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The Demonstration Project as a Procedure for Accelerating the Application of New Technology

(Charpie Task Force Report)

February 1978

U. S. Department of Energy
Assistant Secretary for Resource Applications

MASTER

Dec. 31 RESEARCH AND DEVELOPMENT P.L. 93-577

FEDERAL NONNUCLEAR ENERGY RESEARCH AND DEVELOPMENT ACT OF 1974

For Legislative History of Act, see p. 6861

PUBLIC LAW 93-577; 88 STAT. 1878

[S. 1283]

An Act to establish a national program for research and development in nonnuclear energy sources.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That:

SHORT TITLE

Section 1. This Act may be cited as the "Federal Nonnuclear Energy Research and Development Act of 1974".

STATEMENT OF FINDINGS

Sec. 2. The Congress hereby finds that—

(a) The Nation is suffering from a shortage of environmentally acceptable forms of energy.

(b) Compounding this energy shortage is our past and present failure to formulate a comprehensive and aggressive research and development program designed to make available to American consumers our large domestic energy reserves including fossil fuels, nuclear fuels, geothermal resources, solar energy, and other forms of energy. This failure is partially because the unconventional energy technologies have not been judged to be economically competitive with traditional energy technologies.

(c) The energy challenge will require commitments of the magnitude of the Manhattan and Apollo projects. National nonnuclear energy research, development, and demonstration programs may be taken [illegible] or exceed $20,000,000 [illegible]

DEMONSTRATIONS

Sec. 8. (a) The Administrator is authorized to—

(1) identify opportunities to accelerate the commercial applications of new energy technologies, and provide Federal assistance for or participation in demonstration projects (including pilot plants demonstrating technological advances and field demonstrations of new methods and procedures, and demonstrations of prototype commercial applications for the exploration, development, production, transportation, conversion, and utilization of energy resources); and

(2) enter into cooperative agreements with non-Federal entities to demonstrate the technical feasibility and economic potential of energy technologies on a prototype or full-scale basis.

Volume II

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THE DEMONSTRATION PROJECT AS A PROCEDURE FOR ACCELERATING THE APPLICATION OF NEW TECHNOLOGY

(CHARPIE TASK FORCE REPORT)

February 1978

U. S. DEPARTMENT OF ENERGY
Assistant Secretary for Resource Applications
Washington, D. C. 20461

Volume II

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GOVERNMENT SUPPORT FOR THE COMMERCIALIZATION OF NEW ENERGY TECHNOLOGIES

An Analysis and Exploration of the Issues

by

Policy Study Group
Energy Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

Date Published--November, 1976

PREPARED FOR THE UNITED STATES

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The Appendices to this report
are not included but may be obtained
directly from the MIT Energy Laboratory.

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ABSTRACT

This report examines the issues associated with government programs proposed for the "commercialization" of new energy technologies; these programs are intended to hasten the pace at which target technologies are adopted by the private sector. The "commercial demonstration" is the principal tool used in these programs. Most previous government interventions in support of technological change have focussed on R&D and left to the private sector the decision as to adoption for commercial utilization; thus there is relatively little in the way of analysis or experience which bears direct application.

The analysis is divided into four sections. First, the role of R,D&D within the structure of the national energy goals and policies is examined. The issue of "prices versus gaps" is described as a crucial difference of viewpoint concerning the role of the government in the future of the energy system. Second, the process of technological change as it occurs with respect to energy technologies is then examined for possible sources of misalignment of social and private incentives. The process is described as a series of investments. Third, correction of these sources of misalignment then becomes the goal of commercial demonstration programs as this goal and the means for attaining it are explored. Government-supported commercialization may be viewed as a subsidy to the introduction stage of the process; the circumstances under which such subsidies are likely to affect the success of the subsequent diffusion stage are addressed. The discussion then turns to the political, legal, and institutional problems. Finally, methods for the evaluation and planning of commercial demonstration programs are analyzed. The critical areas of ignorance are highlighted and comprise a research agenda for improved analytical techniques to support decisions in this area.

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PREFACE AND ACKNOWLEDGMENTS

On October 15, 1975, the Administrator of the U.S. Energy Research and Development Administration appointed a Task Force on Demonstration Projects as a Commercialization Incentive. The Chairman of the Task Force is Dr. Robert A. Charpie, President of the Cabot Corporation, and the members were chosen to represent the principal groups involved in commercialization decisions in the energy field. The purpose of the Task Force is:

> ...to examine the demonstration project as a commercialization tool in both its technical and nontechnical aspects in order to recommend to ERDA new methods of designing technical demonstrations which will make these demonstrations responsive to the nontechnical uncertainties involved in commercialization decisions.

This Issue Paper has been prepared in support of the work of that Task Force.

As part of the work of this project, five studies were performed on specific technologies which either are, or have been, the subjects of government-supported commercialization programs. They are appendices to this report and are or will be available separately from the M.I.T. Energy Laboratory. They are listed in the Table of Contents.

We would like to specifically acknowledge the monitors of this effort at ERDA, Mssrs. Thomas A. Calhoun and A. Denny Ellerman. Our interaction with Denny Ellerman in particular was fruitful and stimulating, and he contributed substantially and substantively to the conceptualization involved in this work. We also received provocative and useful criticism on drafts of this paper from a number of individuals in academia, industry, and government. To them we express our gratitude.

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PARTICIPANTS

The following members of the Policy Study Group of the M.I.T. Energy Laboratory participated in the preparation of this report:

Henry D. Jacoby, Professor of Management (Co-principal Author)

Lawrence H. Linden, Research Staff, Energy Laboratory; Lecturer in Mechanical Engineering and Management (Co-principal Author)

M.A. Adelman, Professor of Economics

Ben C. Ball, Visiting Senior Lecturer, Sloan School of Management

Ted R.I. Greenwood, Assistant Professor, Political Science

Ogden H. Hammond III, Research Staff, Energy Laboratory; Lecturer in Chemical Engineering

Stewart C. Myers, Professor of Finance, Sloan School of Management

J. Daniel Nyhart, Associate Professor of Management and Ocean Engineering

David O. Wood, Associate Director, Energy Laboratory

Martin B. Zimmerman, Research Staff, Energy Laboratory; Lecturer in Management

They were assisted by the following:

Sudipto Bhattacharya, Research Assistant, Management

Beverly J. Bugos, Research Assistant, Political Science

James W. Meyer, Research Staff, Energy Laboratory

Paul R. Samuelson, Research Assistant, Management

Bruce E. Stangle, Research Assistant, Management

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SUMMARY

The United States government has set out to "commercialize" a number of new energy technologies. This is a relatively new role for federal agencies. Except in areas (such as defense) where the sponsoring agency was simultaneously the customer for the results, public expenditure on technology has generally been confined to research and development. The pace of the process whereby new technologies were put to commercial use, and the decisions about the investments that make up that process, were left to the private sector.

The energy problem is leading us to depart from this norm. Through the Energy Research and Development Administration the government is investing substantially in energy technology, and there is natural pressure--from the Congress, the agency itself, and a wider set of private and public interests--in support of programs to accelerate private adoption of the new techniques and devices. The list of the objects of such programs, either in effect or seriously proposed, includes the breeder reactor, geothermal energy, new automotive powerplants, electric vehicles, solar heating and cooling, solar electricity generation, and synthetic fuels.

This new set of federal programs raises a number of issues of economic policy, public-private relations, and program analysis and management. This report attempts to identify and explore these issues. We hope to contribute to a clearer view of the context in which such programs must operate, and to identify ways to maximize their contribution to the nation's energy future. The focus is on the "commercial demonstration", which is the mechanism most

commonly used in these programs.

R,D&D as a Component of U.S. Energy Policy

There are two aspects to the energy problem facing the United States. First, there is a national security and foreign policy problem caused by our dependence on a small number of foreign countries for an increasing share of our energy supply. This is a short-term difficulty and, if not corrected, a long-term one as well. Second, the United States (and, in a few more decades, the world) faces the depletion of low-cost resources of petroleum and natural gas. Environmentally acceptable substitutes are much more expensive than oil and gas, and the transition from our current energy system to whatever will replace it is potentially a very painful one. This is a longer-term problem--say on a horizon of 20 to 40 years. Because of the time lags associated with the development, introduction, and diffusion of new technologies, R,D&D programs will not have a significant effect on the national security problem, at least for the next decade or two. Other programs (such as a national petroleum stockpile) can help in that regard. R,D&D programs will reduce imports in the long run, and will reduce the costs associated with the transition to energy resources other than oil and gas.

Unfortunately, these two aspects of the energy problem, and the relevant time horizons, tend to get blurred, and much discussion of the issue is founded on disagreements about the formulation of the problem, on disparities in the way we think about its solution, and on differences in conception of the way the U.S. economy operates now and will operate in the future. There is, in particular, one split in perceptions which is of crucial importance in evaluating new technologies and is often not explicitly acknowledged. On the one hand, much thought and analysis is focused on energy "needs", or "gaps" in

energy supply, to be made good by the provision of particular fuels, or by conservation. The concentration is on physical flows. Technologies are rated according to how much can be brought on stream, and how soon, to cover the shortfalls or "gaps". An alternative approach focuses on energy prices as they operate in our market economy. In this view, there is no such thing as an energy "gap": supply is always equal to demand absent price controls and rationing. Some kinds of supply may be less desirable because they are insecure or because they damage the environment. But in all cases the central question is the same: what price are we willing to pay to hold imports down or avoid environmental losses? From this viewpoint the most important fact about a technology is not the extent to which it may "close the gap" but its cost, for it is its cost in relation to price that will determine its contribution, and it is its cost which represents the total real resources it absorbs.

Therefore, a key question is whether the approach via "needs" and "gaps" is appropriate over the next few decades. In the past, energy provision has been left to private markets--some regulated and some not. Energy prices have been the principal determinants of the magnitude and composition of the energy sector, and of energy imports. The driving force has been profits, with government policy measures having a significant influence over what was profitable. Whether this pattern should continue is a matter of some dispute, and only future political events will prove which viewpoint was the more correct for the 1970's.

The hypothesis adopted in this study is that, for the foreseeable future, we are not likely to institute fundamental changes in the structure of the energy sector. Neither are we likely to move in a determined, decisive way to a more centrally-planned energy economy. For better or worse, the market system will predominate in the United States.

In this context, then, what is the role for ERDA's R,D&D programs in meeting the national energy goals? These goals tend to be stated in terms of reducing oil imports. There are two ways to reduce the demand for petroleum: We can lower the demand for energy services (in particular those provided by petroleum-using technologies), or we can substitute other factors of production (capital, labor, and non-energy materials) for petroleum in producing a given level of energy services. R,D&D programs do not directly influence the former. There are several ways to accomplish substitution away from petroleum--for example, by (1) regulation of supply and utilization technology, (2) price controls and financial subsidies, and (3) lowering the cost of substitution of the other factors for petroleum. But again the first two are not in ERDA's hands.

Therefore, the key way ERDA can serve national energy goals may be very simply and starkly stated: it can undertake programs that lower the cost of substitutes for oil, both now and in the future. That is, the basic purpose of the ERDA programs can be seen as the lowering of the cost of substitution of other energy sources or other inputs for oil in the near term, and lowering of cost of transition away from oil to more abundant (or inexhaustible) energy sources in the future. There are two ways in which ERDA can accomplish these ends. The first, and most important, is to support energy R,D&D. By performing such work itself, or supporting it elsewhere, ERDA can change the nature of the technological opportunities, lowering the costs of substitutes for oil. This role is no doubt very important. However, in this paper the focus is on the second way in which ERDA can reduce the cost of substitutes to the consumer. This is to subsidize the introduction of new technologies into the marketplace. As noted earlier, ERDA's chosen instrument for accomplishing this is the commercial demonstration.

Commercialization and the Process of Technological Change

If the United States is unlikely to depart from its long tradition of private markets in the energy sector, then a new energy technology will achieve wide use only if it can meet the test of commercial viability. We can state a simple working definition of necessary conditions for commercialization of a new technology:

> Given: (1) the market prices of labor and material inputs, (2) the relevant cost of capital, (3) the market price of energy, and (4) taxes, legal restrictions on the relevant production possibilities, or other government intervention--then commercialization of a new technology will take place if it is available at a cost that allows the private sector an acceptable rate of return on the capital required.

Only if brought to the point where it meets this condition will a new idea be viable. However, a new technology usually goes through a long process of events in achieving this status. Four rough phases can be identified: invention, development, introduction, and diffusion. Because these activities cost money, and offer no immediate return, the expenditures involved are investments, and each of the steps is usefully thought of as involving an investment choice. That is, at each step the firm acquires a new asset; the asset is expected to yield a favorable return itself, or to open the way to some subsequent investment that will yield a profit. It is the introduction stage and its link to diffusion that is the target of federal programs and proposals in the area of "commercialization."

Several other aspects of this part of the process merit special attention. One is market differentiation. The simple definition given above might be taken to imply that a technology is either "commercial", or it is not. But this would be a misleading simplification of reality. Commercial adoption is not a simple transition from non-use to use; it is a part of the dynamic and complex process whereby a new concept may penetrate some markets but not others, or where the

penetration may move at very different rates depending on prices, weather, market structure, etc. Second, energy technologies themselves may present very different challenges at the introduction stage, and the role played by the first plants may be very different. A third consideration is the set of complex adjustments that may be involved in integrating a new technology into a highly developed and interrelated production and marketing system, where the key firms have a structure and personality compatible with the previous product mix.

Thus the term "commercial" really applies to an equilibrium end-state for the process of technological change, and any attempt to influence the pace of the process must deal with a complex transition from prototype to widespread utilization.

To address the role of ERDA in this context, the process needs to be analyzed for reasons why, or areas where, private markets do not automatically produce the desired results. The point of departure for such analysis is the fact that, for the most part, the system generally does work well. The position of the United States as world leader in many if not most fields of industrial technology is a salient indication of this fact. Therefore, an examination of market performance is a first step in the search for projects ERDA might usefully undertake. We focus in particular on failures in the market process at the introduction stage--failures that might be corrected by commercialization programs.

Such a problem, or "market failure", occurs when energy prices do not reflect the value of energy to society. Domestic petroleum prices are determined by a complex interaction of the usual supply and demand forces, and controls imposed by our own and foreign governments. Because the Organization of Petroleum Exporting Countries (OPEC) determines the price of imports, and

because imports are the marginal source of supply to the United States, the value of a barrel of oil in the United States is at least the landed price of international crude. However, government price controls hold domestic prices well below this level. Thus a private firm will not obtain a suitable return for introducing a conservation technology which would be economic to the purchaser at the international price but not the domestic price. Natural gas price controls have a similar effect. Given these price controls, there are undoubtedly many cases where government subsidies for the introduction of new conservation technologies would provide substantial social returns.

Moreover, the social value of domestic oil is not determined solely by the international price--there is also the issue of import "dependence". This is a social cost which would not be reflected in private prices even if those prices were not controlled by the government. Since a barrel of oil domestically produced or conserved effectively translates into avoidance of an imported barrel, it is the international price plus the "national security premium" which is the effective social value of domestic supplies. Again, the undervaluation of domestic energy results in a failure in private investment decisions.

In addition to the undervaluation of domestic energy, the special costs associated with the introduction of new technologies into the marketplace can result in a market failure which is concentrated at the introduction stage. Thus, it may be that the proprietary technical and cost information developed at the introduction stage is sufficiently attractive to induce socially desirable outlays, but regulatory and other institutional problems intervene. Important institutional, regulatory, and political issues posed by the new technology may be resolved only by substantial production and use. This is certainly true with respect to some synthetic fuels. Important information about

effluent levels of full-scale plants may be inferred from observing pilot plants, for example, but the issue of what effluent levels are acceptable is difficult to resolve until production is attempted on a commercial scale. This is a special kind of distortion of private decision making--investment may be artificially discouraged because society has not gotten around to specifying what rules the new technology will operate under. The pioneering firm must face these regulatory risks, but subsequent firms may not. The nation as a whole benefits from the resolution of the regulatory uncertainties, but the costs are borne by one firm. Thus, a socially desirable introduction may be foregone or delayed.

This circumstance suggests where a well-designed government intervention may be useful. If valuable new technologies are blocked by the regulatory risks, then an off-setting subsidy may be in order. The subsidy would not only encourage use of the technology, which is presumably good in itself, but also lead to a resolution of the regulatory risk and open the way to further, unsubsidized investment. Careful study of the nature of the regulatory problem should, once again, offer guidance as to what kind of subsidy will most effectively resolve the issue.

Other possible sources of market failure are the non-appropriability of technical results, problems of market structure, and excessive risk aversion in private firms. Any of these may be relevant in a given circumstance, though it does not appear that they often will be important. Patents, and the advantages of being first to introduce a new technology, generally allow pioneering firms to capture the major share of the benefits from technical improvements in introduction. The impact of market structure on technological innovation is not well understood, and it is unclear that there is any a priori reason to assume that the introduction of new technologies is inhibited in this regard.

Finally, the nation's capital markets are generally considered to be reasonably efficient at spreading of risk, so in general it is reasonable to assume that investments in profitable new technologies will be forthcoming.

It is problems in energy pricing and the non-appropriability of the resolution of regulatory risks that are most likely to be the sources of socially erroneous investment decisions on the introduction of new energy technologies.

Goals and Means of Government-Supported Commercial Demonstrations

The principal purpose of ERDA's commercial demonstration programs, then, seems reasonably clear: ERDA should subsidize the introduction of socially profitable new energy technologies to the extent that they are being impeded by low energy prices or by high regulatory uncertainties whose resolution would be of value to more than one firm.

However, ERDA must perform this function within an environment which is not under its control. Specifically, energy prices are determined by a combination of foreign governments, higher level policy decisions of the U.S. government, and market forces. As we have discussed, technological change is the result of a series of investments, investments which are made in the expectation of a suitable return. Expected prices are the key parameters, external to the firm, which affect the investment decisions. In the early stages of the process, the relevant expected prices are those several decades in the future. At the introduction stage, however, the relevant prices, in relation to expected costs, are crucial to the investment decision, and they are not changed by a commercial demonstration program.

Thus, in most cases the long-run commercial potential of a new technology will be relatively independent of possible interventions by ERDA in the introduction stage. This is because, in most cases, the costs of the introduction stage which are not recovered during that stage, are a small fraction of the total cost of the product after introduction. Therefore, most technologies which appear to be commercial in the long-run, will be introduced and "commercialized" by the private sector. In most cases, ERDA commercial demonstration programs therefore simply do not have very much leverage. They may be useful, but they are not often likely to be decisive in determining the fate of a new technology.

Even where it appears that a government-supported commercial demonstration can perform the sort of useful social function described here, one must be sure that these expenditures are the most efficient method. In fact, government-supported demonstrations attempt to reduce technical and institutional uncertainties with what might be termed a "brute force" technique. In many cases the resolution of the relevant technical and institutional uncertainties may not require the actual construction of commercial-scale plants. For example, an obvious alternative for resolving legal and regulatory uncertainties is direct intervention in the public decision-making process in support of expedited action. This could take the form of requests or orders to regulatory or legislative bodies, or studies which would provide the key data necessary for resolution of regulatory problems. While it is not clear that such activities will necessarily be less expensive than the net cost of a commercial demonstration, such alternatives should always be considered.

Whatever the details of the specification, the goals of a demonstration program imply criteria for the choice of public instruments. We have argued that the purposes of government-supported commercial demonstration projects are

principally to support the development of the information associated with the resolution of the technical and institutional uncertainties concerning new energy technologies, and to provide a subsidy to foster the introduction and widespread use of technologies faced with inappropriate energy prices. With these goals in mind, some general considerations of program design can be laid out.

Both goals lead immediately to a concern that the commercial demonstrations be conducted in such a way as to simulate the normal workings of the private sector--i.e., the influence of the subsidy should be as small as possible beyond the obvious fact that it is lowering the cost of the actual demonstration to the firms involved. This implies that the participants in the program should be those who would be dealing with the technology under circumstances of widespread use, and that the incentive structure associated with their participation should be as "realistic" as possible.

The incentives to private participants will be strongly dependent on the actual mechanism used to deliver the subsidy. Ideally, the mechanism should provide project managers with a circumstance which looks the same as that which they would face in the unsubsidized case. This is important with respect to the choice of inputs--especially capital as compared with labor, transportation, maintenance, etc. The incentives with respect to risk-taking also should be as realistic as possible.

Finally, financing mechanisms should reveal the full costs of the program and the detailed cost performance of individual technologies. There will of course be large uncertainties in estimates of both the costs and benefits of such programs, but some financing methods allow greater visibility than others. Clearly, if the extent of the subsidy is not well known, then the

true cost will not be readily calculated from the product prices. If this is the case, then uncertainty of major significance will remain.

Many forms for government subsidies have been proposed for commercial demonstration programs. These include tax expenditures, direct government operation, price guarantees, loan guarantees, and the rolling-in of demonstration costs with other costs in the special case of regulated industries. We did not analyze each of these possibilities in the detail they deserve. The key criteria of visibility of subsidy costs and minimal distortion of factor input prices point immediately toward specific project-by-project price supports, which fare well against both criteria. The two criteria similarly point away from the use of loan guarantees--their value is difficult to calculate, they subsidize capital as opposed to other inputs, and they distort incentives for follow-on investments.

Evaluation and Planning

The concepts used here provide a framework for analyzing commercial demonstration programs. However, the leap from qualitative concepts to detailed quantitative calculations is long and uncertain, and we have much to learn about the market processes we must analyze. As a first step in laying out the evaluation program, an evaluation scheme must focus on the probability distribution of the cost of energy saved or produced by the technical option under consideration, should it attain wide-scale usage. This function summarizes at any given time the set of expectations for improvements which would result from investments in R,D&D as well as the technical and institutional uncertainties which might affect the option. The relationship between this function and similar sets of expectations concerning the market price and social value of energy are at the core of the analysis of the likelihood of

private investments in R,D&D on the option and the desirability of public investments.

Our development of the evaluation problem points to the identification of several areas of analysis and forecasting which are crucial to the evaluation of schemes of federal intervention in commercial demonstration. All analytical efforts which attempt to evaluate national income benefits from this type of investment must deal with these issues in one way or another. In each case the available techniques allow analysis to take place but similarly in each case substantial improvements are needed to raise the level of confidence we can place in such analysis. Thus, these key areas comprise an agenda for future research to improve our ability to analyze government investments in energy R,D&D and commercial demonstration in particular.

First, there is a need for price forecasts--both market prices and social values. Such forecasts ultimately depend on analysis of international oil markets, on the tariff or other policies that may be used to buffer the U.S. economy from these prices, on the process of price formation in product and regional markets throughout the economy, and the value to be placed on energy independence.

Second, the evaluation of the benefits of the accelerated introduction of new technologies depends ultimately on forecasts of the rate of diffusion of those technologies through the relevant markets. In general, this requires a set of analyses of transportation, processing, and energy technology choice which can simulate the way the economy adjusts to a new technology, given that the technology has been demonstrated in the introduction stage to offer cost savings. For example, modeling efforts at Stanford Research Institute (originally for Gulf Oil Corporation), and Brookhaven National Laboratory provide a framework for conditional forecasting of the expected penetration of

new and emerging energy technologies and products based upon engineering information concerning the cost and efficiency attributes of these technologies.

However, two significant problems are not addressed by either of these models, or by most other, less formal, studies of these circumstances. First, we would expect that the actual commercial availability of a new technology will depend critically not only on the level of prior R&D activity, but also on market factors. Thus, an analysis which purports to explain the penetration of new technologies must also explain the evolution of circumstances which lead to the availability of those technologies at a point in time. This is an extremely difficult research issue. A second, and closely related issue, concerns the demand for these new technologies. Simple studies of consumer behavior based upon simple cost considerations are probably not adequate to characterize consumer response to a new product or technology. The problem is essentially one of using information on consumer response to existing technologies to project their reactions to technologies and products which they have not yet observed. Both the issues of technology availability and consumer demand for new technologies are not addressed in the SRI-Gulf and Brookhaven models, nor by any other formal studies of energy technology choice with which we are familiar.

Third, a key component of any analysis will be the estimation of the likely investments in R,D&D that would take place without government intervention. For example, it may be that government subsidy only substitutes for industry investment that would take place in any case, or that it only speeds up the introduction process by a period of a few months or a year or two. This once again leads back to a need for a clearer understanding of the nature of the market process of technology development, how it serves the social good, and how one might gather information about likely industry involvement

at the introduction stage for different types of technologies.

The fourth key link is the estimation of the impact of the government-supported commercial demonstration. That is, it is necessary to understand and describe how the distribution function for ultimate costs will be affected by an introduction into the marketplace.

Finally, it is necessary to understand the costs and effects of the different instruments for supporting commercial demonstration. The alternative instruments that may be used by the government to subsidize the introduction stage may have very different costs. Different instruments may have distinct effects on the amount of learning that takes place in the introduction stage. In order to choose among types of programs, one needs to be able to distinguish between the available instruments and their ability to produce a good measure of the technical option's costs. But to know the option's cost in a situation where government subsidies are present, the total cost of the subsidy must be known; this is a difficult problem in and of itself.

These issues of evaluation provide a challenging set of topics which should rank highly on the national agenda for policy research. It seems clear that government programs aimed at accelerating the pace at which new technologies become available and are utilized will absorb an increasing share of public resources over the coming years. Our mixed capitalist economy responds to such interventions in complex ways that analysis can serve to illuminate, so that the public good can be served in the most effective and efficient manner.

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1. INTRODUCTION AND BACKGROUND

The federal government has set out to develop new technical options for the country's energy sector. However, unlike most previous public R&D efforts--especially those in defense, space, and war-time production--the government is not simultaneously the customer for the results. There is no doubt that the long-run measure of the success of the U.S. Energy Research and Development Administration (ERDA) will be the degree to which its new technologies see actual application. But under current policy and well-established tradition, the ultimate technology choices will be left to private corporations and the normal operation of our mixed capitalist system of economic organization. This circumstance, coupled with a strong concern over mounting dependence on oil imports, naturally leads to an attempt by federal authorities to increase the rate at which new technologies are adopted. This is being done through greater federal involvement in "commercial demonstrations" and other "commercialization" schemes to help the introduction of new energy technologies.

It is our purpose (1) to explore the issues that arise in connection with government attempts to use commercial-scale demonstrations to spur technological change, (2) to review what is known about the economic and industrial processes that are involved, and (3) to probe critical areas of ignorance in an attempt to formulate an agenda for research in this area. We have placed a high value on recording well the "facts-of-life" as we understand them.

1.1 PAST AND PRESENT GOVERNMENT ACTIVITIES IN SUPPORT OF TECHNOLOGICAL CHANGE

The federal government has long been involved in supporting technological change in the United States. In the past most of this support has fit into three categories. One category is the development of systems which are part of the government's own procurement needs. The bulk of this effort has been in the areas of military and space technology. Much of modern civil aircraft technology has come out of this activity, even though it was not an explicit goal of the government's R&D programs.

The second category is the support of basic and applied research, with the goal of advancing technology across a broad front, in support of particular economic sectors, national defense, or the growth of the economy as a whole. Federal investment in agricultural technology has a long history; other efforts grew out of the World War II experience, and have been carried out principally by the National Science Foundation and the research offices of the military services. The distinguishing feature of this support has been the fact that the private sector was free to develop and employ the new technology according to its own decision-making mechanisms. Generally, government support for technology for civilian use was stopped when it was ready for incorporation into prototype products.

A third category has been important at times. This is government support for the development and use of new technologies during war-time. A notable example is the federal financing of the final technical development, and the extensive production, of synthetic rubber during World War II. As discussed in Appendix E, much of the basic science and technology of rubber synthesis was available at the beginning of the War. It had not been put to commercial

use because the cost was substantially greater than the price of natural rubber. When natural rubber supplies were cut off, the government commenced a massive program to construct synthetic rubber plants, utilizing a number of different technologies. In this case the government was not the principal purchaser of the product. However, it is distinguished from the current circumstance by the extensive war-time government controls over important sectors of the economy--setting prices, allocating raw materials and intermediate goods, etc. So the infant synthetic rubber industry could hardly be considered "commercial" under the definition used in this study.

The more recent programs and proposals under study here are different from these earlier experiences of federal involvement in R&D. In the energy sector, government action is being undertaken explicitly for the purpose of supporting the commercial application of new technologies. The technologies at issue may or may not have been developed under government support, but at any event the government is not the buyer of the product. The technologies are to be utilized by the private sector.[1] Commercialization programs were embodied in legislation supporting the introduction of solar heating and cooling and geothermal energy, which became law in 1974.[2] The most prominent

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[1]As discussed in a recent Rand Study, ["Analysis of Federally Funded Demonstration Projects" (The Rand Corporation, Santa Monica, California, April, 1976), Reports R-1925-DOC, R-1926-DOC, R-1927-DOC], there have been some programs of this sort in the past. The most prominent are the civilian application of nuclear power for electricity generation, discussed by Rand, and the development of the civil supersonic transport, discussed in Appendix D to this report.

[2]PL 93-409, "The Solar Heating and Cooling Demonstration Act of 1974"; PL 93-410, "The Geothermal Energy Research and Development Act of 1974"; and PL 93-430, "The Solar Energy Research, Development, and Demonstration Act of 1974."

and, if it had become law, by far the largest, would have been "Synthetic Fuels Commercialization Program." The program was proposed by the Administration.[1] As reported out by the House Committee on Science and Technology,[2] the program would have entailed U.S. government loan guarantees and/or price supports for synthetic fuel plants producing the equivalent of 200,000 barrels of oil per day; $4 billion in loan guarantees would have been authorized.

This is the type of program we examine in this paper. However, our attention has not been limited to the solar, geothermal, or synthetic fuels proposals. Because it appears that there will be an increasing number of government-supported commercialization programs, we have attempted to focus on the general issues associated with the government-supported commercialization of energy-related technologies.

1.2 THE FOCUS OF THIS STUDY: ERDA'S COMMERCIAL DEMONSTRATION PROGRAMS

In a study of federal "commercialization" activities there is a temptation to focus discussion on overall national energy goals and on the full range of policies that affect the energy sector. In particular, one of the most important influences on the viability of new energy technologies is the effective market price of energy--which is determined by policies regarding import quotas or tariffs, price controls, widespread subsidies or taxes, etc. Here however, we do not focus on efforts to <u>change</u> the long-run market situation for a new technical option, but rather on those activities aimed at

[1] "Recommendations for a Synthetic Fuels Commercialization Program," Synfuels Interagency Task Force, 1975, Four Volumes.

