; it ignores them. Thus, we find that quite apart from questions of long-term economy, long-range logic, international security, etc., the electric utilities have strong incentives to avoid the LWR business.

The effects of excessive uncertainty become obvious in the actions of vendors. Besides facing certain of the problems described above, they see reduced incentives to make long-term investments in what may be a dying industry. To the best of our knowledge, none of the principal vendors has more than 10% of its business in nuclear reactors and most could as easily make fossil fuel components for electric power plants.

At the other extreme, this uncertainty causes rejoicing. Some groups opposed to nuclear power (see below for some misunderstood reasons) accurately see the proliferation of uncertainty and distrust as helpful to the cause. Far from having any interest in resolving these matters, they actively promote dissension and non-resolution, to further weaken nuclear power as an energy option.

At a peculiar intermediate level, we find the architect-engineering sector whose rewards depend on resolving uncertainty and complexity in the long term, even though in the short term they stand to lose financially if certain standardized designs are adopted.

2.3 Reinforcing Feedback Loops

Many exist which can operate either to reinforce the dominance of a particular technology or to ruin it. The reinforcement of dominance is easy to see: the LWR sector so dominates the nuclear industry that any alternative design (e.g., an advanced CANDU) is given little possibility of success in the U.S. because it could not penetrate the market in time and no U.S. commercial support exists for it. The dominance of the LMFBR over other breeder concepts is a well-known example of how certain programs develop momenta of their own.

Some less obvious reinforcement loops operate the other way to ruin the industry. If the electric utility sector and the manufacturers think that ERDA will develop the technology for new energy options, then the non-ERDA sector sees little benefit in doing much. That attitude leads to less attention and less competence by both the electric utilities and the manufacturers, thus increasingly justifying ERDA's role.

2.4 Imbalances

There are many. We choose three, and leave several others - like the imbalance of information regarding different energy options and its effect on perceptions and choices, to appear inferentially in this synopsis.

2.4.1 The problem and the participants -- The LWR problem involves the technological R&D sectors, manufacturers, electric utilities, regulatory agencies, environmntalists, public interest groups, and financial sectors. In 1970, however, the Federal Government not only denied that several of these groups had any constructive role to play, but through its internal actions also denied that societal issues had any substantial place in the debate.

Now even that statement would be no more than anecdotal history, were it not for the fact that many vital interests in the energy debate are still not included.As just one example, consider cities. A majority of the U.S. population lives in urban areas. Both the highest population density and (in general) the highest energy consumption per unit area occur there. Since the impact of energy use - hence of exercising energy options - per person increases monotonically with energy use per unit area, we see that the major societal impact of energy otpions on people comes via urban effects. These problems manifest themselves in many ways: commuters and urban expressways encouraged by a policy of cheap fuels; general air pollution and smog as a result of energy-environmental trade-offs; large urban buildings with glass curtain walls; urban designs that require air conditioners leaving those without them in even worse condition. So enters urban anomie, the lack of effective urban planning. This problem, now just appearing in full dress, has been evident as just described for years, but still no adequate attention is paid.

By title, we mention more: (i) the connection (or lack thereof) between civilian nuclear power and international weapons proliferation; currently that is a fashionable topic, and yet no one seeks out the real views of LDCs. (ii) energy conservation may be a matter of technical fixes or changes in attitude, but only recently have we begun to study seriously any of the low-energy use scenarios that have been proposed during the past several years. (iii) everyone talks about supposed health effects of energy, but why are the epidemiologists and public health sectors brought in so peripherally?

2.4.2 Different time perspectives -- The non-matching of time perspectives, and especially the lack of attention in this matter has led to much confusion, especially in regards to the proper role to be played by various sectors.

The business sector, figuring money can be obtained at 15% per year, has a six or seven year time horizon for recovering investments. The political sector generally has comparable or, more likely, shorter time horizons. Yet the time to develop major new technological options is typically 25 years (controlled fusion has been at it that long, and will take 25 more), and the time for depleting important resources has now shrunk to a similar period. The distinctly different character of these times leads to decisions that are perfectly justifiable in the short term and make no sense in the longer term: redouble the effort to find more natural gas and domestic oil, but pay relatively little attention to how a civilization will be able to switch <u>from</u> those sources in a very short time. On a longer time scale, the worldwide CO_2 levels are building up toward consequential levels early in the next century, and yet we stimulate conversion to coal.

Policies of short-term fixes and long-term consequences are not new, and can be seen through all of history. Consider for example, the Greeks and Romans who cut down their trees for firewood, then put goats on the land, thus turning much of the Mediterranean littoral from woods to the rocky landscape it has been for nearly 2,000 years.

2.4.3 Regulation and Promotion -- Is the present system stable? Is it inherently incapable of resolving these issues about LWRs? Almost all of our interviewees felt that the present regulatory system was not working well, although different and sometimes opposing reasons were given.

Rather than dwell on anecdotal details, we raise here the question of whether separation of function is really possible. A presumed internal conflict of interest over dual roles of promotion and regulation was the apparent cause of the AEC's demise and transformation. But what was accomplished? One can imagine the situation where each part, not needing any more to concern itself with the other, feels itself unshackled, so to speak, and free to pursue a pure course. Thus, while promotion and regulation become legally separated, the balance is also unstable, for as one side starts winning over the other, the putative loser has to yield more ground to preserve control over its most basic social objectives, to "look good" to public and Governmental sectors. One side captures the other, even though neither planned it that way.

Even if the finest balance persists, the separation guarantees that some major issues will not be resolved at the working level. Thus, in true Hegelian logic, the promotional thesis and regulatory antithesis must seek a synthesis -- i.e., a resolution -- at a higher administrative level. But now, at this higher level, the debate starts all over again -- promotion and regulation under the same roof. Sometimes the larger area is more appropriate, but the logical extension of this dilemma upward often overloads administrators at inappropriately high levels, who then, in desperation, must decide arbitrarily or assign the power of dictatorial decision to some inadequately prepared executive assistant.

Our form of government will not make it easy to resolve this problem (or a number of others). The impediment arises because the Federal government was purposely designed so that too much decision-making power could not be concentrated in one place. The founders' reaction to excesses of England's George III serves the country well in many ways, but it also permits indecision to cycle round and round. One particular manifestation of this in the LWR sector is long procedures that reach higher and higher into the administration, all of which can be overturned by court actions. The possibility or actuality of later court action modifies present decisions at the administrative level, but these modifications often do not prevent later challenges.

The weak Federal system depends for its proper functioning upon a citizenry that is well-informed about the fundamentals of the problem, as noted by Jefferson. Thus arises the need for broad dissemination of information, and the public perception and acceptance of it as well-intentioned and valid.

By this single example, we see how far afield a seemingly straightforward question has led us, and how far we (and ERDA) must reach for a suitably encompassing answer.

2.5 Nuclear Power as a Lifestyle Symbol

Any who doubt that this is a major issue should read A. Lovins' Soft Energy Paths (5). Nuclear power is seen as technology, and is opposed not just for itself, but for what is perceived to come in its train. We do not presume in this synopsis to attempt to debate nuclear versus non-nuclear futures, "high technology" versus "low technology," except to note that many public interest sectors claim that these broader questions are the real ones and that no one listens. One can make a generalization here: there are too few listeners on all sides and too many are prepared to talk right past others with different viewpoints. Our interviews with various groups were marked by the lack of concern - either spontaneous or stimulated - that any group showed toward the deeply felt view of any other group. Exceptions exist, of course, but the lack of charity was clear.

2.6 Who Is Minding the Store?

At present, no one. Both the White House and the Congress have been timid, as if more concerned with short-term popularity than long-term benefit. ERDA itself has interpreted its charter very narrowly; for a confirmatory example outside the scope of this report, see the assessments done by the Congressional Office of Technology Assessment of the ERDA budget and program plans in 1975. Some of those apparent timidities have been overcome (e.g., a much stronger interest in conservation and international issues), yet many more remain.