[2] "Loan Guarantees for Demonstration of New Energy Technologies," U.S. House of Representatives Report No. 94-1170, May 16, 1976.

getting an option into widespread commercial utilization within a given market environment. This is a realistic limitation because by and large the national policies that determine price and market conditions are made independently of their impact on any particular class of new technical options. This restriction holds with particular force as we analyze decisions by ERDA, which has statutory responsibility for the research, development, and demonstration (R,D&D) of new technical options, but not for the long-run conditions which comprise their marketing environment.[1]

ERDA's principal tool in its commercialization programs is the government-supported "commercial demonstration". That is, ERDA may subsidize (or perform itself) the first "commercial-scale" utilization of a new technical option. "Commercial-scale" may be roughly defined as the minimum scale which would be used if the option were being introduced into the marketplace by the private sector without government support. A distinguishing feature of the commercial demonstration (and the source of much confusion) is that the net revenues from sales of the product of the demonstration are likely to return a substantial fraction of the total investment required.[2] This is in contrast to the more common government-supported demonstration, which is generally at smaller scale and uses technology less well developed.

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[1] In the case of technology-specific subsidies, taxes, or regulations, the decision to utilize them would obviously not be made independently of the state of the technology, but even in this case ERDA does not have the relevant responsibility (cf. FEA/ERDA Memorandum of Understanding, April, 1976). The case is similar for other technology-specific governmental controls, such as environmental regulations.

[2] The confusion arises because production is not the principal purpose of the demonstration. Rather, the goal is to clarify the crucial uncertainties associated with the new technical option. This is addressed below at some length.

1.3 ORGANIZATION OF THE STUDY

Because the current and proposed commercialization activities are unprecedented in their complexity and scale, and because the overall energy policy of the country is in a continuing state of flux, it is necessary to begin this discussion with a statement and interpretation of the broad energy goals that have been set by the Administration and Congress. This is undertaken in Section 2, and an attempt is made to take these broad statements and re-phrase them into an operational definition of targets for federal activities in the area of commercial demonstration. A fundamental problem facing the agency is the estimation of the market conditions under which the substitution of new technologies is expected to take place, and this is addressed.

Section 3 considers the role of the federal government in changing the technology of energy supply and utilization. To set the context for subsequent discussion, a brief description of the process of technological change is presented, and an attempt is made to define where the point of "commercialization" is supported to occur. Given a brief description of the process, attention is turned to various flaws or "failures" in that process and to the role of federal intervention.

Section 4 then examines the goals for commercial demonstration programs in particular, and the means for attaining them. The economics of the commercial introduction process is first discussed with a focus on the circumstances where government-supported commercial demonstration projects are likely to be effective. The goals of commercial demonstration projects also may be met by other means at ERDA's disposal; these circumstances are examined as well. There follows a discussion of the political, legal, and instititional problems of commercial demonstration projects; even given a sound economic basis, the implementation of such projects faces substantial difficulties.

Finally, the specific policy measures for supporting commercial demonstrations are addressed. A detailed review and analysis would be beyond the scope of this study. Therefore, we have addressed the general criteria which should be considered, and examined only one of these tools (i.e., loan guarantees) in any detail.

Finally, in Section 5 we apply the general principles developed earlier to an analysis of the problem of project and program evaluation. The discussion becomes somewhat more formal at this point, as the nature of the investment in a commercial demonstration project is examined. Section 5.3 focuses on our key areas of ignorance, and comprises an agenda for research in this vital policy area.

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2. R,D&D AS A COMPONENT OF NATIONAL ENERGY POLICY

2.1 THINKING ABOUT THE ENERGY PROBLEM: GAPS OR PRICES?

Three years after the oil embargo there remains wide disagreement about the nature of the energy problem. Some see a fundamental shortage of resources; others argue that it is primarily a matter of national security. The origin of the problem is variously attributed to the manipulations of oil companies, to too much government interference in private markets, or to insufficient federal action and too little support for new energy technologies. For some observers the answer is found in new energy sources and in technological change; for others the only solution is a fundamental revision in the values and life-style of American society. Naturally, these diverging views lead to calls for a variety of conflicting federal actions. The lack of consensus has been debilitating to the efforts of the Administration and the Congress, and of private parties, to achieve a coordinated and vital energy policy.

One split in viewpoint is especially important to discussions of federal energy programs. So much misunderstanding and real difference of opinion stem from divergence on this issue that it is important to begin with a clear statement of the approach taken by the authors of this study. The issue concerns the character of the energy "crisis" and the proper way to formulate solutions to it. On the one hand, much thought and analysis is focused on energy "needs", or "gaps" in energy supply, to be made good by the provision of

particular fuels, or by conservation. The concentration is on physical flows. Technologies are rated according to how much can be brought on stream, and how soon, to cover the shortfalls or "gaps".

An alternative approach is to focus on energy prices as they operate in a market economy. In this view, there is no such thing as an energy "gap": supply is always equal to demand absent price controls and rationing. Some kinds of supply may be less desirable because they are insecure or because they damage the environment. But in all cases the central question is the same: what price are we willing to pay to hold imports down or avoid environmental losses? From this viewpoint the most important fact about a technology is not the extent to which it may "close the gap" but its cost, for it is cost in relation to price that will determine whether it makes any contribution at all.

The difference in viewpoint is fundamental. Usually it is not a divergence of ideology. Rather, it is a difference in perception of how the U.S. economy actually operates, of the driving force behind changes in the energy sector, and about what policy tools are going to be applied. If the circumstance is formulated in terms of "needs" and the failure of assured supply, then the task of government is to find new supply and utilization technologies, design and build them, and ensure that they are used. This is the way energy is managed in the centrally-controlled economies (where the "needs" approach is called the method of "energy balances"). If the policy tools are available and the society wills to use them, then the view is perfectly appropriate. By consensus many services are provided that way in this country--e.g., postal service, highways. Such an approach was successfully and appropriately used for the planning and subsequent provision of key commodities during World War

II. As discussed in Appendix E, the "gap" left by Japanese control of natural rubber supplies was successfully closed by government-supported production, supplemented by detailed regulation of the importation, pricing and utilization of available synthetic and natural rubber supplies.

The issue is whether the approach via "needs" and "gaps" is appropriate with regard to the United States over the next few decades. In the past, energy provision has been left to the workings of private markets--some regulated and some not. Energy prices and the relation of those prices to the costs of domestic supply and conservation measures have been the principal determinants of the magnitude and composition of the energy sector, and of energy imports. The driving force has been profits, with the government as one of the determinants of what was profitable.[1] Whether this should continue is a matter of some dispute. Perhaps the national security problem presented by oil dependence requires a drastic change. Perhaps the prices implied by a commitment to energy independence are socially intolerable because of the potential impact on life-style and on the income distribution. If so, technological change may relieve this squeeze by producing energy at costs lower than otherwise available. If the new technologies did not prove competitive then they would need to be subsidized, and more government direction of energy markets would serve this end.

The hypothesis adopted here is that for the foreseeable future we are <u>not</u> likely to institute fundamental changes in the structure of the energy sector, or move in a determined, decisive way to a more centrally-controlled energy

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[1]For example, while leaving most investment and operating choices to the private sector, public policy has had a great effect on the oil sector through various financial incentives, such as the foreign tax credit and the depletion allowance.

economy. For better or worse, the market system will predominate in the U.S. In fact the very word "commercialization" presumes that the market system will predominate in the energy sector.

If private markets will pervade the energy sector, then "gap" analysis (which tends to ignore prices and profits) involves analytical and planning tools, and more importantly, policy prescriptions, that are inconsistent with the facts of our economic organization. "Commercial demonstration" of new technologies, either supply-augmenting or demand-diminishing, can lead to economically viable new industries only if the expected price regime which these technologies will face provides the incentives for investments to bring them forth. When the role of prices is ignored, the policy goals seem to be those of reducing uncertainties regarding costs of the new technologies. The implicit assumption is that when the new technologies are demonstrated as technically feasible and the uncertainties regarding costs and productivities are "eliminated", commercial penetration is assured. In fact, these activities may have very little to do with commercial potential, unless one imagines a massive increase in government direction of energy markets.

2.2 NATIONAL ENERGY GOALS

Against this viewpoint, we may contrast recent proclamations of national energy goals. As stated by the current Administration, these goals are heavily related to national security, and to the holding down of energy costs to the American consumer. Three main policy goals were put forth in the 1975 State-of-the-Union message and reaffirmed in the 1976 Energy Message:

--"First, to halt our growing dependence on imported oil during the next few critical years.

--"Second, to attain energy independence by 1985 by achieving invulnerability to disruptions caused by oil import embargoes. Specifically, we must reduce oil imports to between 2 and 3 million barrels a day, with an accompanying ability to off-set any future embargo with stored petroleum reserves and emergency standby measures.

--"Third, to mobilize our technology and resources to supply a significant share of the free world's energy needs beyond 1985."

In additon, the Administration has enunciated a set of principles that are to guide the development of the program:

--"Provide energy to the American consumer at the lowest possible cost consistent with our overall economic goals.

--"Make energy decisions consistent with our overall economic goals.

--"Balance environmental goals with energy requirements.

--"Rely upon the private sector and market forces as the most efficient means of achieving the Nation's goals, but act through the government where the private sector is unable to achieve our goals.

--"Seek equity among all our citizens in sharing of benefits and costs of our energy program.

--"Coordinate our energy policies with those of other consuming nations to promote interdependence, as well as independence."[1]

The three main policy goals are stated in terms of physical quantities and, following the argument laid out above, one's view of the task of a federal energy R,D&D agency is strongly conditioned by the seriousness that is attached to these physical targets. If the import "gap" <u>must</u> be closed to 3-to-5 million barrels per day by 1985, then the task of an R,D&D agency is clear: prepare the technologies to close the gap, at minimum cost, as with

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[1]These goals and guidelines are discussed in "A National Plan for Energy Research, Development and Demonstration: Creating Energy Choices for the Future" (ERDA, April, 1976), ERDA Report No. 76-1.

military procurement. Moreover, it is not unreasonable for R,D&D managers to assume that the necessary federal regulations and directives to employ the new technologies will be forthcoming "where the private sector is unable to achieve our goals". Else the goal would not be stated so starkly.

On the other hand, if one assumes that the country is not likely to institute a major shift toward government direction of energy supply and utilization, then more attention must focus on the traditional forces that have moved the energy sector--prices, costs, and profits. One's political judgment may be that, for the people and Congress, the goal of 1985 imports at half the current level is not so important as to override other aspects of federal policy and well-established tradition. Or, one may feel that such a goal (and the use of federal programs to attain it) is simply wasteful; the price is too high, particularly considering alternative methods for ameliorating the security problem. Either way, rather than formulate the issue in terms of strict quantitative targets one will tend to think in terms of prices, and of an objective of lowering the costs of new technologies.

Of course, in focusing so closely on the real flows of oil and their costs, there are subtleties in the R,D&D policy that may be overlooked. In particular, there may be significant international and political aspects in the medium term, say through 1990, even though the direct effect of "commercialization" efforts on oil imports will be quite small. Thus, there apparently is some hope that merely signalling our intention ultimately to reduce U.S. dependence on Arab exports will influence the psychological environment of international diplomacy so as to reduce the leverage and bargaining power of the Arab states. The room for American initiative will be increased, and the likelihood of Arab nations taking (or threatening) actions inimical to

American interest will decline.

There is another related point. The dependence on our Japanese and European allies on Arab oil is much greater than that of the U.S. itself; this is true now and will continue in the future. Under the assumption that the economic strength and foreign policy orientation of these allies will be no less important in the future than they are now, the resistance to coercion of Europe and Japan is also an important foreign policy objective for the U.S. Yet there is no prospect of these nations, as a group, reducing their relative dependence on oil imports to even the present U.S. level, which is widely considered to be unacceptably high. Thus, even with zero imports to the United States, we would be far from true "energy independence."

Of course, what people believe may be as important as the facts of the matter so far as understanding developments in federal policy are concerned. The ability of the United States to retain its position of leadership in international negotiations over energy and related issues of the world's distribution of income and power will depend in part on perceptions of America's willingness to make major commitments to solve its own energy problems. In these complex international processes, the commercialization activities may play an important symbolic role.

Doubtless, much of the history of these programs, especially the synthetic fuels commercialization program, has been influenced by this aspect. Unfortunately, ambitious-sounding programs, widely publicized internationally, can reduce U.S. credibility if they come to be seen as mere words. The national policy of "Project Independence", as declared in the crisis months of 1973-1974, is now widely discredited abroad (as well as at home). At that time the government policy was that world oil prices were "too high" and that

a combination of domestic and foreign policy would bring them down. They have risen by nearly 50 percent since then.

Based on these observations, we may accept the broad sense of the goals stated above, but we may want to revise the language somewhat. First, we have a national security problem which is created by the fact that we import a large fraction of our petroleum from a small group of countries. One goal is to reduce this insecurity, perhaps by lowering the demand for imports in the short run and by avoiding high import levels in the future. Presumably there is some domestic cost beyond which we would not go in attempting to reduce imports, for at some level there are other, less expensive ways to deal with the security problem (e.g., more extensive storage schemes).

Second, there is a longer-run problem of the transition from oil and gas to other energy sources. The government does well to be concerned with this transition quite apart from the national security problem. Once again, the goal can be stated in terms of powering the demand for energy in the longer term, though presumably not at any price.

2.3 MEANS OF MOVING TOWARD NATIONAL GOALS

If we may accept this more general description of the goals of policy, then we may proceed by noting that there are two ways to reduce the demand for oil:

(i) Lower the demand for energy services, in particular those services involving petroleum-using technologies. As delivered energy prices change, the demand for energy services will be affected. For example, higher gasoline prices will reduce the vehicle miles traveled (all else held the same).

(ii) Substitute other factors of production for petroleum products in producing a given level of energy services. Such factors include both other primary energy sources, and other factors of production (capital, labor, and other material inputs).

Factor substitution may take place either through regulation, or changes in relative factor prices. Examples of important substitutions which could be induced either by regulation or price changes include using coal and/or nuclear power to replace oil in base-load electric power generation, or the use of coal in place of petroleum products as a boiler fuel in operating petroleum refineries. Capital and labor may also be substituted for petroleum in boiler use, for example, through more frequent inspection and maintenance of boiler equipment, and by the installation of more elaborate monitoring systems for detecting leaks.

The substitution process works both ways, of course. As oil prices fell over the past few decades, there was a shift away from coal and wood to oil. Later, with the extension of pipelines, the same process occurred for natural gas. Also, with falling energy prices, consumers substituted energy for other inputs and dropped the use of energy-saving methods. For example, as discussed in Appendix B, the use of recuperators for capturing the heat in stack gases was common in the early part of the century, but this device disappeared from many industries as the price of energy fell (relative to capital) over the intervening decades. If relative energy prices rise, the reverse process takes place.

Three types of government actions may influence the process:

(1) Regulation of supply and utilization technology: For example, this might involve rules against installation of oil-fired burners, the 55 mph speed limit, or energy-conserving building codes for new residential and commercial demonstration.

(2) Price controls and financial subsidies: Government policy influences substitution by affecting the relative prices of factors of production.

(3) Lowered costs: The government may take measures which lower the supply costs of factors competing with oil, thereby encouraging substitution.

But items 1 and 2 above are not in ERDA's hands. Moreover, it is not likely that the federal government will undertake major revisions in the nature and degree of federal direction of energy markets through large-scale efforts at technology regulation or wide-scale subsidy programs.

Therefore, the key means by which ERDA can serve national energy goals may be very simply and starkly stated: Lower the cost of substitutes for oil, both now and in the future. That is, the basic purpose of the ERDA programs can be seen as the lowering of the cost of substitution of other energy sources or other inputs for oil in the near term, and lowering the cost of transition away from oil to more abundant (or inexhaustible) energy sources in the future.

The first and most important way to do this is to support energy R&D. By performing such work itself, or supporting it elsewhere, ERDA can actually change the nature of the technology trade-off. By making new technological options available, ERDA can actually lower the true costs of substitutes for oil.

In this paper, however, we focus on a second way in which ERDA can reduce the cost of substitutes--i.e., to subsidize the introduction of new technologies into the marketplace. Generally before commercial-scale usage of a new product or process is undertaken, the major technical uncertainties associated with it have been resolved. On the other hand, many of the details which will ultimately determine its real cost may remain to be fixed. Thus there often are substantial introduction costs, which must be borne by some pioneer firm, or firms, before the new option can achieve widespread adoption. These introduction costs are most often associated with the lowering of the technical,

institutional, legal, and regulatory uncertainties associated with large-scale production and widespread usage. ERDA's method for giving this subsidy has been the commercial demonstration. Through subsidized commercial demonstration, ERDA lowers the costs of substitution, and therefore indirectly reduces the cost of the substitute.

Needless to say, this is a very roughly summarized view of what ERDA can do. It is useful to have even such a crude conception, however, when discussing the issue of commercial demonstration, for it is this aspect of ERDA policy that most dramatically raises the question of the process by which new technologies are adopted in the economy and of the difficulty of any attempt to affect the direction and pace of this technological change.

2.4 THE PROBLEM OF THE "PLANNING PRICE"

Through R,D&D the federal government is undertaking to develop new lower-cost technologies for adoption in private markets. Where there are special problems at the point of market introduction, ERDA will use the mechanism of commercial demonstration to try to accelerate market penetration. Naturally, for each technology, there is some set of market conditions that will have to be met. There are several aspects of energy markets that are relevant, but the most important is the energy price itself. For technologies that promise to achieve a cost below expected market prices, there is a reasonable expectation that the substitution discussed above will take place. For those with less promise for cost reduction there is no such expectation. Of course, ERDA's mission is to find and support the technologies that offer promise of being competitive, and to do this there must be some notion of what price is appropriate for the analysis and selection process.

As one looks forward to the adoption decisions by private firms, there are other factors besides expected price that are important. For example, the risk perceived by a firm contemplating investment in a new technology is affected not only by the expected future prices but by expectations about the rules or procedures by which those prices will be set. It is one thing if prices are expected to follow, more or less, the developments in world energy markets; it is quite another if there is a prospect of continued domestic price controls (or selective subsidies), or of an active tariff/quota policy, even if the expected price is roughly the same. A policy of more widespread regulation of rates of return represents yet another state of future markets, and the calculation of the viability of particular technologies might be different yet again.

Thus, in order to allocate its resources efficiently, ERDA is faced with a continuing problem of determining an appropriate set of likely prices, and other market conditions, which its technologies must confront in future years. The incorporation of these considerations is particularly important in the evaluation of commercial demonstration programs, where the hope is that the technology will prove profitable (as perceived by private market calculations) at the completion of the program. Today many domestic energy prices are being held down by price controls, even below the cost of imports. There has been discussion of a tariff floor, to protect investments against the risk of failure of the oil cartel, but no policy has been set. Similarly, long-term subsidies for specific fuels have been proposed, but the issue is not resolved. Even the fundamental structure of energy supply industries--private versus public ownership and development, or the regulation of rates of return--is the subject of serious questioning, particularly in the area of new bulk

supply technologies.

Thus, in anticipation of increases in energy price, ERDA may carry new technologies to commercial-scale demonstration and even subsidize the first one or two plants in order to avoid delay in working out critical technical problems and institutional barriers. But then two disturbing questions emerge:

(1) Where does the process of demonstration end and that of longer-term subsidy begin, and how far along this process should ERDA carry its activities? At present, ERDA has no mandate to carry out long-term subsidy programs.

(2) What targets, in terms of expected price and other market conditions, should ERDA be striving for with each of its technologies? Clearly the proper timing of expenditures on particular types of technology, and the allocation among different technologies, depends on the likely future trajectory of energy price and energy sector organization. But these market conditions are being set for a host of reasons other than their influence on substitution in the energy sector.

It is not clear to what degree ERDA has a responsibility or a mandate to try to override or correct for the results of domestic price control policy, or to try to influence the other market conditions that influence the attractiveness of various technologies. It also is not clear what future conditions ERDA should be anticipating in planning its programs, so that reasonable success in lowering the costs of different technologies actually produces results at critical times along the way. This is an issue that clearly calls for further investigation and clarification, and for the development of improved methods of analysis.

Here we call attention to the issue of future market conditions by focusing on two energy prices which ERDA must establish in order to evaluate R,D&D projects. One is a "planning price" which, as discussed above, is the likely effective market price of the relevant energy form. More specifically, it is the actual energy price in private markets, including the effects of the

relevant government modifications to those markets. This would include whatever subsidies are applicable to a particular technical option. Of course, this is a future price--so it must reflect ERDA's expectations for future conditions of supply and demand, and forecasts of goverment intervention. Obviously a single price will not match the gross complexities discussed above; in reality some probability distribution will be required and the distribution will be different for the various energy options.

A second "price" with which ERDA must deal is one that may or may not actually appear in energy markets. It is the social value of energy--the amount the society should be willing to pay for one more unit of a given energy source. Of course, it would be the best of all worlds, at least with respect to economic efficiency in the energy sector, if these two prices were the same. However, for reasons we have already discussed, and will address further below, this condition does not appear to hold now and is not likely to do so in the future. Some measure of the social value of energy is necessary for the evaluation of R,D&D programs, however, for it provides a basis for determinating whether investment in a new technical option is socially profitable.

We return in Section 5 to address more general issues of project evaluation. First, however, it is necessary to review the process by which substitution of new technology takes place, and to put the particular activities of commercial demonstration into perspective within the wider context of the behavior of American industry.

3. "COMMERCIALIZATION" AND THE PROCESS OF TECHNOLOGICAL CHANGE

When we speak of a society's "technology" we refer to the ability to combine capital, labor, and other inputs in the production of goods and services. At any point in time this technology is embodied in the latest capital goods, the skills of labor, and the collective knowledge of how to combine them. By a change in technology it may become possible to produce more of a given good or service from a fixed set of inputs (a change in process) or to produce some totally new product. If input prices hold constant, then a process innovation lowers the cost of the product.

A change in technology has no effect, however, unless it becomes a change in "technique", by which we refer to that combination of input factors and knowledge which is actually in use. When a previously unused but known technology is brought into use, there is a change in technique which is not a change in technology. Recent changes in energy prices have yielded many examples of such changes in technique alone--leading to the substitution of capital, labor, and other inputs for energy. There also are examples of changes in technology that have been (or will be) incorporated as changes in technique. It is this latter type of change that is our concern in this study, with a special focus on changes that facilitate substitution away from the use of petroleum.

It was argued above that the United States is not likely to depart from its long tradition of limited government intervention in the energy sector, and that therefore a new energy technology will achieve the status of a widely-

used technique only if it can meet the test of commercial markets. As a starting point, then, it is useful to state a simple definition of the necessary conditions for commercialization:

> Given: (1) the market prices of labor and material inputs, (2) the relevant cost of capital, (3) the market price of energy, and (4) taxes, legal restrictions on the relevant production possibilities, or other government intervention--then commercialization of a new technology will take place if it is available at a cost that allows the private sector an acceptable rate of return on the capital required.

While this simple definition may apply in markets at equilibrium, it defines only the end point of the process of technical change, and it is this process which will draw our attention here. A new technology must be brought to the point where it meets the above criterion, or it will not ultimately be viable. This is the fundamental hypothesis of a study of the "commercialization" of new technologies, given that a centrally-directed energy sector is not anticipated.

The interesting questions, then, revolve around the way this process of technical change actually seems to work now, where it may fail to serve the goals of the nation, and what corrective measures are available. Such an inquiry helps highlight where government efforts are best put; it also brings an appreciation of the limits of what can be achieved by the types of programs now contemplated.

In the sections that follow we review the process of technical change as it occurs in a sequence of corporate (and perhaps public) investments. Much of the discussion is little more than a repetition of the "facts of life" as we now understand them, but such a survey helps orient subsequent analysis of the role of government in facilitating the process.

Implicit in our discussion is the assumption that most of the new technologies which are likely to be commercialized in the foreseeable future will

not be "radical" innovations, but will be improvements which are more incremental in character.[1] While this assumption is not often constraining (as will be seen) it influences our treatment of the economics of the process of technological change. Pocket calculators may be considered a recent radical innovation; shale oil is an example of the more incremental type we focus on. A radical innovation is generally a new product. When a radical innovation is introduced into the marketplace, conditions are very fluid; performance tends to be maximized at the expense of cost and the market structure and corporate organization may change rapidly as firms move in or out of the business. Incremental innovations occur in more "mature" industries, and are replacements for products (or processes) already in use. Thus, cost is the crucial area of competition, and prices and market structure are relatively stable. The fundamental features of the process, as discussed below, are not different; what is different is the rate of change of technology, the market structure, and product costs.

3.1 THE NATURE OF THE INVESTMENT PROCESS

The process of technological change in the private sector can be divided into four somewhat arbitrary phases: invention, development, introduction, and diffusion. Because these activities cost money, and offer no immediate return, the expenditures involved are investments, and each of the steps is usefully thought of as involving an investment choice. That is, at each step

[1] The differences between the two types of innovations have been made clear in recent work by Abernathy, Utterback, and co-workers, in The Productivity Dilemma: Roadblock to Innovation in the Automobile Industry, W.J. Abernathy (Harvard University Graduate School of Business, Boston, Massachusetts, April, 1976), and "Technology, Productivity, and Process Change", W.J. Abernathy and P.L. Townsend, Technological Forecasting and Social Change, August, 1975.

the firm can be thought of as acquiring a new asset, where that asset is expected to yield a favorable return itself, or to open the way to some subsequent investment that will yield a profit.

To see the differences among these investment choices, it is useful to look at each in a little more detail.[1] Invention refers to the generation of an idea and, usually, includes some initial laboratory-scale demonstration of technical feasibility. Basic research, which is associated with the invention stage, is really a form of investment in the production of new knowledge. This knowledge may not be associated directly with any current product or process, as when investments are made in the hope that some useful invention will result.

Development is the set of activities which takes a concept which has been demonstrated in only a primitive form, and bring it to a condition where the technological uncertainties are nearly eliminated. Other uncertainties--principally concerned with the market response and government reaction--may remain. The development stage generally involves a substantial investment relative to that of invention. The new concept must be tested extensively, and alternative designs must be evaluated until the concept is embodied in an actual model that can function effectively in the working environment. This stage usually involves a search for the most desirable combination of inputs, performance attributes, and cost structure. Large expenditures may be involved in the extensive engineering, construction of models and prototypes, and

[1] A similar delineation of the process of technological change as used in "Federal Support for the Development of Alternative Automotive Power Systems: The General Issue and the Stirling, Diesel, and Electric Cases", L.H. Linden, et al, M.I.T. Energy Laboratory Working Paper No. MIT-EL 76-001WP, March, 1976. We have explicitly sought to bring together both the stages by which new technology is developed and the stages in the "product life cycle".

testing. For such expenditure to be "successful" it must result in a product which management expects to make and sell at a profit.

Introduction into the market includes procurement and set-up of initial production facilities and establishment of all the other activities necessary to generate, support, and subsequently exploit the hoped-for market. This may include a marketing program (advertising, demonstrations, etc.), establishment of distribution channels, formation of a widespread maintenance organization, etc. These activities may be very expensive due to the required investment in plant and equipment. The introduction stage produces knowledge of the market's response to the new product; it also should elicit the government's response as well, if regulatory or other interventions have been in doubt. Very often the investment in the introduction stage is not expected to be profitable in and of itself. Accounting losses may be taken at this stage in anticipation of gains in the operation of subsequent generations of production facilities.[1]

Thus a successful introduction is the prelude to the diffusion stage, when usage becomes widespread. The early part of this stage often involves the spread of production of the innovative product to imitators or licensees of the first firm, as well as a build-up of production capacity by the innovating firm itself. If the new product is bought by purchasers in increasing numbers, and its actual use becomes widespread, then new technology is becoming embodied in current technique. If the innovation is a substitute for an

[1]This occurred, for example, in the initial sales of nuclear reactors for electric power generation. While the losses actually sustained by Westinghouse and General Electric may have been greater than anticipated, it is clear that losses were expected--see "The Economics of Nuclear Power," I.C. Bupp, et al, Technology Review, February, 1975.

existing technology in use, the stock of capital embodying the older technology is retired during this process.

What makes this process go? In our society, it is the pursuit of economic gain. The decision by a firm to make the investment required in any of the stages of the innovation process is based on the expectation that the returns--the incremental incoming cash flows, appropriately discounted--will be greater than the expenditures.

At the most basic level, there is no conceptual difference between the investment decisions made at each stage. The task of management is to allocate the firm's capital to the most valuable investment opportunities. That means finding real or intangible assets that are worth more than they cost--assets with positive net present value--and the essential key to the decision is the "valuation" of the asset to be acquired. But the earlier the firm stands in the innovation process, the harder it is to specify operational procedures for evaluation. At the last stage, diffusion, most firms use standard financial techniques, such as discounted cash flow analysis. At the first stage, decision making is based almost wholly on judgment and intuition.

The problem is not simply the greater uncertainty faced at earlier stages. There are important differences in the <u>kinds</u> of things a firm is purchasing when it makes its choice. Once again, if we think of the investment decision in terms of assets that are acquired by the firm, one important distinction becomes evident. Assets required at earlier stages have value not primarily because they are expected to produce net incremental cash flows in and of themselves, but because they open up the opportunity to take the next step with the technology. In effect, investment in an early stage is like the purchase of an <u>option</u> to invest in later stages.

The complexity of the process, and the difference in the valuation task at each step, can be seen by reviewing each stage in turn. The payoff to investment at the final stage (diffusion) results from acquisition of a set of assets which generates a stream of positive expected cash flows. The valuation process boils down to discounting the stream at a rate appropriate to its risk. The higher the risk, the higher the opportunity cost of capital for the asset under consideration, and the higher the appropriate discount rate.

Many uncertainties are resolved by the time the diffusion stage is reached. A firm can look forward to "normal" business risks--which may be substantial in absolute terms, but still small compared to risks at earlier stages. Once the introduction stage is past, the firm has experience in manufacturing and costs are relatively predictable. Buyers have observed and evaluated the new product, so demands for it can be reasonably well forecasted. To the extent that regulatory, institutional, or legal difficulties are relevant, they often have been flushed out and defined, if not resolved.