3. Technical and Economics Issues

3.1 Summary of Approach

The institutional and regulatory regime within which LWRs are deployed strongly influences both decisions to choose this technology and the technical characteristics and productivity of the technology. In this section we present information on the possibilities for improving LWR technology efficiency, and on the economic implications of these improvements for the electric power industry and electricity consumers. Our approach has been to analyze in detail the current condition of the technology in terms of factors determining capacity utilization, capital and other fixed costs, and variable costs, especially fuel cycle costs. Technical possibilities for improving these factors are then evaluated, and the expected changes in technology efficiency are estimated. These changes may be summarized in terms of changes in the busbar cost of electricity derived from nuclear power (see (3)).

However, changes in cost per unit of electricity delivered from nuclear will have second-order effects upon capacity expansion and production decisions of utilities through changes in relative costs and upon consumption decisions of consumers, through changes in the price of electricity. To measure the benefits of an improvement in nuclear technology requires us to measure these second-order effects.

To do this we make use of the MIT Regional Electricity Model (REM) developed by Martin Baughman and Paul Joskow (see (6, 7)). REM is an economic/engineering model representation characterizing the expansion and production decisions of utilities, and the consumption decisions of consumers. It provides an econometric submodel for determining the demand for electricity and competing fuels, for regional transmission and distribution, and for regulatory controlled pricing. The model can be checked with present data and conditions, and is used here to estimate the present value of possible future changes in LWR capital cost, in nuclear fuel fabrication cost, in LWR capacity factors, and in real fuel costs.

3.2 Targets of Opportunity

3.2.1. Increase Capacity Factor -- The value of improvements in the LWR capacity factor is substantial. In Table I, we summarize information on electric power expansion, production, prices, and fuel consumption under three assumptions about the capacity factors for nuclear power plants coming on line in 1990 (see (3) for further discussion). The most interesting scenario (column 4) involves an increase in the capacity factor from .64 to .75 for plants coming on line in 1990. By 1995, the effect of this improvement in efficiency is to increase total generation 5.4% over the base case with nuclear's share in generation rising to 52% of the total (up from 41% in the base case). Further, there is a savings in petroleum used in electric power generation of approximately .54 million barrels per day (MMBD). The total petroleum savings after accounting for substitution of electricity for direct use of petroleum is .86 MMBD.

The benefits from separate improvements would add less than linearly if, when the power plant shuts down for maintenance and/or repair, up-

Table I

Preliminary Results for Base Case

	Selected Scenarios						
	1 Base Case	2 Lower LWR Capital Costs	3 LWR CF=.85 Starting in 1990	4 LWR CF=.75 Starting in 1990	5 LWR CF=.50 Starting in 1990	6 High Coal Prices	7 Work in Progress in Rate Base
1974							
Total Cap (GW)	471						
LWR Cap (GW)	-33						
Generation (MMWH)	1800						
Price (M/KWH)	23.9						
Oil Cons. (Q Btu)	7.5						
Total Elect ($ * 10^9)	39.1						
1980							
Total Cap (GW)	612	612				612.4	612.4
LWR Cap (GW)	63	63				62.9	62.9
Generation (MMWH)	2353	2351				2354	2329
Price (M/KWH)	32.83	32.89				32.81	34.73
Oil Cons. (Q Btu)	6.5	6.4				6.46	6.21
Total Elect. ($ * 10^9)	70.2	70.3				70.2	73.54
1985							
Total Cap (GW)	727	726	727	727	727	727.4	712.3
LWR Cap (GW)	149	150	149.4	149.4	149.4	149.4	149.4
Generation (MMWH)	3003	3009	2986	2986	2985	2998	2763
Price (M/KWH)	40.67	40.48	40.64	40.64	40.71	41.06	43.83
Oil Cons. (Q Btu)	6.2	6.3	6.11	6.11	6.1	6.14	4.97
Total Elect. ($ x 10^9)	111.0	110.7	110.3	110.3	110.5	111.91	110.1
1990							
Total Cap. (GW)	919	923	912	912	898	916.8	941.5
LWR Cap. (GW)	246	259	257.7	256.8	228.9	245.6	239.0
Generation (MMWH)	3763	3801	3811	3807	3706	3717	3234
Price (M/KWH)	52.31	51.52	51.3	51.38	57.07	53.17	57.94
Oil Cons. (Q Btu)	3.8	3.5	4.42	4.38	4.32	3.81	4.05
Total Elect. ($ * 10^9)	179.0	178.0	177.8	177.8	199.6	179.6	173.49
1995							
Total Cap. (GW)	1106	1130	1134	1131	1071	1094.6	965.5
LWR Cap. (GW)	338	391	423.3	417.9	225.4	354.7	330.6
Generation (MMWH)	4611	4726	4945	4859	4464	4514	3955
Price (M/KWH)	67.54	66.59	63.26	64.29	71.6	69.05	76.11
Oil Cons. (Q Btu)	3.3	2.7	2.03	2.15	3.41	3.17	3.13
Total Elect. ($ * 10^9)	283.1	286.1	284.4	284.0	290.6	283.35	273.63

coming problems were recognized and repaired ahead of time. Most operations and repairs that can be scheduled during the regular refueling period do not affect the capacity factor, although they may affect other decisions about nuclear power quite profoundly. Better planned maintenance and pre-outage scheduling (planned outage and contingency scheduling) could save significant outage time.

With some uncertainty arising from these and other factors, we have analyzed NRC, EPRI, and other data, interviewed several electric utility companies and vendors, and arrive at the following list of items in order of priority. The expected annual dollar savings are based on the assumption of a 1000MWe capacity plant and $250,000/plant-day replacement power cost.*

(i) Refueling time -- If the present average refueling time could be brought down from an average of about 49 days to 30 days, the expected annual saving would be nearly $5.3 million/plant year. Such an improvement could only arise through a number of coordinated activities: increased standardization (hence better-optimized spare parts inventories, more experience with specific items etc.), better identification of key jobs and scheduling thereof, development of new control and monitoring systems, and so forth. We note that additional identical units at the same stations have had significantly better capacity factors.

Perhaps the most important matter is to understand all that is accomplished during refueling outages and which jobs have controlled the length of them. We are carrying on a limited study of the detailed possibilities, as part of this contract.

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*Estimates of replacement power costs depend upon costs of replacement capacity which may vary substantially. Our estimate seems reasonable, if not slightly low.

(ii) Fuel -- This is not refueling, but the fuel itself and the fuel cycle. Total benefits of about $4.9 million/plant year seem possible. For example, about $.5 million/year benefit would accrue if the modern reactor fuel (zircaloy clad) could be cycled as rapidly as could the old-style stainless steel fuel; then nuclear power plants come to full power more quickly. Further in the future they could load-follow to a considerable extent, so that more benefits might accrue from not having to operate fossil plants.

(iii) Turbines -- Savings of $2.3 million/plant year are possible here, mainly in improving reliability of large turbines. We have not studied this area in great detail, but note that while turbine designs have been stable for many years, new monitoring systems may offer advance warning of developing problems. The possibility of repair before failure could save significant outage time.

(iv) Steam generators and condensers -- Perhaps $2.1 million/plant year is available here by improvement of a few percent in plant capacity factor; the benefits come about equally from improvements in each class of device.

This topic allows us to show by example how we think about such matters. Figure I shows a preliminary decision tree for condensers. We have similar ones for turbines, steam generators, etc., which help us to find both critical path items and items for which R&D is liable to pay off. The refinement and analysis of these decision trees is an important part of our continuing work.