The risks at the introduction stage are greater. Technological unknowns have been largely resolved, since the development stage has been completed. However, actual production costs at commercial scale remain somewhat uncertain--simply because production at that scale has never taken place before. Knowledge about demand may not be so well in hand, because the product has not yet faced the test of the market. Market surveys and other data collection and analysis techniques can be used, but they give only partial relief. Uncertainty about government regulations must be faced during introduction. Environmental or other regulatory or political problems may not be resolved until the early plants are built and the product actually used.

A decision maker might attempt to take account of the higher risks of the introduction stage by discounting projected cash flows at an appropriately higher rate, arriving at a discounted present value by the usual procedure. But such a procedure, crudely applied, misses an important aspect of the problem. The most valuable payoff to the introduction stage is the option to make a future, diffusion-stage investment. If the introduction stage is a success, then the diffusion-stage investment will have a positive net present value.

A similar argument can be made if the decision is yet one step further back in the process. The chief motive for making a development-stage investment is to acquire an option to proceed with introduction. If development stage uncertainties are favorably resolved, the firm proceeds to the next stage--it exercises its option. If they are not favorably resolved, the firm still has the option to continue, but the option is not exercised.

Thus, investing in development can be thought of as acquiring an option to purchase an option. Investment in basic research can be thought of as acquiring an option to purchase an option to purchase an option! The early stage investments are the first of many possible follow-on investments. Each is a part of a complex, sequential process.

3.2 THE INTRODUCTION STAGE AND "COMMERCIALIZATION"

In terms of this simple four-way breakdown of the process of technological change, it is the introduction stage that is the target of federal programs and proposals in the area of "commercialization". ERDA and other federal agencies also are engaged in R&D that is more reasonably classified with the invention and development stages, but those activities are not the

main focus of this study. Here the concern is with plants that are at or near commercial scale, or with the marketing introduction of new production under something approximating commercial conditions.

As the previous section stresses, the introduction stage is part of a long process of investments, and is intimately tied to the prospects of profitable diffusion. Now, given that our attention is focused on introduction and its link to diffusion, there are several other aspects of the commercialization process that deserve mention. First is market differentiation. The simple definition given at the beginning of this section might be taken to imply that a technology is either "commercial", or it is not. But this would be a misleading simplification of reality: Today heat pumps are commercial in the south but not in the rest of the United States; electric vehicles are commercial for the delivery of milk in the United Kingdom but not as passenger cars anywhere; even synthetic crude oil has been and is being produced in other countries. This is the usual course of events--technologies are almost always used first in markets for which they are most suited. Some energy technologies which now appear to have reasonable chances of being commercialized within the next decade or two will most likely be utilized first in such limited markets: Automotive gas turbines will likely see first applications in long-haul trucks rather than passenger cars; solar heating and cooling will appear in the southwest United States rather than the northeast, etc.

Commercial adoption therefore is not a simple transition from non-use to use; it is part of the dynamic and complex process whereby a new concept may penetrate some markets but not others, or where the penetration may move at very different rates depending on prices, weather, market structure, etc. The transition often is not a smooth one, as some initial ventures fail and the key technical attributes are sorted out.

Secondly, the energy technologies themselves may present very different challenges at the introduction stage, and the role played by the first plants may be very different. To take a simple but dramatic example, compare the introduction of shale oil with that of solar household hot water heaters. With the introduction of small-scale solar devices, a firm must proceed with an effort large enough to gain reasonable economies of scale, and to sustain a viable marketing and distribution strategy. But the investment need not be large in relation to the size of the investing firm or the supporting capital markets. If the introduction is successful, the firm can anticipate significant economies of scale and "learning" in the diffusion stage.

Shale plants are different. Not only is the potential cost much greater for each plant, both in absolute terms and in relation to operating cost, but the expected pattern of costs in the diffusion step is very different. The firm cannot anticipate such "learning" and scale effects with the second, third, and fourth plants as the solar manufacturer can with a successful market penetration. If the nuclear power industry is any precedent, subsequent synfuels units will each involve a new design, and something of a new start so far as "learning" is concerned. Moreover, the investment is large. If set up as an independent corporation today, a single 50,000 barrel per day shale oil facility would be number 110 of the "Fortune 500" when ranked by assets.

A third consideration is the set of complex adjustments that may be involved in integrating a new technology into a highly developed and interrelated production and marketing system, where the key firms have taken on a structure and personality compatible with the <u>previous</u> product mix. For example, shale oil would involve a whole new "business", even for a major

oil company with considerable experience in refining and petrochemicals; the investment structure would be drastically revised; the financial and management structures would have to change; corporate profits would be made in different parts of the business than before; tax and regulatory issues would arise. It is hard to do justice to the number of considerations that would prove relevant for any particular corporation faced with such a decision, but Table 3.1 shows a suggested list of the types of questions that would have to be dealt with in the corporate planning and decision process.

An additional dimension of complexity is added when the new industry is destined to emerge under the bright lights of public scrutiny, for one of the competitive advantages and bases for profit normally inherent in an emerging industry is its "mystique". When this "mystique" is removed through the externally stimulated dispersion of know-how and the constant need for justification to the public, the effect on the private sector's perceptions of risks and rewards in entering the new industry are unclear, and thus the resulting effects on the private sector's willingness to enter the new industry are unclear as well.

3.3 THE MARKET PROCESS AND SOCIAL GOALS

The previous section stress the complexity of the process of "commercialization" of new technologies under our mixed market system. But the fact of complexity does not mean that the system does not work well. Quite the contrary. The United States stands at a point of world leadership across many if not most fields of industrial technology, and this is the case only because the system does work, and very efficiently.

Table 3.1

FACTORS A LARGE COMPANY WOULD CONSIDER
BEFORE ENTERING INTO A NEW BUSINESS

Internal to the new business:

- Are the margins high or low?
- Is change in technology fast or slow?
- Labor or capital intensive?
- Unit of sale large or small?
- Life cycle long or short?
- Where now on life cycle?
- Where is profit leverage?
- How does it relate to our resource base?
- What are barriers to entry?
- What is the growth rate?
- Where would we and competitors be on the learning curve?

Financing:

- Simple or complex?
- Joint ventures likely or not?
- What is time distribution of cash outlay and payback?
- What is cost of abort?

External to new business:

- Government intervention high or low?
- Competition large or small?
  - --what are our competitive strengths and weaknesses?

Relatedness to existing business:

- Is it an extension or a diversification?
- Is it significant in size?
  - --relative to our firm?
  - --relative to the industry?
- How does it affect the rest of our businesses?
  - --how is it synergistic?
- Subject to same risks, or different ones?
- What parts of existing business <u>must</u> we protect?
  - --does this protect them, or add new areas that must be protected?
- How would we be different with it?
  - --without it?
- What are alternatives?

Timing:

- Why now?
  - --now or never?
  - --should we lead or follow?
- How would we be different if not now?
  - --wait, and buy in later?

There are specific problem areas, however, where the system does not necessarily serve the larger interests of society. Firms are led to employ technologies that are not in the larger national interest, as in the case of uncontrolled industrial pollution. Or there may be technologies which are desirable from a social viewpoint, but which the private sector has no incentive to develop and implement. Since we entrust much economic decision making to the market--and in general we hold to a theory of economics that says that such market decisions will be socially desirable[1]--such undesirable outcomes are often referred to as "failures" in the workings of the market system or "market failures".

Presumably, if we felt that things were going well in the area of energy and technology, we would continue to leave the issue largely to the private sector, as we have for two hundred years.[2] ERDA would not be as large or as diverse in its scope as it now is.

Given this history, and the current private-public split in the energy sector, a useful way to organize inquiries into the federal policy in the area of energy technology is to ask where the instances of "failure" are, and what it takes to correct them. The question addressed in this study is of this type, but is more narrowly defined. Here our concern is with the failures that are related to the introduction stage of important new energy technologies and with the identification of those failures that may be corrected

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[1]Here we do not address the issues surrounding government involvement in the earlier stages of R,D&D. For a discussion of this topic, see Energy Research and Development, J. Herbert Holloman, et al., and Michael Grenon (Ballinger Publishing Co., Cambridge, Massachusetts, 1975).

[2]There are a few notable exceptions, such as government R&D in the nuclear industry. Of course, it also is true that government activities outside the R&D area have had a tremendous effect on the composition of the energy sector--e.g., the interstate highway system and the tax code.

by government subsidies of commercial demonstrations, or other efforts to facilitate "commercialization".

3.3.1 Energy Prices

As suggested in the simple definition of commercial feasibility at the beginning of this section, a key determinant of the viability of any new energy technology is the price of energy itself, and the expectations about this price in the future. If the energy price fails to reflect the social value of a barrel of oil supplied or a BTU saved, then a fundamental flaw is introduced into the normal process of decision making about private investments in new energy technologies. This is not a "failure" that can be directly corrected by government efforts at commercial demonstration or related activities, and so is outside our direct concern here. However, the energy pricing question is critical to the whole process of technological change, most especially at the stages of introduction and diffusion. Expected energy prices are, as a result, especially important to the planning and evaluation of government intervention at the introduction stage.

The situation is both complicated and uncertain, as a brief look at current price-setting processes reveals. Energy prices certainly are not determined by simple considerations of domestic supply and demand. They are the result of a complex set of controls by the U.S. government and foreign nations, as well as the usual market processes. We will discuss only oil and gas, our two "scarcest" domestic resources.

Oil Prices. World petroleum prices are set by a cartel, the members of the Organization of Petroleum Exporting Countries, OPEC. The current Persian Gulf price is $11.50 for the standard or "marker" crude; in 1969-70 the actual market value was around $1.30, or in 1976 prices, around $1.90. At those

prices, and higher ones in producing regions closer to market, there was chronic potential excess capacity. Thus the cartel price is today about six times (inflation-adjusted) a price which was above the competitive level before the cartel became effective. While in the global perspective such a price is very inefficient, this country, and consuming countries generally, can only treat the cartel price as an external fact, and seek the least expensive adaptation to it.

It is widely believed that the current oversupply of oil will gradually be superseded over the next several decades by true scarcity, as existing reserves are replaced only at a very much higher real cost. Thus, even if the cartel holds, the price will then be no lower, in real terms, than today. The cartel's profit-maximizing price may be higher or lower than the current level and thus may be changed. The cartel may run into serious trouble, and the price may fall substantially. Or the cartel may attempt to cut prices in selected markets to destroy competitors. Finally, the cartel may take actions which are not motivated by economics at all, but rather by politics; in this sense it may not play the usual rules of the game. These possibilities make investment more risky (than at the same price without the cartel), which means that the price necessary to draw in investment must be high enough to provide a return above the one suitable for "normal" commercial risk. Thus, for example, rational investors would not support a synthetic crude oil operation whose product cost equaled the cartel price, unless that cost included a "high" rate of return on the investment.

Until 1971, the United States limited crude oil imports through a quota system. (The system remained in existence but without effect for two more years.) This maintained prices in the United States above world levels. The import quota augmented a highly complex system of regulation of domestic oil

production. Partly it operated through the tax system. Depletion allowances lowered the tax burden on the domestic production of oil and gas (along with other minerals), thereby increasing the attractiveness of before-tax profits upstream of the wellhead and drawing in capital from otherwise competitive investment. The most important producing states, notably Texas and Louisiana, controlled the total petroleum production, but on a per-well basis, thus artifically stimulating drilling by individual lease-owners. This resulted in higher investments by the industry than would otherwise have occurred.

This system has largely disappeared, succeeded by a new set of contradictory features. The value to the American economy of a barrel of oil produced at home is (at least) the value of domestic resources which must be shaped into goods and services to be transferred abroad to pay the foreign government-owner. This is the price of international oil delivered to the United States, somewhat over $13 at the present time. But petroleum prices in the United States only indirectly reflect this social value; rather they are presently set by the complex system of petroleum price controls. Domestic producers face prices of $5.25 for "old oil" and $11.33 for "new oil". Oil in these classes will not be produced if it costs the operator more than these prices, even though they are substantially below the real social value of the oil. Buyers, on the other hand, face a price of $9.50, which is the weighted average of these domestic supplies and imports. They then have inadequate incentives to conserve, as the expense avoided in not consuming a barrel of oil is less than its social value. These prices have been established by the federal government, not for economic efficiency but in order to prevent a competitive disadvantage for refiners who do not own crude oil which can still be cheaply produced; and to prevent windfall profits to the

owners of this crude. Obviously, prices designed to regulate competition, and do justice, cannot be expected to give the signal of value emitted under simple competitive conditions.

National Security Premium. The social value of domestic oil is not determined solely by the international price: There is also the issue of import "dependence". It hardly needs to be stated that the United States is increasingly dependent on a small group of foreign nations for our petroleum imports. This group is well organized and may attempt to influence our foreign policy by actual or implicit blackmail. This is a social cost which would not be reflected in private places even if those prices were not controlled by the government. It may be described as a "national security premium", associated with imported oil only. Since a barrel of oil domestically produced or conserved effectively translates into avoidance of an imported barrel, it is the international price plus the national security premium which is the effective social value of domestic supplies. However, while this concept seems a reasonable one, it leaves us with, at minimum, a substantial measurement problem: How much is it worth to us to avoid importing a barrel of oil? We defer discussion of this question to Section 5; for now, we assume that the national security premium is large enough to be a contributing factor in the ensuing discussion. Given the national emphasis on reducing imports of petroleum, this seems a safe assumption.

Natural Gas Prices. The regulation of the price of natural gas is a longer-term and more complex form of the same problems. In the producing areas of the southwest, natural gas is still available on intrastate shipments, at a price which appears to have become approximately equal to that of "new" crude oil in energy-equivalent terms, and to residual oil, but higher than Rocky Mountain coal. Electric utilities appear to be following this signal,

and gas is being phased out. The effective demand for new gas is limited to the intrastate market. For many power plants, especially when located close to areas of gas production which have no alternative pipeline connections, the price of gas is still below that of competing fuels, and there is an incentive to keep burning it.

Outside the producing states, the price of natural gas is only a small fraction of the equivalent price of oil. The national ceiling is 52 cents per million BTU,[1] equating to about $3.12 per barrel of oil, or 7 1/2 cents per gallon. At such prices, there is an enormous unsatisfied demand for natural gas, the well-known "shortage". Strenuous efforts are being made to import liquid natural gas (LNG) from OPEC members, and to manufacture synthetic natural gas (SNG) from coal. Expected costs in the range of $20 to $30 per barrel of oil-equivalent will apparently not attract private investment into SNG production. Since the real resource costs of producing and shipping LNG are considerably lower than SNG costs, the OPEC governments supplying LNG have considerable leeway in their pricing decisions and their policies will determine LNG availability. It is not clear whether gas consumers are prepared to take large amounts at these prices, or whether in time they will substitute away by changing their heating apparatus. In any case, consumers will not be confronted with these high prices for a long time, for the new sources apparently will be "rolled in" with the much lower prices of existing interstate natural gas.

Thus producers and consumers of gas are offered multiple conflicting price signals. Synthetic gas would cost eight times current natural gas

[1]There is a proposed increase now in the courts.

prices to consumers. A gas consumer in Texas is paying, at present, about four times the price charged to the interstate consumer for his gradually dwindling flow for new gas; the new interstate consumer faces an infinitely high price--it is not to be had at any price. Eventually the low price and the infinitely high price will come together at a price which is very high by today's standards, and higher than the price which consumers considered when they installed their equipment.

Were there no price regulation, it is not clear that the demand for LNG and SNG, for base loads, would exceed zero. Some 65 percent of natural gas is in industrial uses (chiefly electrical power) where it can be replaced by residual fuel oil and coal. If gas is to be deregulated over the next ten years, then investment in LNG and SNG, projects which add to gas supply by 1985, may prove completely wasteful. The presently perceived "need" for large-scale supplies of gas will turn out to be the misinformation generated by price regulation.

Impact. The impact of the pricing regulations on investments in technological change depends on the particular circumstances involved. Any conservation technology, for example, is at a strong disadvantage due to low gas and oil prices in domestic markets. The amount a buyer will pay for a piece of energy-conserving equipment is directly related to the price of the energy conserved. If the energy is a petroleum product, for example, then that price is now being held well below the actual marginal cost of the energy to the nation--which is the price set by the OPEC cartel. A barrel of oil saved is valued by the consumer at the domestic price, but the savings to the nation is the cartel price; the difference is a savings accrued by the nation as a whole but not the individual conserver. Clearly, then, any activity

which involves oil or gas conservation is privately undervalued. In particular, the investments in the development and introduction of new energy-conserving technologies will be less extensive than they otherwise would be.

Energy supply technologies will be affected to an equal or lesser extent. Solar heating and cooling of homes, for example, may displace consumption of refined petroleum products. In this case the impact of price controls is similar to that on conservation. On the other hand, new sources of synthetic crude oil, such as oil from oil shale, presently appear to cost more than imported crude, so it is hard to conceive that an attempt would be made to control the sales price.

The distortions caused by inappropriate energy prices apply across-the-board to all stages of the process of technical change. Where the value of the ultimate product of technological change is decreased by undervaluation of domestic energy, there is a lowering of the expected returns to an investment in any stage in the process. Naturally, the importance of the effect is very different at different stages. At the invention stage it is the expectation of prices several decades in the future that is important, for that is when a new innovation would reach the diffusion stage. Needless to say, such prices are very uncertain; therefore, they are likely to enter into the investment calculation only in a very crude manner. The fact that the attributes of the innovation (after any development and introduction stage) are very uncertain as well only serves to further reduce the relative importance of prices in decisions at the invention stage.

The impact of energy prices is very different in the diffusion stage. There the technology is well defined, and the innovation will be adopted to the extent that is profitable to do so. Inappropriate prices have an increasingly

important effect as a technical option advances from invention, through development and introduction, into diffusion.

Thus, domestic price controls create a situation where subsidies to conservation efforts may be socially profitable. However, government intervention in support of the commercialization activities--without long-term subsidies--would be limited in its impact, for the demand for such technologies, once introduced, would remain too low. Commercialization would fail, as diffusion would not occur. In such circumstances price controls and expectations of future controls are a dominant influence on the rate and extent of technological change, and a principal force in preventing adequate private performance.

3.3.2 Failures in the Process of Technological Change

Clearly, the current process of price determination, and likely developments in the future, are an important boundary condition for all of ERDA's planning. Much of this process is poorly understood, particularly where it is heavily influenced by government policies and the associated domestic and international politics. A high priority should go to efforts to understand and analyze it. So far as U.S. domestic policy is concerned, almost any measure to clarify the long-term price policy would be helpful, and of course the higher the energy price that is found tolerable, the more rapid the rate of technological change will be, regardless of federal efforts to help.

Whatever happens on the price side, however, there are a number of other problems that may lead to a less-than-desirable level of investment in new technology by private firms. There are several categories into which these "failures" are conventionally gathered, and a survey of each reveals something about the types of activities where government efforts might be most usefully focused.

Inability to Appropriate Technical Results. Usually, when a firm makes an investment, it expects to capture the outputs or returns for itself; it would prefer that the results not go to everybody, for then no competitive advantage has been gained. Technical information is difficult to control, however, and once it gets out any other firm may use it without paying the originator. That is, the results are not "appropriable". In the terms used earlier, a firm carrying out R&D may not be buying an option for itself alone, but for all its competitors as well. The incentive to make such investments is thus dampened, for the firms' returns from the investment are less than the social returns--which include the profits of other firms as well as the benefits consumers realize from less expensive or improved products. This is a market failure in the sense defined above.

Of course, the patent system is designed to remedy this defect, and firms also make efforts to protect proprietary technology which is not patentable. But there remain substantial classes of knowledge which are excluded from the patent system or are not readily held proprietary, or which might contribute in widespread or unforeseeable ways to new products. One such circumstance is basic research. Because of difficulties in appropriating the benefits of a fundamental contribution to knowledge, government subsidies are commonplace. This type of market failure becomes less significant as a technology progresses to later stages of development. Technical knowledge becomes patentable, or more readily held proprietary, as the new knowledge becomes embodied in a product.

One technique which can be used to mitigate the non-appropriability problem is the use of industry consortia to support development programs. The firms which stand to gain from a given class of advances can join together to finance them. Then the individual firm's proportional investment can be

made to approximate its proportional ability to profit from the advance, and the group as a whole can capture the bulk of the benefits. The Electric Power Research Institute, for example, is supported by contributions from the nation's electric utilities; it supports R&D on electric power generation technology. However, for anti-trust or institutional reasons, it is not always possible to organize the appropriate group.

To what extent does this phenomenon apply in the introduction stage of the process of technological change? There are several types of information involved. First, technological information will be developed as the product embodying the new technology is produced and used. This information is generally reflected in decreased costs of subsequent plants. For example, it is estimated that the first plant to produce a new type of automotive powerplant would cost several times as much as subsequent plants of the same capacity.[1] The major issue, then, is the extent to which cost reductions are appropriable by the firm introducing new technology. It is widely presumed that benefits of this sort in fact are substantially appropriable, in contrast to the extreme case of new fundamental knowledge. One argument is that knowledge is embodied in the collective experience of the engineers and managers of the firm, and so cannot be readily learned by outside observers. Engineers and managers can be lured from firm to firm, but rarely en masse.

Determination of the importance of this "failure" is not a simple matter in any particular case, and the conditions vary greatly across industries. Therefore, continuing efforts to understand this problem are very important

[1] "Should We Have a New Engine? An Automobile Power Systems Evaluation. Volume II, Technical Reports," (Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, August, 1975).

to ERDA's efforts--both to identify which situations are truly blocked for this reason, and to guide the selection of the proper instruments for subsidy.

Regulatory and Political Risk. It may be that the proprietary technical and cost information developed at the introduction stage indicate a technology sufficiently attractive to induce socially desirable outlays, but regulatory and other institutional problems intervene. Important institutional, regulatory, and political issues posed by the new technology may be resolved only by substantial production and use. This is true for synthetic fuels, for example. Information about environmental effects of full-scale plants may be inferred from pilot plants, for example, but the issue of what effluent levels are acceptable is difficult to resolve until production is attempted on a commercial scale. This is a special kind of distortion of private decision making: Investment may be artificially discouraged because society has not gotten around to specifying the rules under which the new technology will operate.

For example, the diesel engine has special emissions problems (e.g., particulates) that may create problems if the engine is ever widely used in private automobiles. As yet the emission standards to be applied to diesel emissions have not been determined by federal regulatory authorities, and so long as this uncertainty remains it is not in the interest of any manufacturer to spend substantial sums of money on the introduction of the diesel engine. Ultimate regulatory constraints may or may not be set at a level that allows the diesel to function as a passenger car engine. But in the meantime, uncertainty about regulation magnifies the risks of development. Unfortunately, it is unlikely that the Environmental Protection Agency will start the necessary impact studies and begin to formulate procedures for setting particulate emission standards until diesel use becomes widespread. Similar regulatory

barriers, or potential ones, will be faced, with greater or lesser impact, by any important new energy technology.

This circumstance suggests that a well-designed government intervention may be very useful. If socially valuable new technologies are blocked by the "regulatory risks", then an off-setting subsidy may be in order. The subsidy would not only encourage use of the technology, which is good in itself, but also lead to a resolution of the regulatory risk and open the way to further, unsubsidized investment in the technology by private firms. Effectively, the subsidy would cover the private costs of developing the necessary case law, regulatory rulings, etc. Careful study of the nature of the regulatory problem should, once again, offer guidance as to what kind of subsidy will most effectively resolve the issue.

There is a cautionary note that needs to be sounded here. We are speaking of intervention by the government to resolve differences created by regulatory procedures, administrative agencies, and court rulings which, speaking loosely, comprise the "government". Therefore, there are several issues that naturally arise in connection with a federal subsidy program which is heavily influenced by these considerations:

1. The barriers may be political, in the sense that there is a latent, unresolved conflict between two or more parts of society. What are the consequences of attempting to force an early resolution of the conflict? What would it take to resolve it?

2. Are the risks truly "artificial" ones, reflecting no more than the tendency of persons or organizations to avoid the effort and controversy required to resolve the issue? Or does the reluctance to decide reflect an actual lack of knowledge about the effects of full-scale use of the new technology? In the former case, all that is needed is for regulatory or other governmental agencies to give a clear statement of the rules of the game. (Of course, this may be difficult to do in a society where political and regulatory authority is decentralized--more on this below.) In the latter case, the building of commercial-scale facilities may or may not be the cheapest way to gather the needed information. (This point is also expanded below.)

Market Structure. Issues of market structure may be important in the process of technological change. Monopoly power in any market generally is associated with excessively high prices. Such prices would certainly have an across-the-board impact on investments in technological change. We have discussed the energy prices above. Any other market would require a detailed analysis of its own.

Potentially more important, and less well understood, is the impact of market structure directly on the propensity to innovate. Simply put, large firms may be needed to support large research and development establishments and to risk the investments needed to introduce new technologies. On the other hand, firms with monopoly power would seem to be under less competitive pressure to hold costs down and generate innovative products. Moreover, under competition the inducement to innovate is greater because the innovator makes all the gains while his competition bears the losses. A monopolist must do a private cost-benefit calculation, and may turn away innovations which would have been profitable under competition.

For example, one situation where there is debate about the influence of concentration on innovation is the automotive industry. The supply of automobiles to the American market is dominated by the "Big Three", with a fringe consisting of one "independent" and a number of importers. In such a circumstance there are good reasons to suspect that the full play of competitive forces is not brought to bear. On the other hand, the existence of such huge industrial complexes gives opportunities for innovation that might not exist were the industry made up of smaller units. There is no consensus on whether more or less innovation takes place under current market structure or some alternative. Government support for commercialization of new automotive engines must deal with the industry structure as it is, at least making some

effort to ensure that such support does not increase the degree of concentration.

Risk and Financial Markets. It is often argued that investment in new energy-related technologies is blocked by lack of financing. The investments at the introduction stage are so large, and so risky, it is argued, that private investors are unwilling to advance the necessary capital.

Even if true, this may or may not be a "market failure". When an investment banker states, for example, that large-scale synthetic gas plants "can't be financed", he may simply mean that the expected profitability of investment in such a plant is not high enough to compensate for the risks that would have to be borne. It is irrational for an investor to commit capital to the high risk use if the anticipated return is not correspondingly large. Society as well should demand a high expected return on capital the higher the associated risks.

A market failure occurs when the private decision maker has a degree of risk aversion different from that appropriate to society at large. A common argument is that private investors are too risk averse. It is held that the government is capable of spreading the risk of a particular technological experiment over a very large pool of alternative activities, whereas a private corporation may be limited in its ability to diversify the risk of large investment. Thus a firm would not undertake such an investment, even if its estimate of the expected value of the investment is the same as that of the government. In such a circumstance there is under-investment, from society's viewpoint, in risky technologies.

On the other hand, the U.S. has a highly elaborated and efficient set of capital markets, and these offer extensive opportunities for spreading risks.

The combination of markets for loan funds and the various stock markets for equity capital--supplemented by various forms of joint corporate ventures--can serve to diversify risks very widely over the community of stock and bond holders.[1] These markets appear to serve well in supporting potentially profitable investment--including very large and risky ones--in energy and in other sectors of the economy. Thus there is no a priori reason to believe that capital markets are demanding an excessive risk premium for investments in new energy-related technologies.

It is true that some ventures with new technology are large from the point of view of a single firm. If the goals of management include objectives other than increasing stockholders' equity, then this "exposure" may be a significant factor in the investment decision. This is likely to be the case for a new venture by one of the many large American corporations which finance their investments almost entirely with internally generated cash, making such investments less sensitive to evaluation by the capital markets. But in general the problem of corporate timidity in the face of risk does not seem a crucial one; it is unlikely that it could long block investment in new technologies, providing that they offered profitability sufficient to attract debt (or perhaps equity) funds from capital markets. Not all corporations or managers are risk averse: we observe corporations, for example, investing hundreds of millions to acquire off-shore drilling rights, even though there

[1]Diversification cannot eliminate all the risks of investing in new energy-related technologies. The revenues and costs of a synthetic gas plant depend on inflation, the rate of growth of the U.S. economy, the OPEC oil price, and many other factors that affect, in varying degrees, the aggregate value and profitability of the economy's real assets. These risks cannot be diversified away by the individual investor or by society as a whole. In principle, only these systematic or non-diversifiable risks are relevant in assessing the present value of an investment opportunity.

is a significance chance (proven by experience) of getting nothing at all.

There are two mechanisms which management can use to mitigate the risks to the corporation. Joint ventures are widely used--for example, the major efforts now underway to commercialize oil shale are mostly combinations of several firms. The other approach is to organize the new venture as a separate corporation. This provides the protection of limited liability for corporate, institutional, or individual owners. Financing for such a venture should be readily forthcoming if anticipated profitability is high enough to compensate for the risks involved.

3.3.3 Prices and Other Problems: Summary

Here we have viewed the process of technological change as a series of investments undertaken principally by the private sector. Government efforts to spur the commercialization of new technologies constitute an intervention in only one stage of a long and complex process. In many respects the process itself is not well understood.

Our analysis of the relative social and private incentives to technological change in the energy sector is summarized in Table 3.2 Several features of the table stand out. First, we have only very limited knowledge of some of the key features of the process of technological change and, in particular, the extent to which it occurs effectively without government intervention. Except in the diffusion stage, where the returns to investments can be calculated with reasonable accuracy, it is very difficult to say whether, in any given case, resources are being allocated to the innovative process in anywhere near the socially appropriate amounts. One is left with examining the incentives to technological change, rather than the amount of the investment itself. Further, as indicated in Table 3.2, there are cases where even

Table 3.2

IMPACT OF MARKET FAILURE ON STAGES IN THE PROCESS OF TECHNOLOGICAL CHANGE

Stage in the Process

Source of Market Failure	Invention	Development	Introduction	Diffusion
Oil and Gas Price Controls	Probably Unimportant	Important Where Relevant	Very Important Where Relevant	Crucial Where Relevant
National Security Premium	As Above	As Above but Magnitude Unclear	→	→
Inability to Appropriate Technical Results	Probably Important	Less Important	Usually Considered Unimportant	Unimportant
Regulatory and Political Risks	Unimportant	Less Important	Unclear May Be Important	Unimportant
Market Structure	Unclear Depends on Industry	→	→	→
Risk and Financial Markets	Unclear	→	→	→

the direction of the effects of the incentives are unclear.