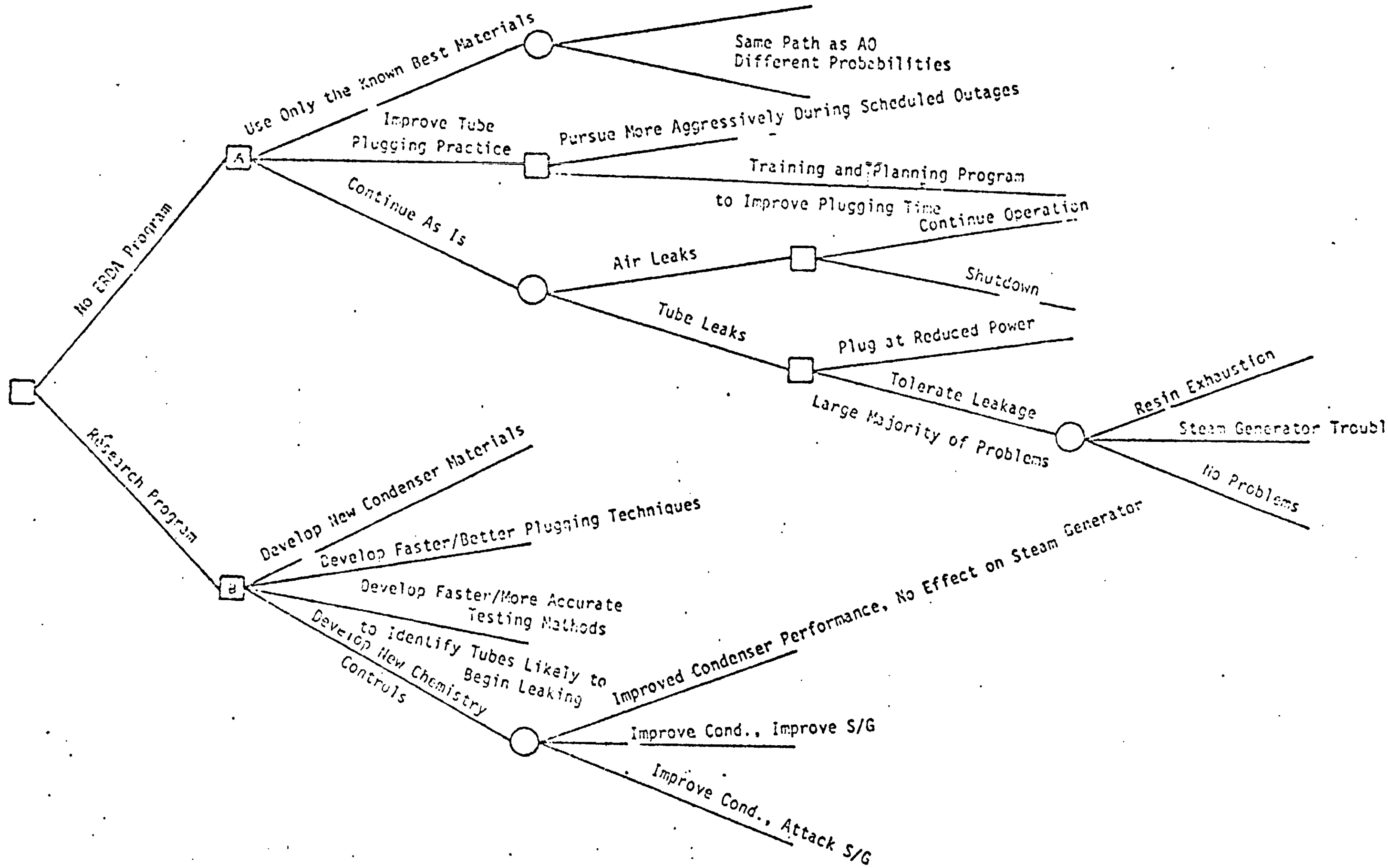

FIGURE I

PRELIMINARY DECISION TREE FOR CONDENSERS

(v) Pumps and valves -- Here, as much as $4.1 million/plant year might be capturable, via a detailed set of improvements, both in the equipment itself and its maintenance. Except for reactor coolant pumps which have experienced a significant number of similar failures, these problems are distributed over a great variety of components operated under many different environments. Design practices - redundancies and standardization - and improved maintenance practices seem the best paths available overall.