Government-supported commercial demonstrations affect only the introduction stage in the process of technological change. A crucial issue, then, is the extent to which there are market failures in that stage only, which might be corrected. We will take this question up at some length in the following section. An examination of Table 3.2 indicates, however, that the non-appropriability of the benefits from the resolution of institutional problems is the only such difficulty. Other problems--energy price problems in particular--may lead to inadequate incentives in the introduction stage. But these difficulties apply to other stages as well, and must be examined in a larger context.

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4. GOVERNMENT-SUPPORTED COMMERCIAL DEMONSTRATION: GOALS AND MEANS

In this section we focus on government-supported commercial demonstration programs. First the circumstances under which such programs are likely to be both effective and socially profitable are examined. Next the alternatives to commercial-scale demonstrations are examined. Such programs are bound to be tangled in political and institutional problems; these difficultes are reviewed. Finally, we discuss the specific financial instruments which might be considered in supporting such demonstrations.

4.1 THE ROLE OF GOVERNMENT INTERVENTION

In Section 2 we concluded that ERDA's goal should be to lower the cost of substitutes for oil. This would be the result of R,D&D programs which make new technological possibilities available to the private sector. ERDA must perform this function within an environment which is not under its control: Specifically, energy prices are determined by a combination of foreign governments, higher level policy decisions of the U.S. government, and market forces.

Section 3 examined the process of technological change as it normally occurs in the private sector. Technological change is the result of a series of investments which are made in the expectation of a suitable return. Expected prices are the key parameters, external to the firm, which affect the investment decisions. In the early stages of the process, the relevant prices are those expected several decades in the future. They are therefore very uncertain, and the uncertain technological potentials are the dominant factors in the investment decision. At the introduction stage, however, the relevant

prices are crucial to the investment decision. There may be some technological uncertainties remaining at the time of the decision, but they are relatively small; the cost of the new technology is reasonably well known (usually, though not always, within 50 percent or so), and the relation of this expected cost to the expected price is of crucial importance.

Ideally, ERDA and industry should be using the same prices in their evaluations of the commercial potential of new technologies. They are both estimating the same quantities--the market prices of the product and the key inputs in its production. These prices may be heavily influenced by future government action, and may show the effects of significant market failures; at any rate they are out of the control of both ERDA and industry. Thus, unless there are significant differences in technical judgment between ERDA and industry, their evaluations of the long-run commercial potential of a technology, estimated at the point of the introduction decision, should be essentially the same.

In most cases the long-run commercial potential of a new technology, when evaluated prior to the introduction decision, will be independent of possible federal interventions in the introduction stage. In most cases, the costs of the introduction stage (which often are not recovered <u>during</u> that stage) are a small fraction of the total cost of the product <u>after</u> introduction.[1] If, when examined at the end of its development, a technology appears to be commercial in the long run, it usually will be introduced and "commercialized" by the

[1]This is the usual case; consider synthetic fuels or a new automotive engine for example. A possible counterexample is the SST, depending on how one defines the stages in that case (see Appendix D).

private sector. In most cases, ERDA commercial demonstration programs therefore simply do not have very much leverage. They may be useful, but they are not often likely to be decisive in determining the fate of a new technology.

Thus, ERDA's commercial demonstration programs can be viewed somewhat crudely as subsidies or offsets to the "introduction stage"--i.e., the excess of cost over production revenues during the introduction stage. It may be viewed as an "industry-front-end" cost, analogous to the usual "plant-front-end" costs necessary to get a single plant into operation. After these costs are sunk, the industry operates at some "long-run marginal cost".

Before these costs are sunk (i.e., at the introduction decision) private firms will include them in their evaluations of whether or not to commercialize a new technology. Where the long-run marginal cost plus an appropriate return on the introduction cost is less than or equal to the expected price, industry will proceed. ERDA commercial demonstration programs can reduce the introduction cost, and therefore they may affect a firm's introduction decision. ERDA's ability to influence such decisions with commercial demonstration programs depends on the relative magnitude of the amortized industry-front-end cost and the expected long-run marginal cost.

Under what conditions should ERDA intervene to reduce these costs? The answer to this question hinges on the analysis, in Section 3, of market failure in the process of technological change. There are two important circumstances where private industry may not have sufficient incentive to commercialize a new technology, and where subsidies to the introduction stage can be socially profitable.

The first is the non-appropriability of the technical and institutional information generated at that stage. Because of the complex and dynamic

nature of the markets for new products and processes, the importance of this failure is an open issue. However, we assume that a crucial role of government-supported commercialization is to subsidize the acquisition of this information.

The second occurs when energy is underpriced. When the expected social value of energy is greater than the expected market price, then subsidies to any of the stages of the process of technological change may be good investments. ERDA's forecast of the social value of energy depends principally on projections of OPEC's pricing policies and the extra social cost of the insecurity of imported oil. The market prices of primary energy resources, on the other hand, depend on the OPEC price and government price controls.

Thus, the second possible driving force for government-supported commercial demonstration programs would not be the correction of a market failure of the "usual" sort. Rather, it is the direct attainment of the social benefits associated with domestic production or conservation of energy which is undervalued at going market prices. In this case the introduction subsidy would go beyond the provision of the non-appropriable technical and institutional information discussed above.

The principal benefits which would accrue to ERDA commercial demonstration programs are independent of which of these considerations is used to justify the program. ERDA should subsidize the introduction costs of a technology up to the point where its private cost at introduction just equals the market price. Then the benefit attributable to the program is the present value of the difference between the social value and market price for all the fuel supplied or saved domestically as a result of the program. (Or, if the program only accelerated the introduction of the technology, it is the benefit of the earlier flows which must be computed.) If the total costs of the program,

whether devoted to subsidizing appropriable or non-appropriable developments, are less than this benefit, the program is a socially profitable one.

It would be misleading to close this discussion without reference to an important problem which poses further difficulties of program analysis and design. This is the problem of unintended side effects of government programs. Government subsidies to particular technologies may drive out private efforts that would otherwise take place. Firms may decide that they cannot compete with a heavily subsidized program; or corporate management may find it difficult to justify large demonstration expenditures to their boards and stockholders when they can see that the government is doing the job anyway. Thus, on balance, federal support may lower the total resources devoted to commercializing a new technology.[1] Clearly, the planning of government investments in a new technology should take account of the net effect on the entire market, not just on the firm receiving the subsidy. An automotive industry executive communicated this problem to us with the following "hypothetical" example; while it refers to support of R,D&D it applies to subsidized commercial demonstration as well:

> I wonder if you have considered the following hypothetical situation in which it would appear that perhaps government participation might be counterproductive to competition and private industry investments. Assume two automotive companies are working on a similar technology with the objective that if they are successful, they will obtain a competitive advantage and, therefore, recover their investment with profits. Assume now that a government agency decides that the private effort was not as large as would be warranted by the benefits, and therefore elects to support one of the companies with public funds. The second company might drop its own efforts in that area on the basis that the technology developed with the public funds would be available to them as well as to the company carrying out the work with government

[1] Alternatively, it is possible for a government program to lead to an <u>increase</u> in private funding. Something of the kind apparently occurred in the nuclear program when General Electric proceeded to accept turnkey contracts for reactors while Westinghouse projects were being subsidized.

support. This response to reduced competition would result in a smaller increase in the total effort on that particular technology than had been intended by the original government action.

I don't have a good feel for the likelihood of a response like this example, but certainly government funding could have a significant effect on normal competitive forces.

A related problem arises when government subsidies seem to be pending. Firms may hold back their own projects in the hope the government will pick up part of the tab. It seems, for example, that this may be happening in the solar heating and cooling market at the present time (see Appendix C). Even within the conceptual layout discussed above, this problem provides a formidable challenge to the present state-of-the-art in the design of government programs.

4.2 ALTERNATIVES TO COMMERCIAL DEMONSTRATION

By subsidizing the construction of commercial-scale plants by private firms, it is hoped that most technical, regulatory, and institutional difficulties associated with plants of that size will be raised, if not resolved. Given that the tactical goal of the program is to address these uncertainties, the choice of plant technologies, locations, etc., would presumably be designed to <u>insure</u> that all the important uncertainties are addressed; the resolution of these uncertainties is a principal component of the introduction cost.

However, as with any investment, alternatives which might accomplish the same goals at lower cost must be considered. In fact, government-supported commercial demonstrations attempt to reduce technical and institutional uncertainties with what might be termed a "brute force" technique. It is not clear that the resolution of the relevant technical and institutional uncertainties requires the actual construction of commercial scale plants.

Consider first the technical uncertainties. A commercial scale plant is one which is of sufficient size that there appears to be no great economies gained by simply making it larger. That is, it is designed to produce the product at a scale that is believed to be that which ultimately will prove to yield the minimum unit cost. In any such plant--be it an automotive engine plant or a coal gasification plant--there generally is some subsection of the relevant process technology which is significantly different at commercial scale than at smaller scale. If this were not true, then there would be no economies of scale to be gained by going to the larger size, and the "commercial scale" would be smaller. The crucial question, then, is whether these limited technical subunits are so different from their smaller counterparts that they are not readily scalable. If they are readily scalable--e.g., a larger pressure vessel--then there are no significant technical uncertainties which require commercial scale construction for their resolution.

There may be cases where the crucial subunit is not readily scalable--for example, if it involves the handling of materials volumes substantially larger than in any previous effort. In this case, then, the alternative to building a full-scale demonstration plant is clear: build a facility <u>only</u> of the crucial subunit, and no larger than that necessary to resolve the relevant technical uncertainties.

The case of the institutional or regulatory uncertainties is different. The most obvious alternative would appear to take direct action to resolve the issue. Consider again, for example, the case of particulate emissions from automotive diesel engines. As discussed in Section 3.3, it appears that action to set an emission standard for particulates from automotive diesel engines will not take place until after, possibly well after, a substantial

increase in the number of diesel-powered vehicles on the road. Thus the first American manufacturer to engage in substantial production must face a risk that subsequent firms might not have to face.

However, there might be ways to resolve this uncertainty which do not require the construction of large automotive diesel engine plants. Specifically, the Administrator of the Environmental Protection Agency could be ordered, by the President or by Congress, to establish such a standard. He would have to perform the studies necessary to support the sequence of decisions required under the Clean Air Act for the establishment of automotive emissions standards. Of course the proposal and establishment of a standard would not necessarily resolve the uncertainty in a final manner. Just as the standards for pollutants presently emitted from automotive engines are the subject of continuing debate, so the particulate standard might be. However, the gross magnitude of the standard, and its likely effect on engine design, would hopefully be determined. At a minimum, the debate would have been initiated.

Short of a Congressional or Presidential order, other steps might be taken. For example, ERDA might fund the studies necessary to determine whether or not a substantial fleet of automotive diesels would be likely to cause a significant increase in ambient particulate levels. If not, then it might be presumed that any emission standards would not be likely to be constraining, or that they might not be necessary at all. An opposite determination would also lead to a reduction in uncertainty, though the outcome would be less pleasant for the potential manufacturers.

One can, however, imagine circumstances in which nothing short of a set of plants would do the job. For example, it may be the case that nothing short of a completely credible proposal for the construction of a coal gasification

plant would force the resolution of the allocation of rights to Colorado River Basin water. There simply may be no other way to force the relevant actors and institutions to come to grips with the problem. Whether this is the case in any given instance would have to be carefully analyzed. The crucial point is that creatively designed strategies for resolution of specific uncertainties might accomplish the same ends as a commercial demonstration program, without the construction of complete commercial scale plants.

It is not obvious that such alternatives would be less expensive than support of commercial demonstrations in resolving the relevant uncertainties. Consider the simpliest possible case: a technology which would be just economic if the institutional and technical uncertainties were resolved, but would not be economic otherwise. The government invites proposals for the construction of a single plant to the relevant non-appropriable information. The incentive is a cash grant, to be awarded competitively. If there is reasonable competition, the bids would be roughly the cost to the firms of dealing with the uncertainties, i.e., the introduction cost. The firms would expect all other costs to be recovered from sales of the product. Thus, unless it were less expensive for ERDA to attempt to resolve the uncertainties directly rather than for the contracting firm to resolve them, there would be no advantage to the direct procedure. Of course this simplistic model misses much of the complex dynamics of the institutional and technical problems in question, but the lesson is clear.

In summary, in any given instance careful analysis is necessary to determine just what uncertainties are being addressed, and whether a commercial-scale demonstration of an entire production unit is necessary for their resolution.

4.3 POLITICAL, LEGAL, AND INSTITUTIONAL PROBLEMS

Even with a sound analytical basis, the implementation of commercial demonstration programs will face substantial political, legal, and institutional problems. These must be carefully distinguished from those factors which are not associated with the government's program, but rather with the actual technologies that are being demonstrated and the industries which the government is hoping to foster. The latter problems, discussed in Section 3, are likely to be the subject of the program.

4.3.1 Lack of Political Consensus, Division of Government Authority, and Lack of Legitimacy

As already suggested in Section 2, ERDA's commercialization programs, like all other aspects of American energy policy, must be implemented in a political environment that lacks national consensus on both the definition of the energy problems and the preferred mechanisms for dealing with it. As a result, the political base of support for any particular commercialization program will probably be narrow, weak, and perhaps fickle. Success at mobilizing support (and therefore necessary resources) at any particular time will not guarantee continuing support in the future. Even success, as measured in terms of the successful completion of a commercial demonstration plant, could as easily erode as strengthen the political support for the overall program. Changes in social values may lead to a reinterpretation of a particular programmatic success as a social or environmental failure. In the absence of assured political support and the guarantee of independence and resources that flow from it, the organization charged with implementing the commercialization program is in a weak position. There will be ample opportunity to falter in one way or another. The cost of faltering, even in a minor and totally reasonable

manner, could well be the legitimacy of the whole program or of the organization itself.

Related to the lack of political consensus on energy issues, including those related to commercialization, is the fragmentation of decision-making authority within the federal government and between the federal, state, and local governments. At the federal level, authority for setting policy and providing funding is split between the Congress and the Executive branches. There is no reason to expect that the energy commercialization programs will escape the sort of jurisdictional and power struggles among Congressional committees and between those two branches of government that regularly delay or prevent action in other energy and non-energy policy areas. Within the Executive branch there will be conflicts among agencies and departments that have overlapping or conflicting responsibility for relevant aspects of energy, economic, or environmental policy. Adversary relationships and differences in perspective may develop between such regulatory bodies as the Federal Power Commission and Environmental Protection Agency, and operating government agencies such as ERDA. Difficulties in organizing the commercialization function are indicated by the ambiguities in the responsibilities of the non-operating offices within ERDA itself: the Office of the Assistant Administrator for Planning, Analysis and Evaluation, the new Office of Commercialization, and the newer Office of Program Integration. Possibly even more important is uncertainty regarding the division of responsibilities between these offices and the program divisions, which are responsible for research, development, and demonstration, but not, apparently, commercial demonstration. The allocation of responsibilities, the coordination of policies and the assurance of cooperation among these various branches, units, and sub-units of government will be a difficult but important task, requiring both continuing attention at all

levels of government and adequate appreciation for existing traditions, prerogatives, expectations, and power relationships.

In many instances a concerted policy on the part of the federal government, as difficult as that will be to achieve, will not be sufficient. Regulatory and decision-making authority with respect to land use policy, environmental protection, economic viability and tax burden, health and safety facilities, and access to markets via transportation systems may all depend in part on state and local governments and state regulatory commissions. At this level the divergence of interest may be every bit as broad as at the federal level. A split can be expected, for example, between those who seek the help of outside capital to develop the industrialization of a region or local area and those who wish to avoid the social disruption of a large influx of workers and a major alteration of the traditional economic and social structure. This issue has already been joined in some regions of the western coal country, and in coastal regions near prospective off-shore oil operations.

The multilayering of government responsibility would make construction and operation of first plants difficult enough simply because of the need to satisfy many masters, even if the masters agreed on overall policy. In the likely absence of such agreement, the requirements will be particularly onerous. Still, the requirements might be manageable if only there were some societal mechanism with nearly universal respect and legitimacy for making decisions about new technologies and industries. Unfortunately, in the United States today no such mechanism exists. In part this is because of the fragmentation of authority already discussed, but it also derives from the current lack of respect and legitimacy afforded to government leaders and institutions. This in turn is in large measure the result of ten divisive years of Vietnam and Watergate, and as such is by no means unique to energy policy.

But there are additional factors at work in the energy area. For one thing, as with other public policies involving technology, the lack of an authentic and recognized source of technological knowledge often leads to a lengthy and frequently bitter adversarial process.[1] Also, energy policy cuts across, involves, and influences more otherwise largely independent policy areas, and more divergent interests and more ideological perspectives, than most other major contemporary issues of government policy.

There are several results of this absence of a national decision-making process with political legitimacy. Not only does decision making require extended periods of time and frequently involves repeated legal proceedings, but it also is rarely conclusive. Losers rarely accept a decision against them as legitimate and decisive, although repugnant, and instead frequently pursue the matter from one forum and procedure to another. As a consequence, there is a trade-off between expediting programs and providing a wider access of interested parties to the decision-making process.

While these issues of fragmented governmental authority and lack of legitimacy in decision making have an impact far broader than ERDA's commercialization activities, they are highly relevant to these programs. They raise questions about the structure of the political process involved in reaching decisions in this area, about the degree and manner in which various interest groups can be given access to that process, and about the interrelationships and coordination among various governmental entities.

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[1]The case of the supersonic transport, where technological questions interacted with legal, political, and economic ones in a continuing and extended controversy in many forums, illustrates the possibilities (see Appendix D).

4.3.2 Instititionalization

The creation of ERDA resolved one major issue of institutionalizing the energy technology programs: the creation of a single government agency with primary responsibility for energy-related R,D&D. ERDA's responsibility for commercial demonstration programs has not been so well finalized--there remain ambiguities in the relationship between ERDA and the Federal Energy Administration, and the proposed Energy Independence Authority clouds the horizon as well. Furthermore, both within ERDA and between ERDA and industry, the divisions of responsibility and authority are not yet clearly defined. The degree of public ownership of and control over facilities built as part of the commercialization program, and the legal and organizational structure of owning and managing entities, have not yet been decided. In this circumstance the following dilemma is common: There is a need to give operating control to those with the greatest experience and to simulate market conditions as closely as possible. But a concern not to "give away" taxpayers' money with insufficient controls may lead to avoidance of market forces in favor of more government management and control, and pollution of the data on real operating conditions and costs.

As the commercialization programs grow in size and expenditure, considerable institutional momentum and bureaucratic advocacy will be generated. ERDA officials, Congressional backers, industrial firms, and benefitting regions will all acquire career or other vested interest in the programs' continued existence, strength, and growth. It will be difficult simultaneously to maintain effective control, program flexibility, and the ability to reduce government involvement when industry is able to take over on its own or when the initial justifications for government intervention have disappeared.

One example of this type of problem is the continuing limitation on utility liability in case of an accident at a nuclear power plant, which is provided by the federal government through the Price-Anderson Act. This intervention has been maintained well beyond the years of the nuclear power industry's infancy. The difficulties the federal government had in removing itself from the synthetic rubber industry during the decade after World War II testify as well to these problems (see Appendix E).

Efforts should be made to minimize these problems by appropriately designing institutional and policy instruments from the beginning. Incentives are needed for the achievement of cost-effectiveness, and periodic program review by Congress and high-level ERDA officials at significant milestones and decision points. Perhaps automatic termination of some government subsidies could be embodied from the start. Such measures would not guarantee avoidance of the identified pitfalls, but they would reduce the likelihood of being trapped in them. The overriding need is a clear commitment to limited demonstration and information-gathering objectives.

This issue rises partly out of the lack of clarity of the relationship between a successful demonstration and a successful industry, and an unfounded assumption that the second will automatically flow smoothly out of the first. In fact, this is not necessarily so, for the conditions and criteria for a successful demonstration may well be vastly different from those for a successful industry. Inherent in the market place are successes and failures, and trials and errors; it is only after such traumas that a new industry attains relative stability. Seldom do the industry pioneers remain as leaders in the mature industry. If ERDA or any other government agency is to "select" projects or processes for commercialization, rather than allowing the market to

permit them to emerge, then ERDA must assess the real risks of alternatives, and allow those to fail which should fail by market criteria.

Underlying these issues is the fact that the U.S. government lacks not only the tools but, fundamentally, it lacks the cultural framework in which to effect energy policy through detailed involvement in the marketplace. Traditionally, we have looked to the marketplace to solve long-range energy problems, and to the government (primarily through regulation and tax policy) only to see that the marketplace does not yield unacceptable environmental or distributional effects. Only in short-term crises has there been detailed intervention, and we are very short on either experience or precedent for the establishment by government of long-term policy direction of the solution of economic problems by the private sector. Other countries, of course, have different forms of private-public intervention, and it is always possible that fundamental changes can be wrought in the political economy of the U.S. For better or worse, however, we appear likely to stay with the market-oriented institutions we have. The challenge is to adapt them to this new and different situation in the energy sector.

4.3.3 Anti-trust and the Issue of "Bigness"

In many cases it is only the large established firms that will be able to achieve a widespread and speedy market penetration of new technologies. For example, loan guarantees for the commercialization of a new automotive powerplant will not bring forward a fifth domestic auto manufacturer--the tremendous capital requirements required for such an attempted entry will not be met, even with a partial government debt guarantee. Careful planning will be required in such circumstances to insure that federal programs do not have the effect of decreasing the level of competition that exists now. For

example, this concern might lead to the funding of redundant projects, where the advantages of competition are seen to outweigh the increased costs of duplication.[1]

But this does not resolve a different issue. Inevitably, many or most of the demonstration plants will be built with some form of subsidy by large, well-known companies, some of whom are unfavorably regarded by important segments of the electorate. The new plants will make some very big firms even bigger, and many persons would equate greater size with more "power". There is a need to decide what steps we are willing to take, and can afford, not merely to foster competition but to insure that large companies do not get more of the program than is socially desirable. Given the current political climate regarding the large oil companies and the tradition of strong Congressional support for small businesses, this is an especially important issue.

A further anti-trust problem is that of group action. There may well be instances where commercialization of energy technology would best be expedited through cooperation and information exchange among the firms in a particular industry. A prudent management would be deterred by even a low probability of a finding of criminal violation, or even a moderate probability that a suit would be filed, with the accompanying publicity. Yet the anti-trust agencies, if they could devote adequate time to the problem, might see no violation. The problem is basically one of fact: Will the proposed group activity have any undesirable effect on supply and market price? In order to avoid the harmful results of uncertainty about the government's actions, it would be well to seek anti-trust clearance at an early stage.

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[1]See Economic Strategy for Developing Nuclear Breeder Reactors, P.W. MacAvoy (M.I.T. Press, 1969) for a detailed evaluation of the breeder reactor case where he reaches just this conclusion.

The "bigness" problem is not new, and has been often resolved in particular cases. A satisfactory way of handling it may be difficult to obtain at the present time. However, as discussed above, the situation depends on a variety of essentially political factors that bear little or no relation to the importance of such an exemption to the success of new technologies.

4.4 MECHANISMS OF SUPPORT

The institutional problems inherent in a commercial demonstration program are, as we have seen, formidable. The latter must be taken into account, however, in the choice of instruments for subsidizing commercial-scale plants. This is the issue we now address: How should the government go about providing the incentives which will result in the construction of the plants?

4.4.1 General Considerations

We have argued that the purposes of government-supported commercial demonstration projects are principally (1) to support the development of the information associated with the resolution of the technical and institutional uncertainties concerning new energy technologies, and (2) to provide a subsidy to foster the introduction of such technologies when they are being retarded by inappropriate energy prices. With these goals in mind, some general considerations of program design can be laid out.

Both goals lead to an argument that commercial demonstrations should be conducted in such a way as to simulate the normal workings of the private sector--i.e., the influence of the subsidy should be as small as possible and still lower the costs of the actual demonstration to the point where it will

go ahead. This implies that the participants in the program should be those who would be dealing with the technology under circumstances of widespread use, and that the incentive structure associated with their participation should approximate that which they will face after the government program is over.

The choice of industrial participants must focus on those firms which show the clearest promise for long-term involvement in the industry (taking into account the "bigness" issue). As stated by the recent Rand study: "Demonstration projects that enjoy greater diffusion success are those operating with a strong technology delivery system."[1] These firms will have the incentive to make the technology a long-term economic success. Furthermore, the very prospect of such success will stimulate the initiation of the relevant regulatory and institutional proceedings.

The importance of a careful choice of industrial participants can be seen when we considered that there are strategies that would be profitable to some segments of industry, but would fail to accomplish the goals of commercial demonstration. That is to say, the construction and operation of government-supported demonstration plants can be seen as a business in itself quite apart from the ultimate development of viable industries. For example, if the variance in construction costs is very high (as may often be the case), substantial profit at low risk is possible for construction operating on a cost-plus basis; this fact will tend to attract much interest in the construction of demonstration plants, beyond that stemming from the prospect of their future profitable operation.

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[1] "Analysis of Federally Funded Demonstration Projects: Final Report" (The Rand Corporation, Santa Monica, California, April, 1976), Report R-1926-DOC, p. 51.

Thus the federal program should provide the project managers with a structure of incentives which differs as little as possible from that which they would face in an unsubsidized circumstance. This is important with respect to the choice of the mix of input factors--especially capital as compared with labor, transportation, maintenance, etc. Similarly, the incentives with respect to risk-taking should be as realistic as possible.

There also is a need to foster the spread of the appropriate learning involved in the first few plants and to stimulate competition in the field, and here there will be a trade-off between the number of firms involved and the cost of the program. This trade-off, while clear conceptually, is difficult to evaluate analytically. Many of the issues addressed in Section 5 are relevant, in that the linkages between the government's program and the rate of technological substitution are not well understood; in particular, not much is known about the importance of having a number of firms involved, as opposed to just one.

Clearly any commercial demonstration program must be carefully branded as such. Projects must be chosen so that early government subsidies to private firms can be turned off when the demonstration has been completed. There is a "slippery slope" here, on which commercial demonstration programs may slide into long-term subsidies. Likewise, the government agency must have a clearly bounded authority, and a sense that its mission is accomplished when the demonstration projects are set up and the industry is ready to stand or fall on its own. Avoiding the "slippery slope" should be an important consideration in choosing subsidy mechanisms, though it is difficult to subject this effect to precise analysis.

Simiarly, there is a need for flexibility in program design. One of the principal goals of commercial demonstration programs is the development of

information which is crucial to the long-term success of the new industry, and it follows that this information may have important implications for the demonstration program itself. For example, a technology might be expected to be economically viable in the long run, while the requirements for environmental production are uncertain. During the course of a demonstration the environmental uncertainties might be clarified in a way that drove costs out of the range of economic feasibility. Obviously at that point there would be little utility in continuing the demonstration program (although of course, more fundamental research and development might well continue), and it is important to design subsidies that can be shut off in such a circumstance.

Finally, in order that the program be subjected to careful scrutiny, financing mechanisms should be used which reveal the full costs of the program. Indeed the full cost is one of the most important things the demonstration should be designed to determine. There will of course be large uncertainties in estimates of both the costs and the benefits of such programs. But, as discussed below, some demonstration schemes provide greater visibility of cost than others. Clearly, if the extent of the subsidy is not well known, then the cost of the technologies output cannot be readily calculated. If this is the case, then an uncertainty of major significance will remain.

While the true (total) cost of the project from a subsidized commercial demonstration plant may be determined by this type of program, the long-run cost may not be developed in any case. As discussed above, the cost of the demonstration plant is likely to be higher than that of subsequent plants--otherwise the commercial demonstration program would be of little utility. On the other hand, a firm planning to use the subsidized demonstration plant as a foothold in a new industry may well sell the plant's product below cost

(even counting the subsidy), expecting to make back its losses on subsequent profits in the industry. Once again, the complex dynamics of the commercialization process may make analysis difficult.

4.4.2 Financial Instruments for Supporting Commercial Demonstration Projects

After weighing the general considerations discussed above, a specific program format and set of financial instruments must be chosen. The proper selection and design of the subsidy mechanism may differ from industry to industry, technology to technology, and even from project to project; and therefore a detailed analysis of the issue is beyond the scope of this study. It is possible, on the other hand, to make some general observations about the different approaches.

We begin with loan guarantees, which we have looked at in greater detail than the others because of the large-scale programs currently being proposed. Our discussion of this mechanism indicates the types of issues that need to be better understood about all forms of subsidy. We also look briefly at regulated utilities which can be used as a subsidy mechanism, and comment on tax expenditures, direct government expenditures, and price guarantees.

(i) Loan Guarantees

Loan guarantees are a widely discussed commercial demonstration incentive because, among other things, they provide an off-budget form of financing. However, the use of loan guarantees has been subjected to very little analysis, particularly of their true costs and some of their subtle incentive effects. A loan guarantee appears to be free to the government. When it is estimated that there is a small probability of default and, with a small number of plants,

it appears there might be no budgetary cost at all. But this does not mean that the guarantee is costless to the society. Obviously the principal effect of the guarantee is to shift capital from other less risky projects into the guaranteed project, making capital slightly more expensive for all competing investments. The government has done this by absorbing the risk of default, and the cost is distributed throughout capital markets. The problem of analyzing just what this cost actually is makes the use of this incentive very difficult to evaluate. (We make some suggestions about possible approaches to the problem in Section 5.)

There are other effects as well. Subsidizing risky ventures by means of debt guarantees induces high debt ratios. If privately financed as independent ventures, they would use very little debt.[1] If this avoidance of debt is rational, then one must presume that there are costs of inducing ventures to operate at unusually high debt ratios.[2] This may induce inappropriate operating and investment decisions. Two examples follow.

(a) <u>The existence of risky debt creates a disincentive for follow-on investments</u>. Few ventures operate forward on one initial capital outlay. Follow-on investments are often required for expansion, to cope with unexpected difficulties, etc. These follow-on investments are undertaken because they generate a net increase in the present value of the firms' assets. However,

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[1] They might be undertaken directly by firms which already have substantial debt outstanding. But the new venture would not be regarded as "supporting" any substantial amount of <u>additional</u> borrowing.

[2] It might be argued that risky ventures operate at low debt ratios for the simple reason that investors do not wish to hold risky debt. If this is the <u>only</u> reason then there is no harm in debt guarantees. But there is no reason why risk <u>per se</u> should preclude a market for a firm's bonds. There is an ample market for convertible bonds, for example, which in many ways are similar to straight bonds with a high probability of default. That is, in each case the bonds' market values are highly sensitive to changes in the values of the firm's assets.

the existence of risky debt weakens the incentive for the owners of the firm to make such investments, because part of the increase in asset value is captured by the investors who hold the risky debt.

To take a concrete example, suppose that technical programs are discovered in the initial production runs of a synthetic oil plant. The owners can live with the problems or make a substantial additional investment to solve them. Under normal circumstances the owner would simply ask whether solving the problem increased the plant's present value by more than the investment required. However, in this case there is a large amount of risky debt outstanding, with the government bearing the risk. If the investment is made, the value of the plant increases, and the unguaranteed value of the debt increases also. The government is clearly better off if the additional investment is made.

But if the government captures, say, 20 percent of the value created by the additional investment, that leaves only 80 percent for the plant's owners. They put up 100 percent of the incremental outlay and get only 80 percent of the incremental gain. The incentive for them to make sensible investment decisions is correspondingly weakened. The percent of the increase in asset values captured by lenders depends on how risky their debt is. The riskier the debt the more they capture, and the weaker the incentive for economically sound follow-on investments.

This problem of warped investment incentives exists for any risky debt, whether or not government guaranteed. It is not usually serious, since lenders are careful not to purchase debt claims when there is a high probability of default. They are particularly cautious when the probability of payment is likely to depend on further discretionary outlays by the firm's owners. Lenders recognize that the owners may choose not to advance cash for those outlays, and protect themselves accordingly.

The problem is likely to be much more serious for ventures in commercialization. The offer of debt guarantees will induce debt ratios as high as those of the largest regulated utilities. Yet the underlying assets are viewed as unusually risky even for unregulated firms. The debt of such a firm is, absent the guarantee, a speculative instrument. Consequently the incentive effects will be strong, and very likely improper from an economic standpoint.[1]

Where there is a disincentive for follow-on investment, there is also an incentive for disinvestment. That is, owners gain by liquidating assets and paying dividends. The value of the firm declines by the amount of dividend paid, but part of the decline is "captured" by the risk debt. Bondholders incur a capital loss, because the assets securing their claim are less valuable. This capital loss is the owners' gain. The value of equity declines by less than the cash dividend received.

Similarly, equity gains if additional debt can be issued later in the venture's life. Any increase in the venture's debt ratio increases the risk of initially outstanding debt and causes a capital loss to the initial lenders (to the government, in this case).

This suggests another difficulty with loan guarantees. In normal private financing, bond indentures are carefully written to preclude the kinds of maneuvers just described. Dividend payments and additional debt issues are restricted, as well as a variety of other strategies that would have the same

[1]There are various ways of alleviating the incentive effects, but none seem to apply here. For example, the follow-on investment could be part debt financed. Since the additional debt dilutes the government's claim on assets, the new financing could be arranged to leave the government's position unchanged. Who would buy the additional debt? The reason we need the government guarantee is that private markets avoid debt when it is as risky as the debt we are contemplating here. The government could guarantee the new debt as well, of course, but we doubt ERDA is willing to assume any such open-minded commitment, in which the firm can come back for more subsidy any time a follow-on investment is contemplated.

effect.[1]

Moreover, private lenders monitor the firm's actions to check for actions that violate the spirit or the letter of the indenture provisions.[2] The indenture restrictions and monitoring reduce the likelihood of the behavior described above. But with a government guarantee, private lenders have no incentive to work out appropriate indenture restrictions or to monitor the venture being financed. Moreover, the proposed procedure for loan guarantees contains no explicit equivalent procedure. If indenture restrictions and monitoring are no one's responsibility, then we can expect the various incentive effects described above to operate unchecked in commercialization ventures.

(b) Loan guarantees encourage high risk technology and operating procedure. It is no doubt obvious from what is said above that loan guarantees are worth more to risky ventures than safe ones. The riskier the asset, the larger the different between the guaranteed and unguaranteed value of the debt claim, and the larger the subsidy. Similarly, the loan guarantee creates an incentive for a commercialization venture to be operated by risky strategies rather than safe ones, and for concentrating follow-on investments in relatively risky assets. Anything that makes outstanding debt riskier benefits the venture's owners, other things equal. Finally, the loan guarantees should encourage owners of commercialization ventures to set them up as separately incorporated ventures, so that there are as few assets securing the debt as possible. This maximizes

[1]The disincentive effect of risky debt on follow-on investment is harder to prevent by indenture provisions, since it is difficult for any outsider to determine what the firm's investment opportunities are, or whether any particular opportunity has a positive net present value.

[2]If only the spirit is violated, lenders nevertheless have options open. For example, it is often possible to find a technicality justifying the lenders in declaring that the loan is in default.

the value of the loan-guarantee subsidy, and reduces the owners' exposure and commitment to the venture.

Of course these incentives exist in private financing as well, but they are magnified by the extremely high debt ratios contemplated in the commercialization program, and by the apparent lack of concern for developing appropriate indenture restrictions and monitoring.

Consequently, the subsidy inherent in loan guarantees is not neutral. It favors high risk investment and operating strategies. Now it might be argued that this is exactly what ERDA wants. It is true that the technologies ERDA chooses to support in commercial demonstration will be risky ones--for reasons we have discussed. Here, however, we are dealing with distorted incentives to the operator given the technical option which is subsidized. Under these circumstances a neutral effect of the support is the desired attribute.

(ii) Financing by Regulated Utilities

A number of important energy industries are under price regulation, and this circumstance offers an opportunity for financing demonstration projects--mainly for the regulated industry itself, but not necessarily so limited. In most of these industries, such as natural gas or electric power, the price is set on the basis of average cost of supply. This makes it possible to finance small increments of extremely high cost energy supply, for when rolled into the overall rate structure the price effect felt by consumers is not very great. Of course, managers of regulatory utilities operate under a mandate to serve customers at least cost and normally they would not adopt (nor would regulatory conditions allow them to adopt) supply technologies which were significantly more costly than available alternatives.

In certain cases, however, price regulation can lead to a circumstance

where technologies of almost any cost might be financed (and gladly) by regulated utilities. This occurs in the case of natural gas, for example, where the price of gas in interstate markets is being held below either the price of gas within the producing states or the price of alternative fuels at the point of consumption. As a result, very little new gas is being committed to interstate markets; reserves committed to these markets are declining; and consumers face a choice of switching from cheap gas to high priced oil. Utilities do not really have an option to bid for moderately priced gas. Where excess demand is created by price regulation in this manner, it would be possible to finance a very high cost addition to supply.

Thus these regulatory procedures offer an opportunity to finance commercial demonstrations, and in this circumstance two issues arise: one involves efficiency and the other equity. First, the fact of active consumer desire for the output of a demonstration facility may give a strong push to the use of this particular situation as a demonstration format. Given the likely difficulties in subsidizing demonstration activities by the instruments listed above, it is possible that a significant bias might be introduced into the commercialization program. Technologies and schemes might be financed which are not the most efficient in terms of their ability to open up new options for the country as a whole.

The second issue is the one of equity. Since the knowledge gained by such a demonstration will benefit the nation, it can be argued that the burden of the subsidy of the initial demonstration ought to fall on the nation's taxpayers. If demonstrations are financed by rolling the cost into the rates of a particular regulated utility, then the burden of the demonstration (and the risks of very high cost) are targeted specifically to the consumers of that utility system. As noted earlier, larger issues of utility rate regulation, which lead to

significant excess demand, may create a situation where the utilities seek these projects since they cannot satisfy their excess demand otherwise. Nevertheless, the issue remains as to whether the resulting distribution of economic impact among the customers is a desirable one.

(iii) Tax Expenditures.

A widely discussed method of subsidy is to lower taxes on a given kind of investment, by tax credit or accelerated depreciation. It appears to be costless because the sudsidy does not enter the federal budget. (Of course, the burden is reflected in taxes foregone.) This method seems to be preferred by a number of large corporations who are considering synthetic fuel plants.[1]

Tax expenditures suffer several disadvantages, under the criteria laid out above. First, because the subsidy is indirect, its magnitude may be very hard to identify. One of the most important objectives of a demonstration (i.e., information about cost) is lost. Moreover, the most common forms of tax expenditure for the types of investments involved here are the investment tax credit and/or accelerated depreciation. Both are subsidies to capital--as opposed to materials and labor cost--and therefore they introduce a bias into the selection of factor inputs.

Finally, there is an important institutional problem. It might prove very difficult to target tax expenditures to a small number of particular demonstration plants; the subsidy might end up being applied to many projects that were not part of the R,D&D program. Also, in the past it has proved very

[1] "Response to Questions on Government Incentives for Synfuels Plants," Exxon, U.S.A., in Loan Guarantees for Commercial-Size Synthetic Fuels Demonstration Plants, Volume III (U.S. House of Resentatives Committee on Science and Technology, September and October, 1976, No. 36), p. 2834.

difficult to turn off tax expenditure programs, even after their original justification had faded from the scene.

(iv) Direct Government Expenditures

Other methods of subsidy include sharing of cost between governments and private companies, direct grants to builders or operators, or government construction with private operation and an eventual sale (or offer of first refusal) to the private operator. One finds examples of these methods in World War II. Unfortunately, one cannot claim that there is any "usable past" from which to draw lessons. Appendix D examines the case of synthetic rubber during World War II. It is shown there that that experience bears little relevance to the present problem because of the undeniable "gaps" that had to be filled at "any" cost, and the many economic controls that characterized the war-time years. That data do not exist to support serious analysis of the efficiency of the effort, in spite of the fact that in meeting its own goals the program was widely judged to be a success. Direct cash grants have the obvious advantage of making the extent of the subsidy clearly visible and of not biasing input factor choices. On the other hand, direct government construction and ownership, even if followed by sale to private industry, does not simulate the market situation.

(v) Price Guarantees

A price guarantee has the great advantage of leaving the private firm free to design the demonstration plant as it wishes, in order to minimize total outlays and maximize profits. Thus market situations are minimally distorted.

Furthermore, the extent of the subsidy is very visible, allowing the clearest calculations of the full private cost of the product.

These characteristics make the price guarantee a very attractive instrument, under the criteria laid out above. Of course, there are many ways to design and manage such schemes, as there are with all these approaches, and their detailed formulation would depend on the facts of the particular program.

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5. EVALUATION AND PLANNING

The previous sections reviewed the nature of the investment process by which most technologies are adopted in our economy, and surveyed the situations where government intervention may be called for and the policy instruments available. Next, we come to the issue of how federal officials can evaluate alternative situations which appear to call for intervention, and the procedures by which the year-to-year activities might be planned and monitored.

To study the problems that arise in connection with this evaluation and planning task, we will go through a two-part discussion. First, we explore the nature of the evaluation problem and how, in principle, calculations and judgements might be made. As is evident from the discussion in the preceding sections, the possible technological and market circumstances that such evaluations have to cover are very complex. Therefore, to facilitate the discussion of the analysis issues, a set of simple examples is used. Second, based on this layout of the evaluation problem, we consider the key steps in the required analysis and the availability of the techniques to perform the tasks that are implied. This inquiry leads to a set of areas where additional research and empirical analysis is needed to support attempts to evaluate and plan federal programs.

It should be repeated at the outset that our focus is on the evaluation problems as they present themselves at the stage of commercial demonstration or "commercialization" of new energy technologies. ERDA also faces a larger planning and evaluation task which includes decisions that must be made about expenditures on development of various technologies and on basic research or

invention-type activities. Consideration of the larger planning, analysis, and review problem of such a federal agency is outside the scope of this study. However, it is hoped that the discussion of issues that arise at the introduction stage, and the evaluation techniques that may be applied there, will cast some light on similar tasks that need to be carried out for the ERDA strategy as a whole.

5.1 A SCHEMATIC REPRESENTATION OF THE INTRODUCTION STAGE

To facilitate discussion of the analytical problems that arise, a number of simplifying assumptions are called for. The resulting prototype situation will allow us to raise most of the conceptual issues that must be faced in constructing an evaluation methodology. Naturally, the basic approach outlined here would have to be modified to suit the special characteristics of particular technologies or market circumstances. The following is a formal summary of the economics of the process of technological change, as discussed in previous sections.

We assume that there is a particular technical option which has passed through the development stage, as defined in Section 3. A choice is now faced as to whether it should be introduced into commercial use. The technology, when put into use, produces an output of energy in each year of the future which we may denote by the variable x_t. This product may be energy produced by a new supply technology, such as shale oil or solar heating; it may also be thought of as energy saved by some new utilization device, such as a new automotive engine. From time to time during this discussion of these three examples-- shale oil, solar household heating, and advanced automotive engines-- will be used to illustrate the application of the analysis to different types of cir-

cumstances. Further, it helps to assume that several other conditions hold true:

1. There is only one market in which the good is sold. That is, there are no complex sets of markets differentiated by weather or geography. Furthermore, the demand for the technology is a simple function of price: there are no considerations of consumer acceptance apart from cost as price (as might be the case, for example, if solar collectors were cheaper than other methods of space heating, but consumers did not like the looks of them).

2. The technology produces only one well-defined product, such as synthetic oil gasoline saved, or Btu's in home heating. Many technologies, of course, produce a variety of products, and to simplify the example we will leave those aside.

3. The process of technical change can be summarized along the lines laid out in Section 3 and shown in schematic form in Figure 5.1. The technology has been through the development stage and the firm faces an introduction decision. We define a clear step in the evolution of the technology which is referred to as "introduction". After the introduction into the market, new data will be available about the technology and its market prospects, and at that point a new set of decisions will be made as to whether the technology ultimately diffuses through the market.

As it is evident, these are dramatic simplifications of reality. The introduction stage is an abstraction which may or may not be well distinguished from the processes of development and diffusion. However, since the federal programs under study here are concerned with this specific stage, this provides a useful way to focus on the decision to subsidize commercial demonstrations. Particular circumstances may involve more complex mixes of products and market circumstances, but these complications are best withheld until it is evident that headway can be made in the evaluation task in this more simplified circumstance.

5.2 THE NATURE OF THE EVALUATION PROBLEM

5.2.1 Elements of the Private Investment Decision

The various elements of the evaluation problem are laid out in Figure 5.1. We introduce some algebraic notation in the figure and accompanying text, but the symbols are no more than a shorthand. The logic is the same if the problem is to be approached with an elaborate set of analytical models or simply with common sense and a few key data elements. As shown in the figure, the circumstance is comprised of several elements. First, as noted earlier, the technology produces an output which we define by the variable x, or x_t when we speak of energy in some particular year t. For a shale oil plant we may speak of a facility that produces x barrels of oil in a year. Solar heating produces Btu's of heat directed to domestic heating, and that case x reflects the actual energy delivered. In the case of a new automobile engine, x can be taken to represent gallons of gasoline saved. While more precise definitions would be required before an adequate set of calculations could be made, these will suffice for our purposes.

When these technologies have diffused and are in wide-scale use, the energy delivered and saved, x, will have some cost. This we refer to by the symbol C(x).[1] Of course at the time of an introduction decision, no one knows what that ultimate cost will be, but the dimensions may be stated in terms of ultimate dollars per barrel of the shale oil, cents per million BTU of the energy into household heating, or cents per gallon of gasoline

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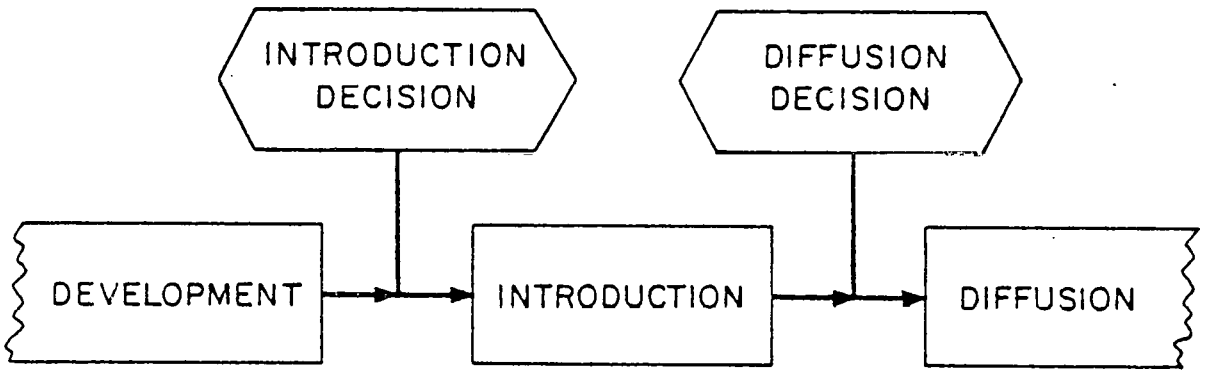
[1]Note that C(x) is the cost <u>after</u> the experience of commercial introduction and after some diffusion has taken place. This means that the term C(x) may involve learning effects and a host of other phenomena. We omit them here to simplfy the discussion.

Figure 5.1

KEY DECISIONS IN COMMERCIALIZATION



Probability of Ultimate Production Cost :	$G^i[C(x)]$	$G^d[C(x)]$
Actual Unit Production Cost :	$C^*(x^*)$	$C(x)$
Total Cost of Stage (net, gross) :	K_n, K_g	

saved. Since this is a representation of the firm's investment decision, these costs are private costs only.

Although C(x) is not known at the point of the introduction decision, there is some expected cost of the technology which may be calculated on the basis of data obtained in the development stage, and using other information about market conditions, regulatory prospects, legal difficulties, and the like. As shown in Figure 5.1, we refer to the probability distribution of ultimate costs by the symbol $G^i[C(x)]$. In the case of a shale oil plant, for example, the distribution of likely ultimate costs may be very broad if the technology has not been tried at large scale. A typical range of values, given that regulatory difficulties are not expected to intervene, may be from $15 per barrel to $35 per barrel.[1] Under some regulatory circumstances, this distribution might extend to much higher values (or even to an infinite cost which would reflect a case where the technology was proven socially unacceptable).

The industries that are concerned with this technology have the information contained in $G^i[C(x)]$ as a result of their own development work or various federal R&D programs. They may take the next step in the technology change process by introducing the technical options into the market. In the case of a shale oil plant this would be to build the first commercial scale plant, or set of such facilities. For solar heating, the introduction step would involve the establishment of a commercial scale manufacturing facility and the setting up of the marketing apparatus necessary to fully explore its potential. As shown in Figure 5.1, we talk of this step as involving a net introduction cost, K_n. This is the net investment in the introduction

[1]These numbers are strictly hypothetical. We discuss actual costs in more detail in Appendix A.

stage, as discussed in Section 4.1. Introduction produces a set of facilities which can produce the annual energy product x*, each unit of which costs an average of C*(x*). Thus K_n equals the gross capital investment of the introduction stage, K_g, minus the net revenues produced from the sale of the annual production x* (all carefully discounted).

Using the language developed in Section 3, a firm buys two things if it decides to make the expenditure K_g:

(a) It buys the capacity to carry out production using the facilities built at the introduction stage, and to sell the resulting product in the market.

(b) It purchases the option to go into production for the diffusion stage if the conditions indicate.

Of course, the results of the introduction decision may be fortunate or unfortunate depending on the circumstances. It is possible that the facilities built at this stage will make a profit in and of themselves, and will lead the way to a profitable diffusion. Alternatively, and more likely, the investment K_g may not yield a reasonable rate of return if considered alone (that is, the first plant loses money). However it still may be a good investment because the option that comes along with it is sufficiently profitable to cover the introduction losses; that is, the value of the option is greater than K_n.

A more unhappy outcome would be where the results of the introduction were so unfavorable that plans for diffusion were abandoned. That is, an option to go on is made available by the investments at the introduction step, but the option is not taken up because its expected value is negative. An example here would be a solar heating option which was expected to achieve significant economies in scaling up to a commercial

size plant, but where these economies were not in fact realized for reasons not fully foreseen before the introduction stage. As a result the resulting heating system is too expensive to capture a significant part of the household market.

The information available after the introduction has been tried is indicated by the distribution $G^d[C(x)]$ in Figure 5.1. This is a new probability distribution of costs of the recently marketed technology, and it is only available after investment in the commercial introduction step (and the net expenditure of K_n has taken place).

When a firm is making decisions about whether to invest in diffusion given $G^d[C(x)]$, or to invest in introduction given $G^i[C(x)]$, a key factor in its calculations is the expected market price of energy over the relevant time horizon--the "planning price" previously discussed. This we will refer to as P_t^m.[1] This price is, of course, uncertain. A separate price which will enter in other calculations is the social value of energy, which we denote here by P_t^s. This price or value is not of relevance to the private decision maker, though it will enter into the types of calculations that would be made by a federal agency in deciding what subsidies are warranted, as discussed below.

There are additional observations that are worth making about the relationshop between $G^i[C(x)]$ and $G^d[C(x)]$. In general, one hopes that each stage of investment in R,D&D--including the introduction stage--will lower the ultimate costs C(x) that are going to be experienced with a particular

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[1]Throughout this discussion we simplify the market circumstance by talking as if there were a single energy price. There are, of course, a whole structure of prices depending upon the area of the country and the particular product involved. Calculation of such prices may offer its own set of difficulties, but there is a common exercise and adds no conceptual problems to the issues already under discussion here.

technology. But note that in this case both these expressions reflect expectations about what the ultimate cost of the technology will be after the diffusion stage has been entered. Thus, viewed from the standpoint of the introduction decision, there is no reason to suppose that the expected values of these two distributions of costs will be different. The shale oil example can serve to elaborate this point. Before a firm would introduce a plant at commercial scale, it would have some estimate of its expected cost in large-scale application in many plants. After it introduced the first round of plants, it would have some revised expectation of the cost of that technology over the 20 or 30 plants to follow. But at the point of introduction decision, it has no basis for knowing why this cost should be different after the experiments than before. Of course, it will be different in fact. But what we mean by the expected value of $G^i[C(x)]$ is precisely the best guess about what the cost will be after diffusion.

On the other hand, the firm will have opinions as to the likely changes in the dispersion of costs between an estimate at the introduction decision and an estimate after the introduction has been tried. Much of the justification for any federal involvement in the commercialization process, and indeed much of the justification for any corporate investment at this level, is that the net investment of K_n and the experience of the introduction experiment itself will serve to reduce the variance of $G[C(x)]$. This is what one means when it is said that the first commercial-scale plants will resolve uncertainties about scaling laws, environmental restrictions, labor problems, etc.[1]

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[1]Of course, it should be noted that it is always possible that the variance in likely outcomes could increase. This would happen when the introduction experiment discovered new sources of uncertainty which were not foreseen at the time the estimates $G^i[C(x)]$ were made.

5.2.2 The Decision Faced by a Private Firm

With this simple model of the introduction and diffusion stages, we can review what was said earlier about the decision faced by a private firm. At the time of the introduction decision, the firm has a probability distribution of the ultimate costs of the technology in diffusion, $G^i[C(x)]$. It also has the prospect of an investment (K_g), that will lead it to the diffusion stage. The firms faces what was earlier called an "investment choice". The expenditure K_g will be a good investment if the total of the returns from the diffusion stage (which may be zero if diffusion is not indicated) and the returns from facilities built during the introduction stage are sufficient to cover the cost K_g. This calculation, of course, is ultimately dependent on what the firm takes as its forecast of P_t^m and how uncertain the cost forecast is.

Naturally, the value of the diffusion option which is being purchased must be sufficiently high to allow for the riskiness of investing K_g. If the current estimate of ultimate costs and prices, $G^i[C(x)]$ and P_m^t, are highly uncertain, then the introduction investment is very risky and must have an expected return which is high enough to draw the firm's resources away from other investments.

In general, when such an investment is not made it is because the returns expected if the diffusion stage were entered are negative. This would be the case, for example, for a shale oil plant where the mean of $G^i[C(x)]$ is \$25 per barrel and the expected value of P_t^m is only \$15 per barrel. Or such would be the case for water heating where the cost of energy from the solar device to be \$15 per million Btu and cost of alternative energy (say. from a gas-fired water heater) to only \$3 per million Btu. Alternatively,

the expected value of returns in the diffusion stage may be positive, but the costs of the introduction stage alone may be so great as to make the overall prospects unattractive (i.e., the expected net present value of introduction is negative).

On the other hand, as noted in Section 3.2, there are circumstances where the market system may "fail" in the sense that corporate decisions at this stage are based on considerations which do not reflect the social benefits and costs of the actions to be taken. We discuss several such prospects below, using concepts discussed in Section 3:

1. P_t^m may be less than P_t^s. This might be due to price controls or to the national security premium. It would lead to a circumstance where firms had no interest in carrying out the introduction investment even though such an advance might be shown to be socially desirable. Of course, the fact that the federal government may be able to bring about such an investment at the introduction stage does not mean that diffusion will take place. Private decision makers will still be faced with a diffusion decision based on P_t^m.

2. Inability to appropriate technical results. In terms of Figure 5.1 this would hold where no firm investing in K_g could expect to capture enough of the market to take advantage of the information a $G^d[C(x)]$, which would be gained by the introduction experiment.

3. Regulatory and political risks. These risks may give $G^i[C(x)]$ a high variance (particularly by introducing extreme low-end events into that distribution) and thus dramatically raise the risk premium which K_g must promise to earn. To the extent that these uncertainties are artificially imposed, they constitute a "failure" under the definition above.

4. Market structure. The lack of competitive pressure may lead some firms to forego investments in innovation which would be socially profitable.

5. Risk and financial markets. The dispersion of $G^i[C(x)]$ and uncertainties in P_t^m may be so large and the gross size of the investment K_g so great that corporate managers forego the introduction, even though a careful expected value calculation (including discounts for risk) predicts a positive return.

5.2.3 Evaluation of the Benefits of Government Intervention

Most of the instruments discussed in Section 4 are methods for subsidizing the cost K_g. A need for such support would be indicated by evidence of one of the market failures noted above. The ultimate decision to go ahead with the federal subsidy would depend on a calculation of the costs and benefits of the expenditure involved.[1]

To see the nature of the evaluation problem, we may pursue our simple example another step. Assume that for some reason the introduction investment will not be taken by private industry. The precise reasons why this is not happening need not concern us here (later we take up the case where introduction will eventually be undertaken by private capital, but the government may speed up the process through a subsidy). We may look first at the evaluation of the benefits of a direct federal expenditure of K_n. Later, we return to look at the issues raised by the calculation of cost, for the actual estimate of K_n may vary depending on the particular financial instrument achieved to bring the investment about. For now, however, assume that K_n is a simple direct federal expenditure.

Case 1. Prices and Costs are Known with Certainty, Instantaneous Diffusion, No Social Premium on Energy. Suppose that the real price of imported oil is $13 per barrel and that this price will prevail for the foreseeable future. No extra value is attributed to independence from insecure energy sources, so that the imported price is the social cost. Also suppose that the shale oil plant we are using as an example can produce oil at a cost of $20 per barrel with the first plant and that, because of what it learned, all subsequent

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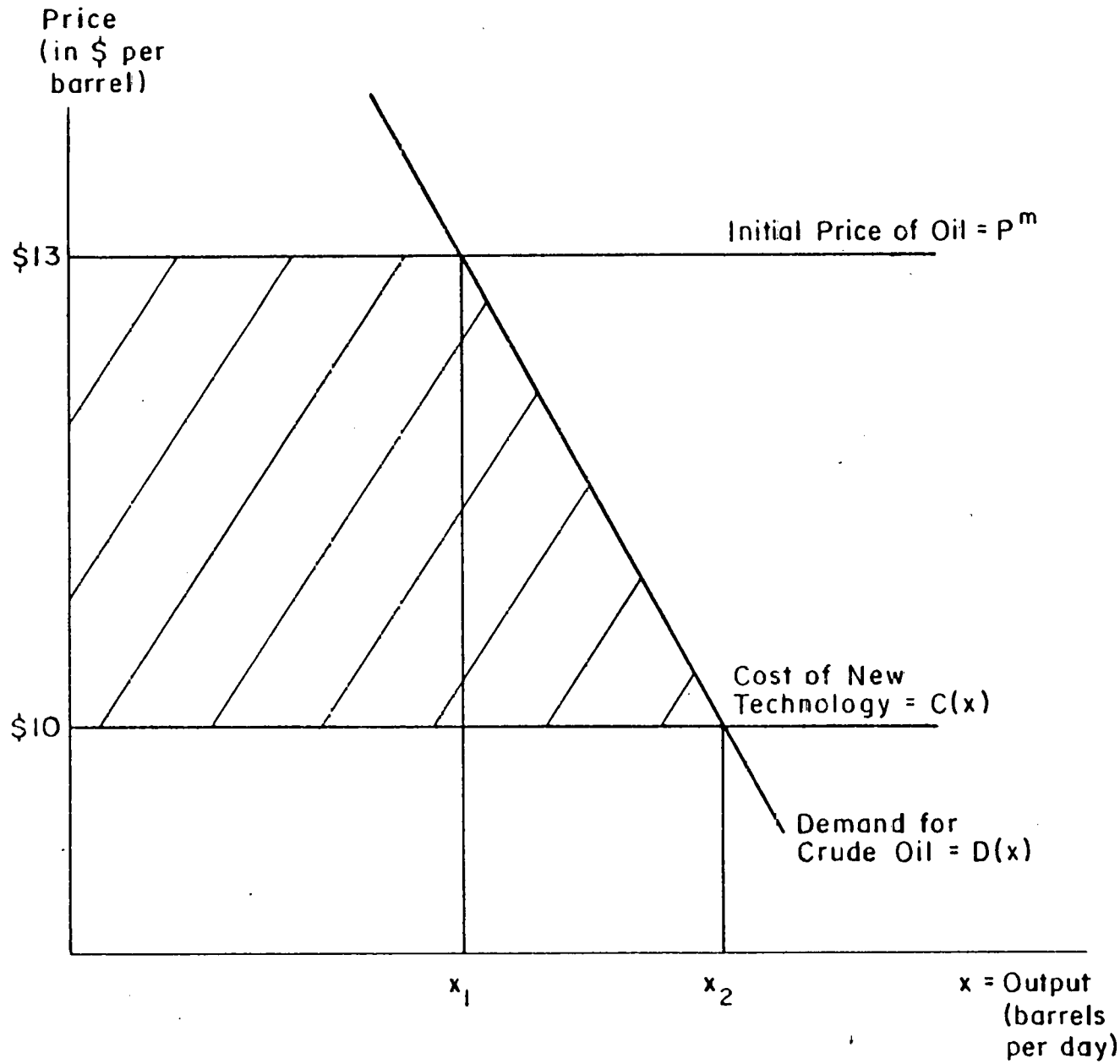
[1]That is, there may be "failures" that are not worth correcting, given the opportunity costs of the resources required.

units are expected to produce at a cost of \$10 per barrel. That is, $C^*(x^*)$ = \$20 per barrel but the means of $G^i[C(x)]$ and $G^d[C(x)]$ are \$10 per barrel.