3.2.2 Reduce Capital Costs -- Several possibilities exist, but as usual a number of impediments exist also. The effects are indeed significant. In Table I we find that lowering LWR capital costs from $490/KW to $430/KW (1976 $) beginning in 1980 has a significant effect upon the role of nuclear in total generation, as well as upon price and consequently the total generation. Because of the 10-year lead time in constructing LWR plants, the effect is not apparent until 1990, except for minor changes due to interest charges on construction and lower coal capacity expansion in anticipation of increased nuclear capacity. By 1995, however, nuclear power accounts for 35% of capacity (up from 31% in the base case) and provides over 46% of electricity (up from 41% in the base case).

Another way to interpret the effect of a change in technology costs and efficiencies is in terms of the discounted present value of the benefits to the energy system, or in terms of the savings in a scarce fuel, such as petroleum, which is thought to be priced below its social value. For example, reducing LWR capital costs from $490/KWh to $430 KWh in 1980 reduces the total cost of delivered energy in the U.S. by $3.1 billion measured in terms of the discounted value of decreases in the total cost of energy (assume 6% discount rate , horizon 1977-1997). Such a decrease in LWR capital costs might be attained through plant standardization. We may interpret this number as meaning that we should be willing to pay up to this amount to obtain this benefit. Of course, the same benefit might be obtained by other investments to improve LWR technology or other energy technologies.

We now explore some technical possibilities for reducing LWR capital costs.

(i) Standardization -- Standardization of power plant design and equipment can be accomplished by the floatation, duplication or replication concepts. Or it can be accomplished on a partial basis by using an NSSS reference system design, a standard electric plant or turbine generator plant design, or standardized major pieces of equipment. The CONCEPT 4 computer code for estimating costs of specified reactor configurations has been used to determine cost sensitivity to standardization. We find that,

- Greater cost reduction results from time-related factors rather than from hardware
- A 10% reduction in nuclear lead time contributes 7% savings in direct costs.
- a 10% reduction in man hours/KWe contributes 3.5% savings in direct costs.
- A 10% reduction in equipment costs contributes 3.3% savings in direct costs (thus indirectly supporting the legend that to scale from component cost to plant cost, multiply by π).
- A 10% reduction in equipment escalation rate contributes 1.15% savings in direct costs.

- Savings in direct costs are linearly proportional to the reduction for each contributor.
- Total savings in direct costs through standardization are around 10-12.5%, resulting in a reduction of capital costs from $490/KW to $430/KW in 1980 (1976 $)
- Savings on interest and escalation due to shorter construction time are less than proportional to the reduction in construction time.

A number of difficulties in achieving more standardization need mentioning. The benefits are significant but not overwhelming, and come in the long term and via sustained efforts by vendors, utilities, regulatory agencies, and ERDA. Present attitudes toward LWRs do not clearly warrant any one manufacturer making large investments, expecting payback within conventional economic time horizonons (5-7 years, say). Furthermore, it is not clear how much any plant can be "standardized," or whether such plants will be accepted without further serious court challenges. For example, siting a nuclear electric power plant involves specific and non-specific features. The boundary between the two is fuzzy. Does one handle nuclear reactors near airports, near geologic fault zones, etc., the same as all others, thus escalating the cost of all?

(ii) Shortened construction time. Several suggestions are commonly heard, which fall into two general classes.

(a) Siting policy. Can the U.S., like France, for example, choose in advance sites potentially suitable or non-suitable for electric power plants, thus removing from the electric utility companies both some degree of freedom and also some corrosive uncertainties. In principle, and in scientific environmental terms, much could be done, but even here some regulatory changes would be required, because sites and plants are considered together in the present licensing procedures.

(b) Change the regulatory constraints, approvals and challenge procedures with respect to construction. It is both impossible and undesirable to try to return to the pre-Calvert Cliffs (i.e., pre-1970) era; but since then, the net result of the inclusion of the environmental review and of increasing the complexity of the safety review has been a 49-month increase in the average time to completion of power station construction. Of greater concern to a utility than the increase in the average construction and licensing time is the possibility that a particular plant could take much longer than the mean time for complete construction and licensing. Several unfortunate case histories of this sort are available (with additional delays as great as 30 months), and a few more appear to be developing currently. Significant costs accrue to the utility - and ultimately the public - as such delays occur, and this, coupled with unforeseen delays in the past and the continuing prospect for such delays in the future, leads utilities to adopt special caution in their approach to ordering new nuclear plants.

The dollar cost of delay is not nearly so large as interest and escalation calculated for the whole plant over the whole delay period. First, if the delay occurs at the beginning when not much money is committed, delay is cheap, provided that it does not lead to an expensive shortage later. Second, some have claimed that the time-pattern of expenditures will be changed by the delay, usually toward a more intensive and shorter period, but our data tend not to support this notion. Third, many vendors offer no-cost (or cheap) contract extensions, because they don't want to lose the business. This latter favor granted the electric utility companies depends on prevailing economic conditions, and may not persist. Our studies to discover the true costs of these delays are still under way.

It is instructive to note that in other countries (notably France) with more centralized government, much of the cost of possible delays is avoided by performing most licensing functions prior to the decision to build a particular type of power station on a particular site. That is to say, in such cases site-specific issues are reviewed and environmental protection rulings are made before a site is chosen for specific power station use. Similarly, generic nuclear safety questions are resolved before deciding to match a specific type of plant to a particular site. Finally, site-specific safety issues are resolved prior to the utility's commitment to construct a plant at the site in question. Only after resolution of all substantial regulatory questions is the decision made to commit funds to plant construction; and at that point further review of previous regulatory decisions, either by the agencies or courts, is made very difficult. Dealing with such issues means dealing with the structure of government itself, as we remarked earlier.

(iii) Improved project management and financing -- Improved project management could save on labor requirements, material consumption and construction time while new financing practices could increase the availability of capital to allow selection of plant types to minimize the levelized cost of electricity. However, there is much more to it.

Consider the motivation of the relevant sectors. The electric utilities are not motivated very well by the present institutions and reward systems. That is, if the electric utility makes an improvement, they may have to pay a penalty to get approved. Electric utilities do not bear the cost of continuation of the status quo, and wrong decisions are often perpetuated. Historically, utilities let vendors and architect-engineers do the R&D. Vendors have relatively little incentive either, and most A-E's would lose in the short run by such strategems as plant standardization.

A possible restructuring of electric utility, vendor, and national Laboratory R,D&D with a different basis for Federal and private funding is being studied, to see if incentives can be offered for improvement in all the sectors simultaneously. Our present ideas run along the following general lines:

(a) Electric utilities, which presently spend less than 0.5% of their gross income of R,D&D, be required by law to contribute a larger fraction to a consortium effort (larger than present or planned (EPRI)). Electric utilities will be stimulated thereby to look more seriously into their future. These utility increases can be passed through to users (with certain safeguards against losing incentives to be efficient). The consortium also makes commitments on behalf of all the electric utility companies of sufficient pooled resources to handle the consequences of serious accidents. Thus the Price-Anderson problem becomes defused.

(b) ERDA and other federal groups continue to supply substantial funds for R,D&D, but not exercise such full control over what the options will be.

(c) The new consortium should have "drawing rights" on the national laboratories. Thus the national labs, industry, and the utilities are naturally motivated to interact, which needed to be done for lo! these many years. Also, the electric utilities will realize (1) they can get help; (2) they must help themselves; and (3) the future they contemplate is their own. Almost the same can be said for the national labs.