If new firms can take advantage of the learning and produce at \$10, and new plants can be built very quickly, then the price of all crude oil will fall to \$10. Thus it will be impossible for the first investor to recover the introduction investment and no individual firm will undertake the initial expenditure K_g. Nevertheless, society clearly stands to gain a great deal from having the price of oil reduced to \$10 per barrel. Here is a clear market failure: the returns to the initial investment are not appropriable. The societal returns come in the form of consumers' surplus--i.e., consumers pay less for energy.

We illustrate the case with Figure 5.2. In this diagram that market price of energy, P^m (assumed here to be independent of the time after introduction), is measured on vertical axis and quantities produced and consumed on the horizontal axis. The P_{oil} line illustrates the assumption that oil is available in any quantity we want at a price set by the international cartel. The line C(x) demonstrates that with the new technology, we could produce any quantity desired at a cost pf \$10. Finally, the D(x) curve indicates what quantities would be consumed at various prices. As price declines, more energy is consumed. The result then of lowering the cost to consumers from P_{oil} to C(x) is an expansion in the amount consumed. We can measure the benefits as the shaded area. This area represents the difference between what consumers pay for oil, $P^m = C(x)$, and what they would have been



CALCULATION OF COMMERCIALIZATION PROGRAM BENEFITS

Figure 5.2

willing to pay for each unit. This is the change in "consumers' surplus" and represents the benefits to society.[1]

In this example, we assume that the investment will not take place without government intervention (without specifying why). In a real situation, the first analytical need would be to forecast actions of private investors in the absence of intervention, as well as the likely behavior after the intervention. As we have seen, it is the incremental changes due to the intervention that constitute the benefits of the government action. In order to be able to simulate this behavior, we need an understanding of why the market is not functioning. It is obvious, for example, that in reality, entry to the new industry will not occur instantaneously as in the example. Therefore all knowledge produced will not be inappropriable, and in this simple example we would expect some private investment to eventually take place in the absence of intervention. Nevertheless, if some benefits are inappropriable, investment will be less than desired and the timing may be delayed. More accurate descriptions of private incentives are needed in order to understand what will ensue from government intervention and what is the necessary level of subsidy.

Case 2. No Diffusion. Once we understand the market structure, the key to the decision analyses is distribution of costs of production $G[C(x)]$ and prices of delived output P^m. The profitability of government intervention in Case 1 revolves around the price of energy before the new technology,

[1]The cost of obtaining these benefits is the amount of the initial subsidy. Note, however, that this example is highly simplified. The cost of the new technology might depend on the rate of output. Also, technologies based on depleted resources will exhibit rising costs as the cheapest deposits are depleted, unless new technologies are developed. These issues will be taken up below.

the initial cost of the technology, and the cost of the technology after the introduction stage. If, for example, we change the above example so that the new option will produce energy at a cost of $14 per barrel once we build the first plant, the evaluation changes dramatically. The government subsidy no longer yields positive benefits. Now we lose $7 per barrel on the initial plant, but wind up at a situation where the price of energy is no lower than $13 per barrel. There has been no return to consumers, producers are no better off, and the government has lost its initial subsidy. We may have learned a great deal about the technology and the environmental and institutional barriers, but the knowledge is not worth anything in the market.

Clearly, prices need not be static. If oil prices rise, the situation changes. Then $14 oil might, in fact, ultimately prove economic and the returns to the subsidy would be positive.

In summary, we need to know (a) what the energy price P^m will be in the absence of the technology, and with it; (b) what initial subsidy is necessary to encourage the first plant; (c) what the cost of subsequent plants will be; and (d) what quantities will be demanded. We would then simulate behavior before and after the intervention and sum the benefits to consumers and producers as a whole. To know (a), (c), and (d), we need information on the supply curves for the new technology, the old energy source, and the demand curve. To know (b), we must understand the nature of the market failure. We will return to these issues in Section 5.3 below.

Case 3. Diffusion over Time. To approach a step closer to reality we assume that the market price of energy, P^m, will continue to be set by imports of oil, because the new technique will not instantaneously diffuse to take over the entire import volume. The crux of the analysis then is the forecasting

of x_t given $G^i[C(x)]$ and an estimate of P^m. During the period when the market price is greater than the cost of the new option there is another component of the social benefits (besides consumers' surplus). This is producers' surplus--the difference between the selling price of the new product and its cost.

Case 4. Uncertain Prices, Uncertain Costs, Diffusion over Time. In Cases 1, 2, and 3 we treat the problem as a simple calculation under complete certainty about future prices and costs. Of course, such certainty never exists and decisions must be made without full knowledge of future prices and costs. The problem then becomes more complicated. A planner will have an expected market price, but will realize that the actual price P^m could vary within a wide range. Similarly, as discussed earlier, the costs for the initial plant, K_g, will be uncertain as well as costs of production from subsequent units $G[C(x)]$. In this case, the evaluation will be made based on expected costs and benefits.

Let us extend our example to encompass this case. Assume that in the future the real price of oil as set by the cartel is most likely to be \$13 per barrel but could be as low as \$5 and as high as \$20. Assume also that the product costs from subsequent plants are expected to be \$10, but could be as high as \$20 and as low as \$5. Let us make these ranges more precise by attaching a 1/2 probability to the medium and 1/4 probability to each of the extremes. We then have the probabilities for each outcome shown in Table 5.1. There is a return to the initial subsidy attached to each possible outcome. If the cost of the technology turns out to be no less than the price of oil, the return is zero or negative. If the cost is less, there is a positive return. The total returns will depend on the output levels for the new technology over time, x_t, given by demand conditions and the associated pace of diffusion of the new technology.

Table 5.1

PROBABILITY OF EACH COMBINATION OF POSSIBLE OIL PRICE AND NEW TECHNOLOGY COST

		Price of Oil P^m (Probability of Occurrence)		
		$5(.25)	$13(.5)	$20(.25)
$G^i[C(x)]$ Technology Cost (Probability of Occurance)	$5(.25)	.0625	.125	.0625
	$10(.5)	.125	.25	.125
	$20(.25)	.0625	.125	.0625

The probability information may be incorporated into our framework as follows. The joint probabilities of the price of oil and the cost of the new technology being a particular value is given in Table 5.1. Assume that the cost of output from the first plant, $C^*(x^*)$, is known with certainty. There are nine possible benefit outcomes and three possible cost outcomes. The expected net benefits are found by summing the two sets of outcomes weighted by the probability of occurance. Thus:

$$\text{Expected net social benefits} = \sum_{i=1}^{9} P_i B_i - \sum_{j=1}^{3} P_j C_j$$

where P_i, P_j, are the probabilities of occurrence and B_i, C_j are the results of evaluating the costs and benefits using the analysis developed in the previous three cases.

Case 5. Government Speedup of Introduction, No Social Premium on Energy. In actuality, of course, many (if not most) of the technical options supported in government commercialization programs would ultimately be introduced into the market without the subsidy--the government only accelerates the process. Thus a crucial analytical issue becomes industry's behavior without the government subsidy. The benefit analyses then become more complex, with the difference in the timing of the benefit streams due to government's investment taking the place of the total benefit associated with the new technique.

Case 6. Premium on Energy. Finally, there is the additional but crucial evaluation issue associated with the fact that the market price of energy is not likely to reflect its social value. As discussed earlier, this will likely be due to government price controls and the benefits of reducing imports.

In this case the increased availability of domestic supplies, increased conservation, and reduction of imports need to be valued not at the market price, but at the social value. The analysis of private investment decisions continues, of course, to be made at the market price.

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[1] The decision, of course, need not be made only on the basis of this simple expected payoff. Even if the expected payoff were negative, we might be willing to undertake the program just to be sure that if price goes to $20 per barrel, we have the new technology available. In a world of uncertainty, of course, private firms will be willing to speculate on higher prices. However, institutional constraints often prevent the price from rising to a level that clears the market. Private firms will therefore not invest enough in the new technology and the government could provide insurance. In this case, we would have to compare this form of insurance to other alternatives to make sure this is the cheapest way for the country to purchase protection.

Case 7. The Government Waits. The discussion so far has treated the problem as if the decision to subsidize or not must be made now. This, of couse, is unrealistic. An important variable under the decision maker's control is when to invest. Are we much better off waiting? What do we gain (or lose) by waiting? Several things can make it worthwhile to wait. If there are new technologies under development that offer the hope of lower costs, it clearly can pay to wait. Also, more can be discovered about the future costs and prices, thus changing the probability distributions described in Case 4. The risk of an investment-cum-subsidy program can be reduced as future outcomes become clearer. Of course, it is possible nothing will become clearer. For example, uncertainty about P^m due to lack of information about the oil cartel behavior might remain high. No new technology might appear promising. In this case, there is no reason to wait.

5.3 THE STATE-OF-THE ART OF ANALYSIS

The previous discussion, and the simple cases used to illustrate the problems of analysis, lead to the identification of several areas of analysis and forecasting which are crucial to the evaluation of schemes of federal intervention in commercial demonstration. All analytical efforts which attempt to evaluate national income benefits from this type of investment must deal with these issues in one way or another. As might be expected from the sheer complexity of the problem, these constitute key areas for future research and analysis in an effort to improve our ability to analyze these circumstances. A brief discussion of the key problems follows; they constitute an agenda for research in this vital policy area.

5.3.1 Forecasts of Prices

As is evident from the cases presented here, a key input to all the analysis is a forecast of the market prices that will hold over the period when a technology might be introduced and diffused. In addition, the forecast of price needs to convey some notion of the rules of the game under which energy prices in general are being determined, as that will affect the likely response of private markets. In general, the analysis would be based on a single price (or a single distribution of prices) which would not be assumed to be affected by the commercialization investments under study, although as Case 1 illustrates there may be circumstances where the analysis would need to take account of such an effect by a new technology.

This emphasis on a price forecast was argued in Section 2, where it was stated that a key problem for ERDA planning is that the agency must incorporate some notion of likely future market conditions--and, in particular, some estimate of a "planning price"--in its analyses of commercialization investments. (Of course, the problem presented by the need to analyze ERDA planning decisions at the commercialization stage will appear in connection with earlier stages in R&D as well.) Without such a forecast of price, and perhaps other market conditions, it is not possible to distinguish clearly between technologies which may yield positive benefits if introduced and those which will not.

The forecast of market price ultimately depends on analysis of international oil markets, on the tariff or other policies that may be used to buffer the U.S. economy from these prices, and on the process of price formation in product and region markets throughout the economy. Some steps in this process are well understood, others are not. Overall, this is a key area

for further research and analysis because of its importance to the evaluation procedure discussed above.

In addition, for evaluation purposes one also needs a forecast of a companion price to go along with the market price forecast--this price to reflect the social value of energy produced or saved. As discussed in Section 3.3.1 above, the social value of energy may depart from the market price. With respect to domestic petroleum, it seems clear that the social value is at least the price of landed imports--OPEC is the source of marginal supplies to the United States and will remain so for some time to come. It is argued in Section 3.3.2 that in fact the social value is even higher--that there is a national security premium associated with our dependence on imports. The premium is the amount the United States would be willing to pay for a barrel of oil, above the imported price, to be free from the insecurity associated with it. Thus, some form of national security premium must be estimated to arrive at a social value.

One measure of the national security premium is given by the cost of a stockpile which would counteract the effect of the imports. Suppose, for the purpose of illustration, that all imports are equally insecure, and that a storage program can in fact provide a counteractive security to imports. Then clearly the size of the appropriate stockpile is a monotonically increasing function of the level of imports. At any given level of imports, the incremental cost of the stockpile associated with one more daily barrel of imported oil would then be the national security premium.

The appropriate stockpile size might be calculated as an optimum where the cost of maintaining the stockpile is traded off against the expected savings in the case of an embargo plus the value of the deterrent effect

(i.e., the lowered probability of embargo). A more intuitive measure of the incremental stockpile cost can be found by assuming that the size of the stockpile should always be directly proportional to the level of imports; then the proportionality constant can be thought of as the period over which the stockpile could replace the imports. If the stockpile is chosen to provide N years of supply at the annual rate of imports I, if the cost of the stockpile is solely the opportunity cost of the capital investment in inventoried petroleum (i), and the petroleum is purchased at the international market price (P^m), then the annual cost of the stockpile for each barrel per year of imports is $L \times P^m \times N \times i$. Thus, the national security premium would be $N \times i$ per cent of the imported price. If the interest rate were 6% and a 1-year stockpile were deemed sufficient, then the premium on each barrel would be 6% of the landed cost. Of course this simple calculation misses many complicating factors in the international and domestic petroleum scene, but it illustrates that a social value based on reasonable assumptions and judgements could be constructed.

5.3.2. Analysis of the Diffusion Process

As shown in Case 3, the evaluation of the benefits of the more rapid introduction of new technology depends ultimately on forecasts of the diffusion of those technologies through the relevant energy markets. That is, given estimates of cost, $G^i[C(x)]$ or $G^d[C(x)]$, the analysis depends on some method for estimating x_t given these cost forecasts and the market price data discussed above.

In general, this step requires a set of methods for analyzing transportation, processing, and energy technology choice, so that one can simulate

the way the economy adjusts to a new technology given that is has survived the introduction stage. These estimates may be made in a variety of ways--ranging from informed judgements and calculations to highly elaborated formal models. In the latter category, for example, efforts at Stanford Research Institute[1] and Brookhaven National Laboratory[2] provide a framework for conditional forecasting of the expected penetration of new and emerging energy technologies and products based on the cost and efficiency attributes of these technologies. The SRI-Gulf model is a network representation of the U.S. energy system which provides a very detailed description of the processing, conversion, and transportation activities required to process primary energy supplies (coal, oil, gas, and uranium) into energy forms desired for end-use demand. The model has sub-national supply and consuming regions. It requires as input the cost and efficiency attributes of existing and new technologies, end-use demands, and supply functions for the primary energy resources; it determines the quantities and prices of energy in intermediate and final delivered forms. The model has been used extensively in support of the Inter-Agency Task Force on Synthetic Fuels.[3]

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[1] SRI-Gulf Energy Model: Overview of Methodology, E.J. Cazelet (Stanford Research Institute, Menlo Park, California, 1975). The development of the SRI model was supported by Gulf, which is continuing to develop and utilize the model independently of SRI.

[2] Brookhaven Energy System Optimization Model (Associated Universities, Inc. Upton, New York, 1974), E.A. Cherniavsky, Brookhaven National Laboratory Topical Report No. BNL-19569.

[3] "Recommendations for a Synthetic Fuels Commercialization Program," Synfuels Inter-Agency Task Force (Government Printing Office, Washington, D.C., November, 1975). Four Volumes.

The Brookhaven Energy System Optimization Model (BESOM), is an explicit optimization model which also includes a network representation of the energy system, describing the intermediate processing and conversion activities between extraction of primary energy supplies and delivery of final energy forms. The model is national in scope and requires input data on end-use demands, the primary supplies available, and the characterization of the intermediate processing and conversion technology costs and efficiencies. The model uses this information to determine the least-cost combination of existing and new energy technologies required to satisfy end-use demands, consistent with environmental restrictions included as constraints in the model.

Both the SRI-Gulf and Brookhaven models are valuable tools for conditional analysis of technology choice. Two crucial problems are not addressed by either of these modelling efforts however. First, we would expect that the actual commercial availability of a new technology will depend critically on market factors. As we have emphasized, the process of technological change can be viewed as a series of investments. If these investments are made by industry, then they are very much dependent on expectations of future market circumstances.

Thus, a model which purports to explain the penetration of new technologies must also explain the evolution of events which lead to the "availability" of those technologies at a point in time. None of the existing analyses come close to doing this. This is an extremely important (and difficult) research issue.

A second, and closely related, issue concerns the demand for these new technologies. Simple models of consumer behavior based upon simple cost considerations are probably not adequate to characterize consumer response

to a new product or technology. A more reasonable approach would be to consider expected consumer reaction to the attributes of new technologies, based upon observing their response to these attributes in existing technologies. The problem is essentially one of using information on consumer response to existing technologies to project reactions to technologies and products not yet observed. The issue of consumer demand for new technologies is not addressed in the SRI-Gulf and Brookhaven models, nor by any other models of energy technology choice with which we are familiar.[1]

5.3.3 Estimation of Industry Activity in the Absence of Government Intervention

As illustrated by Case 4, the benefits of a government program at the point of commerical introduction depends on the likely events that would take place if there were no intervention. It may be, as assumed in Case 1 that nothing would happen without government subsidy. On the other hand, it may be that government subsidy only substitutes for industry investment that would take place in any case, or that it only speeds up the introduction process by a period of a few months or a year or two. In such a case, precious public resources are being devoted to a low-value project. In order to analyze any particular proposal, or to compare proposals, it is necessary to have some understanding of what may take place without intervention, and this once again leads to a need for a clearer understanding of the nature of the market process, how it fails, and how one might gather information about likely industry involvement at the introduction stage.

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[1] A third deficiency is that demands for energy services are assumed by the model to be inelastic with price.

5.3.4 Estimation of the Likely Effect of a Commercial Demonstration

The next key link in the evaluation process is between the introduction investment given some ex ante appreciation of likely costs $G^i[C(x)]$ and the resulting information after the introduction has been tried, $G^d[C(x)]$. One may be able to develop methods for forecasting the rate of market diffusion given assumptions about the cost of the technology, as discussed in Subsection 5.3.2, but analysis of any particular scheme requires some way to make a link between current expected costs, the government subsidy in commercial demonstration, and the cost inputs that one would put into such a model for forecasting diffusion.

5.3.5 Estimation of the Differential Costs and Effects of Alternative Instruments

As discussed in Section 4.4, the alternative instruments used by the government to subsidize the introduction stage may have very different costs. A fact not discussed earlier is that different instruments may have different effects on the amount of learning that takes place in the introduction stage. In order to choose among the different types of programs discussed in Section 4, one needs to be able to distinguish between the different instruments and their ability to produce a good measure of $G^d[C(x)]$.

The problem of estimating the costs of various government incentives can be illustrated by again turning to the loan guarantee. The cost of a loan guarantee (i.e., the dollar value of the subsidy provided) is the difference between (1) the market value of the debt claim with the guarantee and (2) what the claim's market value would be if the guarantee were removed. Estimating the cost is not difficult if the debt would be a high-grade issue absent the guarantee. But in such cases the cost is probably small--that is,

the loan guarantee is unlikely to provide a subtantial subsidy--and therefore is not likely to have much impact.

Loan guarantees are effective subsidies only when the unguaranteed debt has a high probability of default. ("High" is measured relative to the default probabilities normally incurred by private lenders.) But the higher the likelihood of default, the harder it will be to find an existing debt issue that is (1) actively traded and (2) a close substitute for the guaranteed bond in all aspects except the guarantee. The only candidates will bonds of firms which are already in financial distress. It would be difficult to find any existing traded bonds which would be close substitutes for unguaranteed debt secured by, say, a shale oil facility, with a 50 percent ratio of debt to total capitalization.

There is a methodology for evaluating risky debt claims that does not require observing the prices of substitutes.[1] It states that the difference between a debt claim's guaranteed and unguaranteed values is a positive function of the actual present value of the assets standing behind the debt, the

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[1]The methodology is an extension of the option-pricing formula developed by Black and Scholes ("The Pricing of Options and Corporate Liabilities," F. Black and M. Scholes, Journal of Political Economy, May-June, 1974, 637-50). There is an article published by Merton applying the methodology to value relatively simple debt claims ("On the Pricing of Corporate Debt: The Risk Structure of Interest Rates," R.C. Merton, Journal of Finance, May, 1974, 449-70). Other work (as yet unpublished) indicates that the approach gives reasonable estimates of the value of actual risky debt claims.

An alternative approach is to use information available (from solicitations or from calculations) on the price guarantees which would be demanded for a given commercial demonstration with and without loan guarantees and then estimate the value of the guarantee as the net present value of the difference in revenue streams to the firms. This method and that discussed above are utilized in Appendix A.

degree of uncertainty about the assets' future value, the maturity of the debt claim, the provisions of the indenture (coupon payments, repayment schedules, etc.) and the current time value of money. The theory's advantage is that it provides a rigorous basis for calculating the value of the guarantee.

One difficulty with this theory is that it assumes that the value of the firms' assets--the value of all its outstanding securities--is independent of the proportions of debt and equity financing. This may not be true, since the existence of risky debt changes the incentives governing operating and investment strategy. This happens regardless of whether the risky debt is guaranteed. Estimating the uncertainty of the assets' future value is a major task as well.

5.3.6 Summary

In Section 5.1 we presented a semi-formal model of government-supported commercialization efforts which summarized the qualitative discussion of Sections 3 and 4. We then (in Section 5.2) built up the key elements of the analysis problem. In Section 5.3 we have addressed the deficiencies in our analytical capabilities. While the general features of the analysis problem are clear, there are important issues where both conceptual development and new analytical tools are required. However, the concepts and tools which are available are sufficient for analyses incorporating many of the key elements of the framework discussed in this paper.

APPENDIX B

WN-9190-DOC (Abridgment)

December 1975

AN ANALYSIS OF FEDERALLY FUNDED DEMONSTRATION PROJECTS: REPORT ON PHASE I

Leland Johnson, Edward Merrow, and Walter Baer

A WORKING NOTE
prepared for the
EXPERIMENTAL TECHNOLOGY INCENTIVES PROGRAM
DEPARTMENT OF COMMERCE

PRESENTATION TO
ERDA TASK FORCE ON DEMONSTRATION PROJECTS
AS A COMMERCIAL INCENTIVE

This Note is intended only to transmit preliminary research results to a Rand sponsor and may not be distributed without the approval of that sponsor. Views or conclusions expressed herein may be tentative and do not necessarily represent the opinion of the sponsor.

PREFACE

The federal government has had extensive experience in funding demonstration projects with the goal of stimulating technological change in the civilian economy. The results have been mixed. Some demonstrations appear to have aided the diffusion of innovation while others have contributed little. Pressing questions arise about what can be learned from this experience to enhance the effectiveness of future federal involvement.

In July 1974, under a contract from the Experimental Technology Incentives Program of the U.S. Department of Commerce, Rand began a study of federally funded demonstration projects. By undertaking case studies of past demonstration projects, the overall goal of this study is to formulate guidelines for use by federal agencies to improve the processes of planning, implementation, monitoring, evaluation, and dissemination of results for future demonstration projects.

This study is divided into two phases extending over an 18-month period. Phase I, included in this report, covers the first year. The purpose of Phase I is to analyze a wide range of past demonstration projects in order to generate hypotheses about relationships between project characteristics and outcomes, and, on that basis, to delineate tentative guidelines for future federal action. This report includes a general discussion of federal demonstration projects; brief descriptions of the fifteen cases we have so far examined; a description of our conceptual framework involving the goals, strategies, and outcomes of demonstration projects; and a discussion of the broad outcomes and patterns we perceive from the cases completed to date. It continues into a step-by-step discussion of tentative guidelines, directed toward federal agencies, for each major component of a demonstration project.

Other Working Notes listed subsequently describe the conceptual framework developed early in the study and present individual case studies of demonstration projects.

Phase II, covering the last six months of the study, will include examination of additional cases to test the hypotheses, and to make more operational and specific the guidelines discussed here as the basis for a final report to be completed in early 1976.

SUMMARY

PART I: AN ASSESSMENT OF DEMONSTRATION PROJECTS

Drawing from case studies of past experience, this analysis seeks to delineate generalizations, hypotheses, and guidelines for future action by federal agencies involved in technological demonstration projects. We define a demonstration project in terms of five characteristics: (a) support by federal funds, (b) involvement of the civilian sector, (c) stimulation of technological change involving hardware, (d) significant private sector involvement, and (e) operation in a real world environment, rather than in a laboratory.

The study addresses two principal policy issues:

- Under what circumstances is a federally funded demonstration project an appropriate instrument of government action?
- How should a demonstration project be organized, funded, managed, and its results disseminated in order to maximize its effectiveness?

The overall goal of demonstration projects is to stimulate the diffusion of technological innovations. With this overall goal, demonstration projects have one or more of the following objectives: (a) production of new information to reduce uncertainties perceived by potential adopters of the technological innovation, (b) exemplification of the technological innovation to provide potential adopters with opportunities for first hand assessment of its usefulness and applicability, and (c) catalyzation of institutional and organizational changes to facilitate adoption. A few demonstration projects we have examined have been employed also as tools in meeting high level national goals such as "Atoms for Peace" and exploiting the resources of the oceans to meet worldwide problems. The outcomes of demonstration projects can be assessed in terms of the extent to which they succeed in meeting these objectives.

Demonstration projects have become major instruments of government intervention in civilian technology. We have identified 41 programs

in 12 federal departments and independent agencies that include demonstration activities. We estimate that federal funding for demonstration projects in fiscal year 1974 totaled more than $600 million. Federal support for demonstrations will probably increase substantially in the future, particularly in the energy field. The 1974 Nonnuclear Energy Act states that nonnuclear energy R&D and demonstrations may require up to $20 billion over the next decade.

A major purpose of most demonstrations is to generate new information, in order to aid decisionmaking by potential adopters. In our conceptual framework, new information is directed to reducing uncertainties in five dimensions: technological, cost, demand, institutional and organizational, and externalities. One measure of a demonstration's outcome, then, is in terms of "information success"--which occurs if uncertainties are reduced to a point where well-informed adoption decisions can be made. However, even if a demonstration is a complete information success, no diffusion may follow for several reasons: (1) the information indicates that adoption would be uneconomic, (2) although the project generates information showing economic promise, potential adopters are unaware of the information, and (3) although the information may both show economic promise and be in the hands of adopters, they are unable to act because of institutional and organizational barriers to the use of the new knowledge.

A second demonstration objective is to make potential adopters aware of the innovation and provide them with opportunities to examine its operation in an environment similar to their own. Most demonstrations are intended to perform this exemplary function. The outcome measure of exemplary demonstrations is first the achievement of "application success," reflecting the extent to which the demonstration project meets local needs and thus can serve as a successful model. An exemplary demonstration must also achieve "dissemination success," in terms of broadcasting its results to all potential adopters.

A third objective can be to change the organization of an industry, to create a new industry, or technology delivery system, or to cope with other specific barriers to technological change. If the changes required

can take place in an essentially competitive environment, and if the demonstration project shows that the product or process in question is economic, then we can be reasonably confident that market forces will bring about whatever organizational changes are required. However, many institutional and organizational changes encounter barriers to competitive behavior, including such factors as inappropriate labor union policies, nonuniform building codes, and weak incentives of potential adopters to reduce costs. In these cases, it is unlikely that a demonstration project will succeed, because these barriers arise due to policy decisions and private sector activities over which a demonstration project has little control.

CASE STUDY DESCRIPTIONS

Case studies undertaken in Phase I of our study are described in this section. The descriptions offer brief overviews of the cases so that the reader can understand the context in which they are used as examples throughout the text. For a more complete understanding of any particular case, the reader should consult the appropriate Rand Working Note.

For each case study, the following pages supply a list of basic information about the case, a brief description of the demonstration, the primary goals and outcomes, and any special characteristics which distinguish the demonstration from other cases.

DIAL-A-RIDE TRANSPORTATION SYSTEM

The growing problems of pollution, highway congestion, and energy consumption have spurred greater federal concern for alternatives to the private automobile as a means of transportation. This concern is evidenced in the Urban Mass Transportation Administration's funding of a number of demonstration projects which either improve on existing public transportation modes (such as bus corridors on freeways) or seek to introduce new forms of public transit (such as the personal rapid transit system in Morgantown, West Virginia, and the Dial-A-Ride demonstration in Haddonfield, New Jersey). The intent of Dial-A-Ride is to create a public transportation system that provides door-to-door service like a taxi or private auto, but at only a fraction of the expense.

Dial-A-Ride systems employ small buses, and generally offer both preplanned and responsive service. In responsive service the patron's request is made just before the trip; in preplanned service the request is made somewhat in advance. The key to a smoothly functioning system is the control center, which receives requests for service and relays the information and routes to the drivers of the buses. In 1971 UMTA

and the New Jersey Department of Transportation sponsored a demonstration of Dial-A-Ride in Haddonfield, which is located 10 miles from Philadelphia.

Basic Information List

Federal Funding Agency: Office of Research, Development, and Demonstration, Urban Mass Transportation Administration, Department of Transportation.

Operating Agency: New Jersey Department of Transportation

Other Organizations Involved: Department of Housing and Urban Development had previously funded research. LEX Systems and DAVE Systems contracted for systems design and operations management on-site. MITRE, software development and evaluation.

Project Life: August 1971 - June 1975 (operations began May 1972).

Primary Source of Demonstration Proposal: Urban Mass Transportation Administration

Federal Cost: c. $10 million including a substantial fraction for concept development.

Cost, Local: New Jersey Department of Transportation c. $420,000 for vehicle purchase. Revenue from fares: c. $250,000.

Cost Sharing with Profitmaking Firms: No.

Cost Sharing with Public Agencies: Yes.

Target Audiences:

Potential adopters: public and private local transit companies

Potential users: local travelers

Between 1964 and 1971 as many as 10 Dial-A-Ride systems had been operated in the United States. None of these, however, had served a general market (as opposed to the handicapped, for example), provided full door-to-door service, or provided feeder service to an integrated regional transit system. Thus the hoped for general potential of Dial-A-Ride had not been demonstrated in the United States. To meet these needs UMTA decided to fund a demonstration for which Haddonfield was finally selected as a site.

The project was intended to demonstrate not only the general potential of Dial-A-Ride, but two technologies for vehicle routing and control -- one manual, the other computer-based. Under the manually controlled system, a substantial ridership was achieved, especially as fares were decreased and new forms of service introduced. But even with a manual system, very large subsidy-to-fare-revenue ratios prevailed. Reliable operation of the computer-based system was never achieved.

Special Characteristics

The case illustrates the difficulties that can arise when a demonstration requires extensive subsidies to continue operation. Subsidies of public transit are expected, of course, but the Haddonfield system is more costly than many other public transit systems.

COMPUTER-ASSISTED ELECTROCARDIOGRAM ANALYSIS

The Health Care Technology Division of DHEW has funded several projects that demonstrate the applicability of computer technology to health care. During the period 1970-72, HCTD funded a demonstration of the use of the computer to aid in the interpretation of electrocardiogram (EKG) results in several Denver hospitals. It was hoped that the use of the computer would reduce the time necessary for EKG interpretation, improve accuracy, and lower costs (or at least improve productivity).

Basic Information List

Federal Funding Agency: Health Care Technology Division, National Center for Health Services Research and Development, Health Services and Mental Health Administration, DHEW.

Operating Agency: Community Electrocardiographic Interpretative Service, St. Lukes Hospital, Denver, Colorado.

Other Organizations Involved: Colorado Heart Association. Members of computer equipment and software industry.

Project Life: July 1969 - August 1972 (operations started January 1970)

Primary Source of Demonstration Proposal: HCTD (R and D was largely performed at DHEW for this project).

Federal Cost: c. $658,000

Cost Other Sources: $250,000 from industry and Heart Association. $650,000 from user fees.

Cost Sharing with Profitmaking Firms: Yes.

Cost Sharing with Non-Profit Organizations: Yes.

Target Audiences:

Potential adopters: hospitals

Potential users: cardiographers and physicians

Potential manufacturers: computer and medical equipment manufacturers

The EKG is an essential tool of modern medicine. More than 50 million EKGs are processed annually in the United States at an average price (to the patient) of about $20, placing the total EKG market at upwards of $1 billion per year.

In the standard EKG procedure, leads from an EKG recording machine are attached to the patient, whose electrical heart signals are amplified and displayed on a strip-chart recorded that is part of the self-contained EKG apparatus. In a physician's office, clinic, or small hospital, the procedure usually is performed by a nurse or paraprofessional; in a larger hospital the equipment may be moved to the patient's bedside on an "EKG cart" operated by a specially trained technician. A technician can acquire roughly four EKGs per hour.

After an EKG tracing is acquired, the technician cuts and mounts it for interpretation by a physician. Some physicians in private practice interpret the EKGs they acquire, but most send them to specialists -- electrocardiographers -- for interpretation. Large hospitals employ thei own staff of electrocardiographers, while small hospitals (typically those with 200 or fewer beds) send EKGs by mail or courier to a larger

facility for interpretation. The interpreted EKG, signed by the electrocardiographer, is then returned to the patient's bedside and included in his medical chart.

In Denver, prior to the computer-assisted EKG demonstration, the turnaround time from EKG acquisition to inclusion in the patient's chart ranged from about 24 hours in the major metropolitan hospitals to up to 72 hours in outlying facilities. In emergency cases a patient would often be brought by ambulance from a smaller hospital to a larger center for more rapid EKG interpretation.

The innovation demonstrated in Denver involved computer processing of EKG signals as an aid to electrocardiographer interpretation. In the demonstration system, the EKG signals were acquired with a special cart equipped for recording them on magnetic tape or transmitting them by telephone to a central computer. The computer then analyzed the data according to a stored program and transmitted an "unconfirmed report" back to the EKG cart within a few minutes. This report and the original EKG tracing were immediately put into the patient's chart. Simultaneously, a duplicate tracing and report were sent to the hospital electrocardiographer for interpretation. The signed "confirmed report" was then sent to the patient's bedside through a conventional delivery system.

Goals and Outcomes

The primary goals for the Denver demonstration were:

1. to test the computer software on a commercial scale;
2. to reduce the costs of the computer interpretation, largely by by finding the optimal economies of scale;
3. to test physician and cardiographer acceptance of the system.

All of these goals met with considerable success in the demonstration. The Denver system has remained in operation after the withdrawal of federal funds. The system was accepted by physicians without difficulty and because it did not affect the cardiographer's income or status, it has been accepted by them. In addition, the third-party payer, Blue Cross, has agreed to pay the additional costs of the computer interpretation.

The basic technology of computer EKG interpretation has been rapidly diffusing throughout the nation, but the impact of the Denver demonstration on this process is not clear. A number of private firms were entering or already in the computer EKG market when the Denver demonstration began.

Special Characteristics

1. This may be a case in which federal intervention in the process of technological change was not necessary. Where there is strong private sector activity in developing and commercializing a technology, the effects of the demonstration are difficult to isolate.

2. The Denver demonstration contained the elements that lead to successful demonstration: technology well in hand, cost-sharing with profitmaking firms, and inclusion of all relevant organizations in the demonstration project.

SALINE WATER CONVERSION PLANT

Since its creation in 1952, the Office of Saline Water (OSW) had directed government R&D on the desalination of sea and brackish inland water. Presidential interest in the program stressed international applications of desalting technologies, while congressional interest was domestically focused. In 1958, PL-85-883 authorized OSW to $10 million to demonstrate at commercial scale. The Freeport (Texas) plant was to demonstrate a promising new technology which had been developed under contract with OSW (in response to this legislation).

Basic Information List

Federal Funding Agency: Office of Saline Water, Department of Interior.
Operating Agency: Stearns-Roger Manufacturing Company.
Other Organizations Involved: W. L. Badger and Associates, design, A&E; Chicago Bridge and Iron Company Construction.
Project Life: 1958-1965; in operation 1961-65.
Primary Source of Demonstration Proposal: OSW
Cost: Federal Government: $2.3 million

Local: Dow Chemical Company: land, in-kind subsidies, water purchase
City of Freeport: water purchase

Cost Sharing with Profitmaking Firm: Yes, but largely in kind, and as water purchases.

Cost Sharing with Non-Profit Agency: Yes, but only as water purchases.

Target Audiences:

Potential adopters: municipal water systems and industrial water users in United States and abroad.

Potential manufacturers: manufacturers of large distillation equipment.

Under OSW sponsorship a new desalting technology, the long tube vertical evaporator process, had been developed and was in use in a small pilot facility. When OSW was authorized to demonstrate desalting technologies in 1958, this process was judged to be very promising and was among those chosen for demonstration.

A plant designed to produce one million gallons of distilled water per day from sea water was constructed in Freeport, Texas and began operation in mid-1961 amid much political fanfare.

The early years of operation were plagued by technical difficulties which arose from lack of past experience with the process on a large scale. When the plant was ready for continuous operation, OSW and the contractor agreed to perform development to improve the process rather than demonstrate the technology in continuous operation. The plant did in fact demonstrate the cost-superiority of the technology over others in use. But the lack of continuous operation helped prompt the produce water purchasers to withdraw support and gave the misimpression that the technology was unreliable.

Goals and Outcomes

The primary goals of the Freeport Plant were:

1. to demonstrate the technical feasibility of the long tube evaporator process;

2. to demonstrate the economic competitiveness of the process with other desalting technologies.

The plant met the first goal which, given the previous level of development of the technology, was a significant accomplishment. But the second goal was not met. The process was in fact slightly superior to the competing technologies in terms of cost, but because of the lack of sustained operation, the technology was *perceived* by potential adopters as unreliable, which is of course an important component of overall cost effectiveness.

Special Characteristics

1. This case exemplifies the inherent contradictions between a demonstration and a development activity. The process needed more development before it could be demonstrated at a commercial scale. In this particular case it may have been possible to accomplish both of these goals with the same facility, but only if the development work at the plant had preceded the demonstration aspects of the project.

2. This case (and in fact the OSW desalting program) suggests the importance of private industry's willingness to cost share as a screen for the selection of demonstration activities. There was substantial private sector activity in R&D, but because the potential market for desalination did not exist on a sustained basis, industry was unwilling to make significant investments at the demonstration level.

3. The counterproductive effect of political pressure to hurry the development and application of a technology is exemplified by this case. New desalting technologies were not ready for demonstration, and the technology for desalting was in the midst of considerable change when the demonstration authorization was passed. Nevertheless, OSW did advance the development of the technology in this demonstration.

4. OSW was an agency made up largely of technical personnel. It had been involved almost exclusively in the research and development of desalting, not in its commercialization. This case suggests that in order to shift from R&D to demonstration activities, an agency should add commercially oriented personnel to its staff.

FISH PROTEIN CONCENTRATE PLANT

One of the basic nutritional problems of the less developed countries, and indeed for some portions of our population, is the lack of high quality protein in the diet, particularly in the diets of young children. Fish is a source of excellent protein, but in 1965 the world harvested only about 10 percent of the estimated maximum sustainable yield of ocean fish. Among the primary reasons for the small harvest are that fish are difficult to store (especially in the less technologically advanced nations) and many fish are simply too small or too bony to make usable solid portions for human consumption. Consequently, the possibility of developing a stable concentrated food from fish for human consumption is an intuitively appealing idea. Fish protein concentrate is such a food.

In 1961 the Bureau of Commercial Fisheries (BCF) -- now renamed the National Marine Fisheries Service (NMFS) -- began research on FPC. Two years later the Secretary of the Interior reoriented the FPC program toward more rapid commercialization, in support of a U.S. foreign policy goal to expand food supplies in developing nations. In 1966 special legislation authorized construction of a demonstration plant for the production of FPC from hake, a lean fish species. After a series of problems and delays, the plant was constructed in Aberdeen, Washington, and began operation in the summer of 1971. Modifications to permit FPC processing from fatty fish were made in the fall of 1971, but FPC production runs from fatty fish were never successful. The demonstration plant was closed in June 1972. Few of the program's basic goals were in fact achieved by the demonstration.

Basic Information List

Federal Funding Agency: Bureau of Commercial Fisheries, Department of the Interior (which became in 1970) National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Department of Commerce.

Operating Agency: Ocean Harvesters, Inc. (a joint venture of Sweco, Inc. and Star-Kist, Inc.).

Project Life: 1967-1972 (operations began 1971)

Primary Source of Demonstration Proposal: Bureau of Commercial Fisheries under pressure from the Marine Sciences Council.

Cost, Federal Share: c. $3.5 million (for construction and operation and undoubtedly quite conservative).

No Cost-sharing.

Target Audiences:

Potential adopters: U.S. fish processing industry, governments of less developed nations.

Potential manufacturers: U.S. fish processing equipment manufacturers.

Potential users: U.S. food processors, U.S. consumer directly (to minimal extent), foreign food processors and consumers.

The production of FPC is a complex problem of biochemical engineering.* Although a good deal of R&D had been performed on FPC processes when the demonstration began, a large number of important technical issues remained unresolved. This high level of uncertainty about the technology for constructing an FPC plant at semi-works scale plagued the demonstration project throughout. The FPC demonstration (in terms of the technology's diffusion) very unlikely:

- The demonstration was underfunded, but overpromised.
- Political pressures determined an inappropriate site.
- Food and Drug Administration regulations were extremely strict.
- Getting raw material proved very difficult.
- The overseas marketing effort failed completely, and there was little or no demand for FPC on the domestic market.

Goals and Outcomes

The basic goals of the FPC demonstration were:

- to provide technical and economic data upon which fish meal producers could rationally base entry into the FPC business and

*The technology is sufficiently complex that no attempt will be made to describe it here. For a description of the technology and its problems consult WN-9073-DOC, especially pp. 1-4, 18-33.

o to break down FDA restriction on the manufacturing and marketing of FPC.

The second goal was largely accomplished. The last of the FDA restrictions on FPC was removed in 1974. But it can be reasonably argued that the demonstration project would not have been necessary to accomplish this goal if industry had been moderately interested in pursuing the FPC technology. The first and most important goal was not met. A great deal of uncertainty about the production techniques and costs for FPC still exists. Knowledge of the demand for FPC was not appreciably increased. If anything, the FPC demonstration experience may have soured industry unjustifiably on the product. However, the demonstration did produce a great deal of information about the technology and related matters that could prove useful for a future demonstration. Much if not all of this information, however, might have been obtained at lower cost by further R&D and the construction of a pilot facility.

Special Characteristics

The FPC project is a good example of the various difficulties to which demonstration projects are susceptible.

1. Operating a successful demonstration when the technology is not fairly well in hand is extremely difficult, and is probably impossible when other aspects of the project are also uncertain.

2. Political pressure, whether from friends or opponents of the technology, places success in jeopardy.

3. This case illustrates the importance of there being private firms willing to share the risks of the demonstration project. When private firms were approached for cost sharing, their responses were negative for the reason that they considered that the technology was not sufficiently well developed.

MECHANIZED REFUSE COLLECTION (GODZILLA)

American families lead the world in refuse production. This solid waste is costly to collect and dispose of. In recognition of the growing problems caused by municipal refuse, Congress passed the Solid Waste Disposal Act of 1965 granting DHEW broad authority to support efforts to develop or test new approaches to solid waste management. In 1970 this authority was extended and further broadened and the program was transferred to the newly created Environmental Protection Agency. It was under the grant of this legislation that the City of Scottsdale, Arizona was funded in 1969 to develop and demonstrate a new mechanized means of collecting family refuse with the goal of decreasing the costs of collection. The first mechanized garbage collection truck developed in Scottsdale was affectionately called Godzilla, which serves as our short name for this demonstration.

Basic Information List

Federal Funding Agency: Initially the Department of Health, Education, and Welfare later the Office of Solid Waste Management Programs of the Environmental Protection Agency.

Operating Agency: Department of Public Works, City of Scottsdale, Arizona

Project Life: March 1969 - June 1972

Primary Source of Demonstration Proposal: City of Scottsdale (unsolicited proposal)

Cost, Federal Shared: c. $184,000

Local Share: c. $112,000

Cost Sharing with Profitmaking Firm: No.

Cost Sharing with Public Agency: Yes

Target Audiences:

Potential adopters: public and private refuse collectors

Potential manufacturers: garbage truck outfitting industry

Potential users: the public

Soon after the City of Scottsdale began refuse collection services in 1964, a study group was formed to develop more economical means of providing the service. By 1967, under the leadership of the City's refuse commissioner, initial plans for the mechanization of refuse collection had been started. The basic concept was to modify existing collection trucks by adding a hydraulic arm which could pick up, dump, and then return a collection can without the need for the driver to leave the truck. The primary goal was to save labor by cutting the size of each crew from three persons to one. Implementation of such a system required changes in the way people deposited their refuse. Instead of individual garbage cans, large containers ranging in size from 80 to 300 gallons were necessary. After some difficulty, the City found a manufacturer willing to supply the new type of containers -- but only after the City had agreed to absorb all costs of manufacture. City personnel used off-the-shelf components to design new parts for the garbage trucks. By the end of the demonstration in 1972, a family of mechanized vehicles had been designed and put into service.

Goals and Outcomes

The primary goals of the Godzilla demonstration were:

- to demonstrate that such vehicles led to substantial cost savings and
- to test public acceptance of a collection system in which families would frequently have to share containers.

These goals were met in Scottsdale. Despite this striking success, the innovation's diffusion, while substantial, has been much slower than one might have expected. A number of factors have no doubt contributed to this result, but we believe that the most important reasons are (1) the lack of a garbage truck outfitting firm in the demonstration which could have plugged the innovation into the existing technology delivery system and (2) the lack of consistent effort on the part of EPA to diffuse the

technology, apparently due to a change of program emphasis and reduction of budget.

Special Characteristics

1. The proposal for Godzilla came from the potential adopter level. It was prompted by a pressing local need for decreased cost in refuse collection.

2. Godzilla had been preceded by a substantial period of planning even before the application was made for federal funding.

3. Godzilla shows the advantages of having a demonstration performed by the same organizations that developed the idea initially, as in the refuse firing demonstration.

4. Godzilla illustrates the importance of tying a demonstration to the existing technology delivery system.

SHIPBUILDING R & D PROGRAM

The shipbuilding industry in the United States has been a declining industry since World War II. The number of ships built for commercial use has declined despite substantial subsidies from the federal government. Not only have foreign shipyards been competing more successfully, but the United States industry has lagged behind its foreign competitors in the use of technological innovations. This lack of innovation and weak competitive position stem from many factors, including the effect of federal subsidies, orientation toward the military market, restrictive union work rules, tight Coast Guard regulation, a relatively unstable market for merchant ships, and the relatively small capitalization of even the major shipyards. For these and perhaps other reasons U.S. yards had become extremely protective of their technical and market information, and had funded R&D at a very low level.

In an attempt to change this state of affairs, the Maritime Administration has introduced a number of programs, the most successful of which has been the shipbuilding R&D program. The goal of this program was not to

demonstrate new technologies -- in fact, its demonstration aspects should be considered strictly secondary -- but to bring about organizational changes in the industry. In particular, MarAd wished to increase the amount of communication within the industry on technical matters to ease the introduction of technological innovations in the industry. The advent of this program was as a part of a major reorientation of federal policy toward the maritime industry contained in the *Merchant Marine Act of 1970*.

MarAd developed its program by coopting a professional association, the Society of Naval Architects and Marine Engineers and in particular, its Ship Production Committee (SPC). From the nine subcommittees of SPC, which dealt with different aspects of ship production, came many of the proposals to MarAd for the development and demonstration of new cost-saving devices in shipbuilding. Meetings of the various committees included representatives of MarAd and frequently representatives of the Coast Guard, which is principally responsible for the regulation of the industry. MarAd's philosophy for the program was to develop as much control and responsibility as possible to the industry.

Among the results of the program have been:

- the introduction of a number of new techniques for shipbuilding, especially in ship welding which is a major area of expense
- the development of R&D consortia in the industry
- a general increase in the level of cooperation and communication within the shipbuilding industry.

It is too soon to determine whether these apparent changes in the industry will endure; the real test will come as federal support for the program is eliminated. Nonetheless, the program appears to have recognized that the basic problem of the industry is not technology per se, but industry organization and institutional constraints.

Special Characteristics

The shipbuilding R&D program, although not primarily a demonstration program, has aided in restructuring the industry to accommodate new

technologies. MarAd's efforts to stimulate change in the industry before 1970 when the new legislation was passed and its program of organizational change was begun, met with absolutely no success. It was in part out of frustration with earlier attempts that the new approach was born. This case strengthens our basic contention that where institutional and organizational barriers to diffusion of technologies exist, demonstration projects alone are unlikely to have much impact.

NUCLEAR SHIP *SAVANNAH*

In the mid-1950s the dominant symbols of America's development of nuclear energy were the bombs dropped on Japan, and the naval submarine *Nautilus*. President Eisenhower was very desirous of showing the world that the nation intended to employ its nuclear knowledge for peaceful purposes. To this end, the President proposed in 1955 that the United States construct a nuclear powered merchant ship, which would become a visible symbol of the nation's commitment to Atoms for Peace. A year later Congress passed a law authorizing the construction of the *N. S. Savannah*, and the Atomic Energy Commission and the Maritime Administration began a joint project to construct the vessel.

Basic Information List

Federal Funding Agencies: Atomic Energy Commission and the Maritime Administration under special appropriation.

Construction Contractors: Babcock and Wilcox, reactor; New York Shipbuilding, hull; George Sharp Co., naval architect.

Contract for Operation: States Marine Lines (1959-1962); American Export Isbrandtsen (1963-1970).

Project Life: 1956-1970 (operations began 1959)

Primary Source of Demonstration Proposal: Highest executive and congressional levels of Federal Government.

Federal Cost: Construction costs c. $55 million; total costs including operations subsidies, $100 million plus.

No cost-sharing.

Target Audiences:

Public opinion leaders in U.S. and abroad (Atoms for Peace goal).

Potential adopters: merchant fleet owners

Potential manufacturers: shipbuilding industry; reactor design and manufacturing industry

The construction of the world's first nuclear powered merchant ship was a technologically and organizationally complex project. Organizationally, the project involved the coordination of two federal agencies (AEC and MarAd) which had no history of joint projects; it involved the coordination of a number of contractors; and it involved making important compromises between the President's desire for an aesthetically pleasing ship and the designer's and Congress's desire for a ship to demonstrate economic feasibility. Technologically, the project entailed the design and construction of a fundamentally new type of reactor and the design of a new type of ship with extensive safety precautions.

To understand the *Savannah* project, one must recognize that its primary goal was political. First conceived as a political symbol of the nation's commitment to the peaceful uses of atomic energy, the ship was never intended to primarily demonstrate the economic feasibility of nuclear merchant vessels. To use *Savannah* as the first step toward a nuclear merchant fleet was a subsidiary goal pursued by the *Savannah* project team. The overriding political goal, however, directly conflicted with this aim. The ship was designed to be beautiful, rather than efficient. By White House direction, the ship was a hybrid passenger-cargo vessel, which meant that it was optimal for neither use. Because of budget constraints and because the ship was not meant to be economically viable, shortcuts were made in outfitting the ship, especially in its cargo handling capability.

Other goals were:

- to demonstrate the safety and reliability of nuclear merchant ships in regular operation.
- to establish precedents for international liability and indemnification in case of accidents
- to demonstrate that regular mariners can be trained to operate nuclear ships.

In terms of the original goals for the *Savannah* project, the demonstration was a considerable success, and about three years after the project was initiated, the ship was put to sea. Significant advances in marine reactor design and safety had been accomplished, the ship could carry both passengers and cargo, and the ship was an aesthetic triumph. She was greeted enthusiastically at many foreign ports and was indeed a symbol of Atoms for Peace.

Subsequently, a combination of labor problems and the need for extensive operating subsidies soured public and Congressional enthusiasm for the project, and no follow-up demonstrations have been authorized.

Special Characteristics

1. A primary lesson of *Savannah* is the potential incongruence of political goals and commercial diffusion of a technology.

2. Despite the lack of diffusion of *Savannah*'s technology, a great deal was learned about naval reactor technology from the project.

TELEPROCESSING OF MEDICAID CLAIMS

More and more physician's medical services in the U.S. are being paid through third-party payers, e.g., Medicare or Blue Cross. In terms of the physician's time and the costs to the third-party payers, it is estimated that the administrative costs of filing the claim amount to as much as 25 percent of the cost of the claim itself. The National Institutes of Health and the Health Care Technology Division of HEW (HCTD) had performed in-house research on the possible use of the telephone in conjunction with computers in health care delivery. Independent research on a Medicaid billing system using the telephone and computer was being conducted by the Clinical Information Systems Group (CISG) at the University of Alabama. Therefore, when HCTD decided to pursue demonstrations of the applicability of telephone and computer technology to health care, CISG was contacted and asked to submit a proposal. CISG proposed to demonstrate a system whereby physicians, using appropriate codes, could send billing information by phone directly to a central computer

and thus cut down on the time and errors involved in billing for Medicaid claims. This proposal was immediately accepted and the demonstration was begun.

Basic Information List

Federal Funding Agency: Health Care Technology Division, National Center for Health Services Research and Development, Health Services and Mental Health Administration, DHEW

Operating Agency: Clinical Information Systems Group, University of Alabama (Birmingham). Other involved organizations (software development): International Business Machines.

Project Life: June 1971 - April 1974 (operations started December 1971)

Primary Source of Demonstration Proposal: HCTD

Cost, Federal Government: c. $575,000

Cost, Other Sources: User fees c. $31,000

No cost-sharing

Target Audiences:

Potential adopters: third-party payers (e.g., Blue Cross - Blue Shield) and State and Federal medical insurance programs (e.g., Medicaid, Medicare)

Potential users: physicians in private practice, limited application to hospitals

Potential manufacturers: off-the-shelf computers would be used

Potentially interested agency: Social Security Administration

The Alabama Medicaid billing system involved the use of a Touch-Tone^R telephone equipped with Carddialer^R as an on-line input device to a central computer. Instead of filling out a claims form manually, the doctor's assistant merely dialed the computer and input the information by using the touch-tone buttons and a set of standard codes. To save time, the Carddialer^R could be used to enter four kinds of information: (a) the doctor's name and Medicaid provider number; (b) the patient's name and identification number; (c) routine diagnoses (50 cards could handle over 2/3 of all diagnoses specified); (d) common medical treatments (50 cards represented 94 percent of all treatments for which Medicaid reimbursement was requested).

The input system was an interactive voice-answerback system. At any stage in which there was information either missing or incomplete, the computer would inform the nurse or assistant so that she could add that information. The voice-answerback system also told the nurse or assistant what information was to be entered at each stage. For users with experience with the system, the voice instructions could be replaced by a set of tones which either told the inputter to enter the next bit of information or to supply missing information. As each bit of information was entered, the computer would search its files for relevant screening information. For example, it could tell whether the physician number was valid, whether the patient was eligible for Medicaid, whether a diagnosis was valid and whether the point of service was appropriate (e.g., hospital vs. doctor's office), whether a procedure was valid, whether a diagnosis was valid, and whether the charges were within an allowable range. Most of this was just information checking -- that is, in checking diagnosis validity, the computer was *not* indicating that the diagnosis was incorrect (or whether a given procedure was appropriate), but simply whether the nurse had entered a number for which a diagnosis existed. The benefits of the innovation included:

- reducing input time at the physician's office from over half an hour per claim to only 1-1/2 minutes;
- providing immediate feedback on missing or incomplete information for each claim, thus reducing the number of claims submitted with errors to practically zero;
- reducing average cost per claim from a $1.25-$2.50 range to $.50-$.75 per claim at the physician's office;
- reducing manual input time at the intermediary end by at least 50 percent, thereby cutting back processing costs.

This was accomplished using well-known standard technology.

Physicians joined the program because of the significant savings that would accrue to them.

Goals and Outcomes

The primary goals of the project were:

1. to test the technical feasibility of a computer-telephone billing system;

2. to determine the economic feasibility of such a system;

3. to determine physician acceptance of such a system;

4. to see the system diffused throughout the country.

The first three goals were met very successfully. The system not only worked, but was very effective in reducing costs, and was accepted without difficulty by physicians. The fourth (and perhaps most important) goal has not been met, for two partially related reasons:

The primary potential adopters of this system are third party payers such as Blue Cross. In the case of federal and state medical insurance programs, the third party payer is typically under contract with the government on a cost plus fixed fee basis. This greatly reduces the incentive to adopt cost-saving technological innovations. The third party payers were not explicit target audiences of the demonstration until it became clear that Blue Cross in Alabama would refuse to adopt the system.

The Social Security Administration (SSA) through which Medicare is funded was developing a similar system. HCTD did very little to coordinate their project with SSA, and the development of the SSA system continued in competition. SSA declined to put any pressure on the third party payers to adopt the Alabama innovation.

Special Characteristics

1. This appears to be a case in which the primary barrier to technological change was not the lack of available appropriate technology, but the lack of incentive on the part of the primary potential adopters to use cost saving technology. It is not clear how any demonstration project could have removed this institutional barrier to technological change. And if the incentives of the third party payer were changed to make cost saving an important goal for them, it is not at all clear that

a demonstration project would have been necessary for the adoption of this straightforward, off-the-shelf technology.

2. This case exemplifies a situation in which technically oriented staff (in the federal agency) were attempting to promote the commercialization of a technology. Perhaps because of their lack of experience in the marketplace, they failed to understand the mechanisms by which their innovation could be diffused.

YANKEE CIVILIAN POWER REACTOR

Under the Atomic Energy Acts of 1946 and 1954, the Atomic Energy Commission was charged by Congress with the development and promotion of atomic energy for civilian purposes, including the use of atomic reactors to generate electricity. Under its mandate the AEC sponsored several experimental reactors for power generation and a pilot sized facility. In early 1955 AEC developed the "Power Demonstration Reactor Program" (PDRP) and issued its first round RFP seeking cooperative proposals from the utility industry. The Yankee Atomic Electric Company, a consortium of electric utilities in the energy-hungry Northeast, responded to the RFP and the Yankee demonstration project was born. In 1956 a contract between Yankee Atomic and AEC was signed which called for construction and operation of a pressurized light water-cooled and moderated reactor which was capable of producing at least 134 megawatts of electricity, much larger than the pilot facility. AEC agreed to waive fuel costs for five years, support up to $4 million in private R&D, and perform $1 million in R&D in its own laboratories, for a total federal contribution of about $8.3 million. The rest of the cost, and all of the risks from cost overruns, were to be paid by Yankee Atomic and the other contractors.

Basic Information List

Federal Funding Agency: Reactor Development Division, Atomic Energy Commission.

Operating Agency: Yankee Atomic Electric Company

Other Involved Organizations: Westinghouse - Prime contractor for the reactor; Stone and Webster: Architect-engineer contractor.

Site: Rowe, Massachusetts (a rural town on the Deerfield River)
Project Life: 1956-1965 (operation started in 1961, the plant is presently producing electricity).
Primary Source of Demonstration Proposal: AEC.
Cost, Federal Share: c. $8.3 million
Cost, Local Share: $38.5 million (capital costs)
Cost-sharing with Profitmaking Firms: Yes
Target Audiences:

Potential adopters: electric utilities in high cost areas of the U.S.
Potential manufacturers: firms in reactor design and construction
Potential regulatory agency: AEC, but only to minor extent

Although the Yankee reactor was a scale up of a well-developed type of reactor, it had a number of novel features which increased the amount of uncertainty about the technology's functioning. Despite the fact that the basic reactor type was proven, the scale of Yankee was considerably beyond any power reactor ever built. Eventually contractors with experience in building reactors and solid plans were found. The contracts were drawn between Yankee Atomic and the contractors without AEC being a party.

Goals and Outcomes

The primary goals of the project were:

- to demonstrate the technical feasibility of large scale pressurized water-cooled reactors for power generation
- to discover the costs of operating such a reactor in continuous operation

After a number of minor technical problems were ironed out, the Yankee plant began an enviable history of operation. Plant availability was excellent, and the plan generated considerably more electricity than had been expected. The cost of the plant turned out lower than originally estimated, but this probably reflected high uncertainty in the original estimates. The plant's cooperative ownership became a model for future activity of the utilities involved.

Special Characteristics

1. Yankee illustrates that under special circumstances a demonstration project can succeed despite considerable technological uncertainty. This was possible because most of the other aspects of the project were not subject to much uncertainty.

2. Yankee is an excellent example of how federal intervention, even involving a small portion of the total costs, can positively affect technological innovation. Federal support tipped the balance in favor of the project.

CONNECTICUT YANKEE CIVILIAN POWER REACTOR

Encouraged by the successful operating experience of such nuclear plants as Shippingport, Dresden, and Yankee, AEC issued an invitation for proposals to build large-scale power reactors. While the invitation for Yankee in 1956 was for a reactor larger than 134 megawatts (Mwe), the invitation for proposals in 1962 was for a nuclear power plant larger than 400 Mwe. The goal was to take a proven reactor concept and demonstrate the economies of large scale reactors as reliable sources of power under base load conditions. In 1962 a consortium of the type which financed the Yankee plant (and in fact including some of the same utilities) was formed to explore the possibilities of a power reactor in Connecticut, and after AEC issued its RFP, Connecticut Yankee Atomic Power Company, the consortium, decided to respond.