The role of architect-engineer poses delicate difficulties. They are the principal entrepreneurs in the nuclear power sector (and in construction of many types of industrial plants), and therefore by conventional thinking, are essential to the industry. But some large electric utility companies do their own A-E work, and claim significantly lower plant costs as a result. In addition, the A-E sectors tend to thrive on resolving complex problems, and plans to streamline the nuclear industry via either new manufacturing or new regulatory arrangements would threaten to reduce their role. Thus some of them may not be expected to be enthusiastic about change.

3.2.3 Fuel Cycle Costs -- A number of important issues regarding the fuel cycle have been identified and are under investigation. These include:

- Institutional problems currently dominate the fuel cycle, preventing application of available technology, and making necessary non-commercial incentives for new technology.

- Analysis of cost uncertainties related to fuel technology indicates areas needing attention are U_3O_8 supply and fuel disposal.

- Fuel technology is related to reactor performance (i.e., capacity factor) in two important ways: (a) fuel limitations reduce capacity factor, as described above, and (b) over-optimistic estimates of CF coupled with fixed refueling dates or fuel failure wastes ore in permanent once-through cycles.

- Prospects for development of new or improved fuel cycle technology are waning due to weakened economic base, and government pre-emption of both the back-end and enrichment. This should not necessarily be interpreted as critical of government involvement; it is mere recognition of a fact.

- Sustainability of the policy of no used fuel reprocessing needs re-examination. (a) Can it be supported in the face of contrary policies in other countries? (b) Is new technology needed for whole-assembly disposal? (c) Will Pu recycle be re-examined if an ore shortage develops?

4. Planned Continuation and Important Future Topics

4.1 Things for ERDA to Be Concerned about

From our studies, we see substantial benefits in ERDA's being concerned in a number of areas, and substantial costs (perhaps extinction of the LWR option) if ERDA or some equivalent Federal organization is not concerned. These are evident from our report. The principal ones are:

- Resolve the back-end of the LWR fuel cycle and probably the front end too, not only in terms of technology, but in terms of whether public or private ownership make better sense.

- Study questions related to factory-built reactors, and standardization, including appropriate incentives, economic and operating problems, siting, and public acceptance. Formulate and work to implement policies to achieve increased standardization.

- Study the possibility (and limitations) of separating power plant siting from the licensing of specific plants designs.

- Formulate and recommend strategies to establish new institutional arrangements to connect electric utility companies, manufacturers, the government and the general public in ways likely to lead to better or less expensive energy options.

- Determine what whould be the logical degree of separation between stimulation and promotion and what organizational arrangements are most likely to achieve that condition.

- Explore the possibility of planning that starts with societal goals and leads toward technical and economic options, rather than planning that starts with technical and economic options and calculates the societal impacts. In other words, find out how to think about alternative lifestyles.

- Explore modes by which the government sectors at federal, state, and local levels can interact with the public on public issues, in meaningful ways.

4.2 Activities Planned under Our Present Contract

These include:

- Further analysis of interviews and development of topical essays on imbalance of information, participants in the debate misunderstanding each other's motives and messages, need for upgrading the awareness and extending the time perspectives of the electric utility and other sectors, stability of the electric utility-regulatory-public interaction, etc.

- Further analysis of the history, patterns, and costs of regulatory changes during the past several years, and comparison with the situation in other countries.

- Determination of more detailed costs and benefits of making particular technological changes to reactors, fuel, fuel handling procedures, and balance of plant.

- Further conceptual development of new institutional arrangements, designed to permit better electric utility and public particpation in option development, which could lead to better balance among sectors in funding R&D, and deciding on new options.

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   Part II - Strategies for Improving Fixed Costs (El-Magboub, Lanning)

   Part III - Strategies for Reducing Fuel Cycle Cost (Driscoll, Forbes, Pilat)

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