Basic Information List

Federal Funding Agency: Reactor Development Division, AEC

Operating Agency: Connecticut Yankee Atomic Power Company

Other Organizations Involved: Westinghouse, prime contractor; Stone and Webster, architect-engineer contractor.

Site: Haddan Neck Connecticut, a township close to a population center at the confluence of the Connecticut and Salmon Rivers.

Project Life: 1964-1973 (operation began January, 1968; presently operating).

Primary Source of Demonstration Proposal: AEC (it is quite possible, however, that the plant would have been constructed without federal assistance).

Cost, Federal Share: c. $13.1 million ($7.1 million by waiver of fuel charges for 5 years, $6 million in design assistance).

Cost, Local Share: $103 million (capital costs of nuclear facilities)

Target Audiences:

Potential adopters: electric utilities

Potential manufacturers: commercial nuclear reactor design and construction industry

Potential regulatory agency: AEC

Although incorporating some of the lessons learned from other civilian power reactors, Connecticut Yankee was to a considerable extent an outgrowth technologically and organizationally of the Yankee demonstration. The same contracting team that had been so successful with Yankee built the plant, using the same type of reactor but at larger scale. Members of Yankee Atomic were instrumental in creating the Connecticut Yankee consortium, and Connecticut Yankee Atomic used some of the same management personnel as Yankee. Nonetheless, Connecticut Yankee did incorporate some design advances, particularly in the realm of the control system, somewhat different core design, and pump design. It should be noted, however, that advances in nuclear reactor technology of this sort would be expected with the construction of a new plant at this stage of the technology's development. The confidence with which Connecticut Yankee's expected performance was viewed is illustrated by the fact that the privately borrowed capital for the project was at 4.5 percent interest. Connecticut Yankee did encounter a problem that had not confronted Yankee to the same extent: environmental and safety concerns. Because Connecticut Yankee was close to a population center, because a shift against nuclear plants was occurring in public opinion, and because the regulation of nuclear plants was better developed, Connecticut Yankee Atomic faced a more wary environment than Yankee. The consortium made extensive plans and promises to correct any possible thermal pollution to the river

from the plant which might have cost as much as $5 million. In addition, the plant only escaped a challenge to the granting of its license because of a technicality which disqualified the protesters. The plant did generate a great deal of useful information about possible thermal pollution, but its experience with the licensing procedure cannot be generalized because of the luck involved.

Goals and Outcomes

The primary goals of Connecticut Yankee were:

- to show the economies of scale of a large scale commercial pressurized light water reactor for electric power generation
- to show the utility industry that nuclear power had arrived, both technologically and economically

Connecticut Yankee did in fact show that economies of scale existed for power reactors, which had been generally expected anyway. Today light water cooled reactors dominate the domestic field of power reactors.

Special Characteristics

As a demonstration project Connecticut Yankee raises some questions about the justification of federal intervention. The power plant would in all likelihood have been constructed without government assistance, and it is not clear that the outcomes in terms of the plant's design would have been any different. This demonstration might be justified essentially as an advertisement for a technology which already existed. In subsequent sections, we call these "exemplary demonstrations." As an element in a demonstration program, it also helped provide the production volume necessary to support manufacturers developing the capability to supply a new technology.

OPERATION BREAKTHROUGH

The civil disorders which occurred during the mid-1960s precipitated an increase in federal government concern with the problems confronting America's cities in general and urban housing markets in

particular. The Urban Development Act of 1968 was a direct outgrowth of this concern. It established the goal of producing 26 million housing units by 1978, with at least 6 million for low income families, and authorized a research and development program to investigate the use of new, mass-produced housing technologies as a means of meeting the production goal. In May 1969, George Romney, Secretary of the Department of Housing and Urban Development, announced Operation Breakthrough as the Department's response to this congressional mandate. The program was outlined as a partnership of labor, consumers, private enterprise, local, state, and federal government which would seek to provide housing for all income levels through the use of modern techniques of production, marketing, and management. The implementation of this goal would be achieved in a three-part effort, which would proceed from housing system design and selection (Phase I) to prototype construction and testing (Phase II) and, finally, to volume production (Phase III) for housing markets which would be aggregated at the same time that the production-related steps of the program were being carried forward.

Basic Information List

Federal Funding Agency: Office of Research and Technology, Department of Housing and Urban Development.

Contractors: The program involved three groups of private sector participants as contractors:

1. 22 housing systems producers (HSPs)--companies or consortia whose housing systems would be demonstrated during the program.
2. 9 prototype site planners (PSPs)--professional planning consultants which prepared the planning and design work for the 9 prototype sites.

3. 8 prototype site developers (PSDs)--general contractors at the sites for the prototype construction and demonstration.

The HSP contracts for the prototype construction were signed with the PSDs, not with HUD.

Site: The housing systems were demonstrated on 9 sites around the country.

Project Life: May 1969 - present (Some Phase III construction using Section 236 subsidy funds is still underway)

Primary Source of Demonstration Proposal: HUD

Cost for Phases I and II (design development and prototype construction):

Net federal government cost	$ 72.2 million
Financing by private and state lenders	65.4 million
Rents and sales	8.1 million
	$145.7 million

Cost Sharing with Profitmaking Firm: Yes, with HSPs

Target Audiences:

Potential adopters: state and local public housing authorities, developers and general contractors

Potential manufacturers: firms included as HSPs, building materials suppliers

Regulatory agencies: local government building code and zoning agencies, transportation regulatory agencies (Interstate Commerce Commission, American Association of State Highway Officials)

Other: labor unions, financial institutions, including state housing finance agencies.

Summary of Technology

The national housing goal set forth in the 1968 omnibus housing bill required the production of 2.6 million housing units per year. Such an annual rate of output would be significantly greater than previous peak levels of housing production and would probably be achieved only at substantial increases in cost, given that the residential construction

industry appeared to be operating at full capacity during the 1960s. The major input constraint was a predicted shortage of skilled labor. The most straightforward method for alleviating this shortage would be to move much of the craft-based, on-site construction into a factory setting in which capital and less-skilled labor could be used more intensively.

This was the type of change in residential construction technology embodied in the housing systems selected for the program. Because the producers had only three months to respond to the RFP, the systems represented basically off-the-shelf technology. Several were offshoots of housing systems already in production for the U.S. market, and three were precast concrete panel systems which had already been used extensively in Europe. Three high technology housing systems were demonstrated in Phase II: (1) a fiber reinforced resin and filler to fabricate the system's structural and decorative panels; (2) a mandrel-wrapped, fiber shell module; and (3) a totally coordinated and complete system of concrete panels, interior partitions, and exterior wall units. The systems selected included a variety of structural concepts.

An important aspect of the technology of the program (not fully anticipated at its inception) was the development of a set of evaluation procedures for the Phase II, prototype construction. Since no comprehensive set of performance requirements, criteria, and tests existed in 1970, HUD contracted with the National Bureau of Standards for their development. The result of this effort was the four-volume *Guide Criteria*, which are performance based and systems oriented with respect to the health and safety aspects of housing and which address its livability and durability, subjects of concern to mortgage lenders who are accustomed to using the Federal Housing Administration's Minimum Property Standards.

This decision could potentially increase the incentives for and feasibility of future innovation in the housing industry. However, it became an extremely costly one in terms of Breakthrough's timetable and budget because of the problems associated with interpreting and implementing the Guide Criteria. The criteria were phrased in terms of performance language and contained compliance testing which embodied new

concepts and/or professional judgments. Thus the interpretation was more complex and less uniform than conventional standards.

Goals and Outcomes

According to the RFP for the housing systems producers, the program's primary goal was

> ...the establishment of self-sustaining mechanisms for rapid volume production of marketable housing at progressively lower costs for people of all income levels, with particular emphasis on those groups and individuals which have had difficulty in obtaining satisfactory housing in the past.

The RFP also listed a number of secondary goals designed to assist in achieving the primary objective. The objectives defined a broadly based attack on the entire mechanism for producing housing services, as opposed to just the construction of the housing unit per se. Because the goals were stated in general terms, it is difficult to state precisely whether they have been accomplished.

The following intended goals were obtained:

1. Houses were built, sold, and occupied in Phases II and III in a program run reasonably on budget and on time (in terms of its global schedule). Twenty-nine hundred units are now built in the prototype, and approximately 25,000 units have been planned and are in varying stages of production.
2. The houses were displayed within communities which were integrated racially and economically. In addition these community developments embodied the "planned unit development" design concept, in which a variety of housing types are used on a single site.
3. A comprehensive set of performance-based evaluation and testing procedures have been created, some aspects of which have been incorporated into FHA's minimum property standards, although they have not been adopted by local regulatory agencies.

4. A majority of states have adopted statewide building codes, and a number of reciprocity agreements among the states have been made. The evidence that these can be attributed directly to Breakthrough is only circumstantial but nonetheless persuasive.
5. Several major companies became active in housing production for the first time, and some remain active.
6. Cooperative labor agreements were signed.
7. Transportation charges (point-to-point tariffs) for completed housing modules were reduced.
8. A few local developers were given experience with new approaches to housing. And some minority group subcontractors and workers were provided with new opportunities in the housing field.

However, a number of intended accomplishments did not occur:

1. State and local authorities have not begun to engage in significant housing market aggregation activity.
2. Savings and loan institutions have not significantly changed their involvement or interest in the financing of industrialized housing production.
3. The program did not directly stimulate significant innovation in housing production technology. The quality of Breakthrough housing was not as high as expected and the production costs of the Breakthrough systems were not appreciably lower than those for housing of comparable quality. In addition, several of the housing producers involved in the program lost money.

Special Characteristics

The configuration of outcomes for Operation Breakthrough listed above can be attributed largely to the relationship between the programs goals and its management, and the interplay between policy and program decisions. To a significant degree, the management methods determined which program goals were emphasized and subsequently achieved, rather than vice versa. This confused connection between goals and management

was confounded further by the imposition of a number of policy-level decisions which reduced the program's flexibility and thereby constrained its ability to achieve crucial institutional changes.

Breakthrough's original program design included market aggregation as a significant goal; and research on the housing industry indicates that the fragmented and fluctuating nature of housing demand is probably the primary limited factor with regard to increased construction efficiency. However, the degree to which this would actually be the focus of the program depended on the budget allocations for Phases II and III -- research versus demonstration; hard products versus institutional change. Policy concerns drove Breakthrough in the direction of Phase II, leaving Phase III (as originally planned) and the difficult institutional issues largely untouched and unresolved.

PERSONAL RAPID TRANSIT SYSTEM

Despite efforts to maintain and further develop public transit, the private automobile has continued to play an increasingly dominant role in urban transportation. It has been assumed that one of the major reasons that public transportation has fared poorly in competition with the auto, is the automobile's greater flexibility in moving people where they wish to go when the wish to go without the need for walking or extensive waiting. To meet this problem for public transport, attention has been focused on the prospects of personal rapid transit -- a system using a large number of remotely controlled small cars on an extensive grid of automated guideways. An individual could obtain a vehicle on demand at a nearby station which would take him very close to his ultimate destination. In order to demonstrate such a system the Urban Mass Transit Administration (UMTA) funded the Morgantown PRT.

Basic Information List

Federal Funding Agency: Urban Mass Transportation Administration, Department of Transportation.

Local Operating Agency: University of West Virginia.

Contractors: Boeing, Aerospace, prime contractor (development of vehicles); Bendix Development, computer-based command and control system and software; Frederick R. Harris Associates, design of guide-way.

Location of Site: Morgantown, West Virginia -- population 29,000 plus 22,000 student population.

Project Life: 1970 - continuing.

Cost, Federal Share: c. $61 million.

Cost, Local Share: $2-$3 from University, city and county mostly in land.

Cost Sharing with Profitmaking Firms: No

Cost Sharing with Non-Profit Agencies: Yes

The University of West Virginia, which had a transportation problem for connecting its three campuses in Morgantown, was interested in the possibility of employing advanced technology to solve its problem, and sought and received a grant from UMTA in 1969 to study the feasibility of PRT. This was followed by a formal request for capital funds to build a PRT.

It became quickly apparent that the cost estimates from the feasibility study were unrealistically low. After some major changes, a contract was signed and the Secretary of Transportation announced that the Morgantown PRT would be ready for public demonstration in October 1972, just before the elections. Thus, UMTA became committed to building the PRT in just two years, despite the fact that the technology was unproven, the system had not been designed, and long lead-times were necessary for the delivery of some system components.

As plans went forward, it was realized that the technology for a system with a large number of small vehicles would not possibly be ready, and so the basic concept of the system was changed from *personal* rapid transit with vehicles carrying 3 or 4 passengers, to *group* rapid transit, with vehicle capacity of 20. In addition, the length of the system and the number of stations were reduced to a bare minimum. Meanwhile, costs escalated.

The contract between UMTA and West Virginia University stipulates that if the project does not meet the University's needs, the University reserves the right to require the system to be dismantled and the site restored to its original condition. Thus, the contribution of land by the University, city and county represents a cost-sharing arrangement with little risk sharing.

PRT may or may not be a good mode of rapid public transportation. Unfortunately, the experience in Morgantown, despite the expenditure of over $60 million in federal funds, cannot settle the question.

Special Characteristics

1. Demonstrating a technology which is not sufficiently developed is nearly impossible. Components should have been tested on a test bed, before attempting to design the overall Morgantown system.

2. Political pressures, especially involving time constraints, are detrimental to demonstration success.

3. Cost sharing in the absence of risk sharing, which was the case in Morgantown, is not a good indicator for eventual success.

SOLID WASTE-TO-FUEL CONVERSION PLANT

In response to the growing problem of what to do with municipal solid waste, and in particular the loss of resources involved in current disposal practices, Congress passed the Resource Recovery Act of 1970 which gave the Environmental Protection Agency specific authorization to fund demonstrations of new technologies for resource recovery. At present, the Resource Recovery Division is demonstrating six alternative ways to recover the energy, metals and other materials now lost in solid waste, and ameliorate disposal problems. The Refuse Firing Demonstration (RFD), within which solid waste is specially prepared and then fired into a utility steam boiler in conjunction with coal, is one of these approaches.

Basic Information List

Federal Funding Agency: Energy Recovery Program, Resource Recovery Division, USEPA.

Operating Agency: Refuse Department of City of St. Louis, Missouri, in cooperation with the Union Electric Power Company.

Other Organizations Involved: The Horner-Shifrin Engineering Company designed and constructed the facility for the City and aided in the design of Union Electric's facilities.

Project Life: Feasibility study, 1968-1970, Demonstration Project: 1970-75.

Primary Source of Demonstration Proposal: Horner-Shifrin, Union Electric and the City of St. Louis, jointly developed.

Cost: Federal government $2.6 million plus $1 million for evaluations
Federal basic cost = 67 percent of project costs
Local shares: Union Electric, c. $950,000
City of St. Louis, c. $358,000
Horner-Shifrin, c. $100,000 (development costs above contract amount)

Cost-Sharing with Profitmaking Firm: Yes

Cost-Sharing with Non-Profit Agency: Yes

Target Audiences:

Potential adopters: local governments, electric utilities and others with large boilers to generate steam

Potential manufacturers: design engineering firms, especially firms in the incinerator design and construction market

Regulatory agencies: EPA air quality control

In 1970, the City of St. Louis, in conjunction with the Horner-Shifrin Company and the Union Electric Power Company, submitted a proposal to the federal government requesting funding for the demonstration of new processes to make use of municipal solid waste. This process involves the shredding of municipal refuse into particles no larger than 1-1/2 inches by means of a hammermill. The heavier particles (including most of the ferrous metal) are then extracted by means of an air classifier (amounting, essentially, to a giant vacuum cleaner which sucks up the lighter particles). This lighter portion (about 80 percent by weight)

is then transported by truck to the Union Electric Company, a privately owned utility which supplies electricity to eastern Missouri and nearby counties of Illinois, where the refuse is burned in conjunction with coal in a utilities boiler that has been slightly modified for that purpose. In terms of heat value, the refuse substitutes for from 10 to 15 percent of the coal in the boiler. The project was beset by a number of technical problems, but all of them were relatively minor and most had actually been anticipated by the planners of the demonstration. Technical problems were greatly reduced by the fact that all of the major components of the project were off-the-shelf and the integration required no major modifications of components. The technology was deliberately kept very simple.

Goals and Outcomes

The primary goals of the RFD were:

1. to demonstrate the technical feasibility of burning solid waste in conjunction with coal as a valuable fuel;

2. to supply information about what the costs of building and operating such a solid waste disposal system would be;

3. to discover what the effect of burning solid waste fuel in conjunction with coal would be on the level of air pollutants emitted by boilers.

These primary goals were met successfully and the resulting information was all positive from the point of view of the technology's use.

The primary and most significant outcome of the RFD has been rapid and substantial diffusion of the technology. Given the RFD's role in the original development of the technology, all of the subsequent diffusion is to be directly traced to the demonstration project.

Special Characteristics

1. The EPA made use of what we call "targeted evaluations," i.e., evaluations conducted during the course of the demonstration project aimed at particular aspects of the project. Evaluations were conducted on a major technical component of the system, a market study, system design, and air pollution. These evaluations, conducted by nongovernmental research firms not involves in the demonstration, aided in the

production of information from the demonstration and the subsequent dissemination and diffusion of the innovation.

2. The RFD was planned with the aid of a feasibility study conducted by those who would subsequently operate the demonstration. This appears to have been a highly effective planning device.

HYDRAULIC KNEE PROSTHETIC DEVICE

Stimulated by news accounts of artificial knee prostheses which buckled on their wearers, the Veterans Administration, in cooperation with other federal agencies and the Committee on Prosthetics Research and Development of the National Academy of Sciences, initiated a program to develop a hydraulic knee mechanism in the immediate post-World War II era. Three private firms, under differing contractual arrangements with the government, developed four marketable hydraulic knee models. Each model was tested by the Veterans Administration in a clinical application study designed to indicate functioning under conditions of actual use, user acceptability, and acceptability to the professional prosthetics community.

Basic Information List

Federal Funding Agency: Veterans Administration, Prosthetic and Sensory Air Service, Research and Development Division.

Operating Agency: VA Clinic Teams and participating commercial limb shops.

Other Organizations Involved: National Academy of Sciences-National Research Council's Committee on Prosthetics Research and Development; Mauch Laboratories, Inc., Dayton, Ohio; U.S. Manufacturing Co., Glendale, Ca.; Dupaco, Inc., Arcadia, Ca.

Project Life: Clinical application studies (demonstration) Hydra-Cadence, 1959-62, Dupaco "Hermes," 1963-65, Henschke-Mauch Model B., 1963-64, and Henschke-Mauch S-N-S, 1966-68.

Primary Source of Demonstration Proposal: VA, as part of institutional routine; VA, NRC/CPED, manufacturer in regard to timing of study.

Cost: Veterans Administration: three (3) clinical application studies, approximately $75-$90 thousand total.

Cost Sharing with Manufacturing Firms: None

Cost Sharing with Commercial Limb Shops: Participating limb shops agreed to charge lower price for fitting and alignment in return for exemption from education requirement as a condition of providing devices to eligible veteran amputees.

Target Audiences:

Potential users: veteran above-knee amputees eligible for VA benefits; non-veteran above-knee amputees.

Potential prescribers and providers: VA prosthetic clinic teams and prosthetists associated with commercial limb shops.

Beginning in 1959 and continuing through 1968, the Veterans Administration ran three clinical application studies on four hydraulic fluid-control artificial knee prostheses. Hydraulic knee devices had been developed over the prior decade and a half, introducing improvements over mechanical artifical knee prostheses, both with regard to stance phase and swing phase control. Results of each clinical application study led to a recommendation that the device be accepted by the VA "on contract." This recommendation was favorably acted upon in each instance, thus permitting VA physicians to prescribe and certified prosthetists to provide the particular device to eligible veteran beneficiaries of the VA. Technical uncertainties associated with these devices had essentially been worked out in the development phase.

Goals and Outcomes

The primary goals of the clinical application studies were:

1. To determine the reliability and maintenance costs of the hydraulic knee devices under conditions of actual use.

2. To determine acceptability of hydraulic vs. conventional mechanical artificial knee prostheses by above-knee amputees.

3. To ascertain and favorably influence the attitudes of the professional prosthetics community, both in VA clinic facilities and in commercial limb shops, toward hydraulic knee mechanisms.

These goals were met and the results led to a favorable "on contract" decision by the VA for each of the four devices. Hydraulic knee protheses are increasingly being utilized by above-knee amputees.

Special Characteristics

1. The "demonstration" effort of the VA clinical application studies constitutes an integral component of an overall VA prosthetics R&D program, which is actually part of a research-to-utilization strategy embedded in a technology delivery system.

2. Within the larger prosthetics TDS, uncertainty reduction is allocated across a number of different activities, thus relieving the "demonstration" program of the major burden for this task in any given dimension.

COAL GASIFICATION PROGRAM

Supplies of natural gas and petroleum are not only becoming expensive, but within a relatively short period of time may become simply unattainable. Coal, however, is in abundant long term supply in the United States. For this reason the Energy Research and Development Administration (ERDA) is placing increased emphasis on developing and ultimately demonstrating technologies for producing high quality fuels from coal.

Federal support of research on synthetic fuels processes dates back to the late 1940s, but the economics of coal conversion relative to reliance on natural gas slowed the effort. However, the oil embargo and oil price increases have been instrumental in prompting an eight-fold increase in appropriations for the Coal Conversion Division (CCD) of ERDA between 1973 and 1975.

The goals of future efforts are to find synthetic fuels technology that will decrease the cost of production by at least 10 percent over current commercial technologies. An important part of this program will be the large-scale demonstration of promising gas processes and development of a completely new industrial capacity for gasification production. At present CCD is funding, wholly or in part, research on ten different technologies.

The CCD program has not yet reached a point where demonstrations of a process are possible; the uncertainities surrounding the technologies are such that more development work is needed. Nonetheless, the coal gasification program offers a number of insights into demonstration programs in the early phases when crucial decisions must be made.

- Should the demonstration facilities be constructed at "semi-works" or "full-scale"?
- What cost-sharing policy should be followed for gasification demonstrations?
- The staff of CCD is highly technical, and as is the case with technical staffs involved in several other cases we have studied, is having some difficulty planning toward commercialization.
- Given that there are a number of technological alternatives, which should be chosen for demonstration?
- The CCD program raises a number of interesting questions dealing with how a new industry, and new forms of industry partnerships, can be created with the aid of the federal government. At this point it is not clear how important tasks will be accomplished, nor what the proper role of demonstrations in this process might be.

Despite the fact that the synthetic fuels study cannot be used to support or refute hypotheses, it has been very useful to examine a demonstration program in its pre-demonstration phase as a source of insights into the actual problems of early planning. As we suggest later in this report, the preliminary planning for a demonstration may be the most crucial stage of the process.

APPENDIX C

PERSONAL INTERVIEW METHODOLOGY FOR SOLICITING INDUSTRY EXPERIENCE IN PROGRAM PLANNING

G. C. Sponsler, President

International Planning Management Corporation

PERSONAL INTERVIEW METHODOLOGY FOR SOLICITING INDUSTRY EXPERIENCE IN PROGRAM PLANNING

by

George C. Sponsler, President
International Planning Management Corporation

This paper reviews the methodology of in-depth personal interviews designed to elicit information from industry representatives to guide ERDA in planning its future commercial demonstration programs.

ERDA's long-range plan lists 116 demonstration projects with the primary objective of promoting the commercial application of ERDA-sponsored research and development.[1] Approximately half of those demonstration projects will be initiated within the next five years. Those demonstration programs constitute the primary mechanism through which ERDA plans to introduce its research and development into the commercial marketplace.

Since the purpose of these demonstration projects is to encourage industry to commercialize ERDA-sponsored R&D, their objective must be to demonstrate probable commercial success. Demonstration projects in the past have been employed primarily as a means of confirming technical feasibility on a commercial scale. But more is required of future demonstration projects; they must be undertaken in a manner simulating as closely as possible the ultimate commercial environment in which the technology will be used. The demonstration projects therefore must concern themselves with a wide variety of non-technical uncertainties, including costs, market demand, capital availability, public acceptance, and regulatory compatibility.

ERDA has been charged by Congress to evaluate twelve primary

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[1] Creating Choices for the Future, Vol. 2, "Program Implementation," Energy Research and Development Administration, Report 48, 1975.

aspects of its proposed commercial demonstration projects. It will be seen from Chart 1 that only one of those dozen concerns is technical; the others illustrate the interdisciplinary requirements demanded for successful planning of commercial demonstration projects. With few exceptions, it is very difficult to define quantitative measures of effectiveness for these twelve evaluation responsibilities. They are for the most part non-quantifiable by nature--demanding expert, often subjective judgment for their evaluation.

For this reason, it is difficult to apply the more conventional econometric modeling approach in demonstration program planning. The econometric model transfer function, so to speak, is difficult, in many instances impossible to define. (One promising exception is Kane's cross-impact approach, but even that often requires subjective estimates for the interaction matrix elements.[2]) The personal interview methodology, on the other hand, collects and analyzes the judgments of the very industry executives who will be concerned with the actual commercialization process. Such judgments are in essence the output of a ready-made model of the future commercialization process, as it exists in the minds of the interviewees. If the right people are properly chosen for the personal interview, a "natural" model is realized which includes knowledgeable judgments or estimates of missing facts that would either stop the conventional econometric modeler, or force him to use his own (probably less informed) judgment.

The personal interview approach can also, by collecting data for the models (for example, estimates of the Kane impact matrix elements), complement the econometric modeling approach.

Another approach to collecting industry experience is to hold public

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[2] Julius Kane, "A Primer for a New Cross-Impact Language--KSIM," Technological Forecasting and Social Change, Vol. 4, 1972, pp. 129-142.

ERDA EVALUATION RESPONSIBILITIES FOR DEMONSTRATION PROJECTS*

- Program Objectives Identified/Achieved?
- Economic, Environmental and Societal Significance?
- Urgency of Public Need?
- Private Investment Recapture Opportunities?
- Widespread Significance?
- Non-Federal Duplication?
- Technical Risk?
- Magnitude Precludes Private Investment?
- Availability of Non-Federal Participants?
- Total Cost?
- Private/Federal Joint Endeavors?
- Program Management?

*Public Law 93-438, October 11, 1974

hearings--Congressional investigations, for example. A disadvantage of this approach is that the industry representatives must all appear during a relatively brief and often inconvenient period and, more importantly, they cannot be offered the anonymity necessary to assure forthright responses. In contrast, the personal interview technique offers the advantage of scheduling individual meetings at industry convenience and with anonymity. The interview responses are aggregated over all interviews, and so reported. Thus, in a sense, the personal interview methodology is the "inverse" of the hearings approach.

The personal interview approach is also complementary to the Congressional hearings, in the sense that it can also gather background information to guide subsequent open hearings.

The in-depth personal interview methodology is also superior to mail surveys in that information can be obtained that was not anticipated in preparing the survey questionnaire. Such information usually cannot be elicited in the detail desired with open answer types of written questions.

When a government agency decides to adopt the personal interview approach, an important preliminary question must first be answered: Should the interviewers be agency personnel, or private individuals serving under contract? Government agencies are beginning to appreciate the need for confidential, independent assistance by non-government interviewers in order to obtain the benefits offered by anonymous responses. Such anonymity can obviously not be granted by using government interviewers. When the sponsoring government agency promises the interviewees anonymity, more candid and forthcoming information will be gained. This role of an "honest broker" of information is becoming increasingly valuable as an intermediary between government and industry, particularly in the analysis and evaluation of alternative government policies by private industry.

INTERVIEW PHILOSOPHY

- Retrospective and Prospective
- Aggregate Responses
- Small Sample Truly Representative?
- Prediction Reliable?
- Confidentiality/Anonymity/"Honest Broker"
- "Inverse" of Congressional Hearings
- Statistical Analysis
- Probability Analysis

Four assumptions are inherent in the personal interview methodology.

First, it is assumed that the interviewees will be candid and forthcoming. That frankness can best (and perhaps only) be gained in an atmosphere of confidentiality, with anonymity assured by the government. A letter from the pertinent federal administrator assuring the respondents of the confidential nature of the interview and of personal and corporate anonymity is useful in this regard.

The second assumption is that a relatively small number of selected company interviews is indeed representative of total industry opinion. Experience with the personal interview methodology lends credence to this assumption; the chief executives of a particular company are necessarily familiar with all major aspects of their industry, and demonstrate surprising similarity of understanding and insight. In many cases a particular industry (such as the oil industry) is dominated by a few large companies, in which case a small number of well chosen interviews will accurately reflect the entire industry view. In other cases, the actual interviews must be carefully selected--using industry leaders, for example--to assure that the results truly reflect the opinions of the wider industry membership.

The third assumption is that the interviews will not be unduly clouded by superficial institutional or personal prejudices. Biases of either nature are generally apparent to the interviewer and to the interview analyst. The interviewer must be heedful of this possibility, and identify any such bias in his notes where appropriate. An admonition to minimize such biases should also be incorporated in the introductory background material provided prior to the meeting.

The final assumption on which the personal interview methodology rests is that the respondents and their organizations will in fact do what they anticipate or say they will do; that is, their predictions will be reliable.

Responses must not be superficial; the need for serious judgment is implied in the protocol and reflected in the interview. Confidentiality and anonymity again lend credence to the validity of the anticipated actions. (Should a government program eventuate, statistical longitudinal studies can be conducted to compare the predicted and actual actions. Interview experience indicates that corporate positions will likely eventuate as predicted, provided the environment at the latter time is compatible with the implicit assumptions upon which the company positions were based during the interviews.)

The personal interview methodology is most useful in program evaluation. There are two types of program evaluation: prospective and retrospective. Application of the personal interview methodology in planning commercial demonstration programs is necessarily predictive evaluation. In common usage the term "evaluation" is implicitly assumed to refer to completed programs or projects; yet the government is increasingly being called upon to evaluate planned projects. This paper is concerned only with prospective or predictive evaluations.

Insofar as predictive evaluations are concerned, there are again two kinds which are essential in planning demonstration projects. In the first instance, personal interviews with company executives may be employed to determine industry plans in the absence of government initiatives; in the second, interviews are designed to ascertain probable industry reactions to possible or presumptive federal actions.

As examples of the first kind of prospective interview results, Charts 2 and 3 have been reproduced from an IPMC report for the National Science Foundation.[3] Chart 2 shows the expected number of synfuel demonstration plants (as of August 1974) of four different tech-

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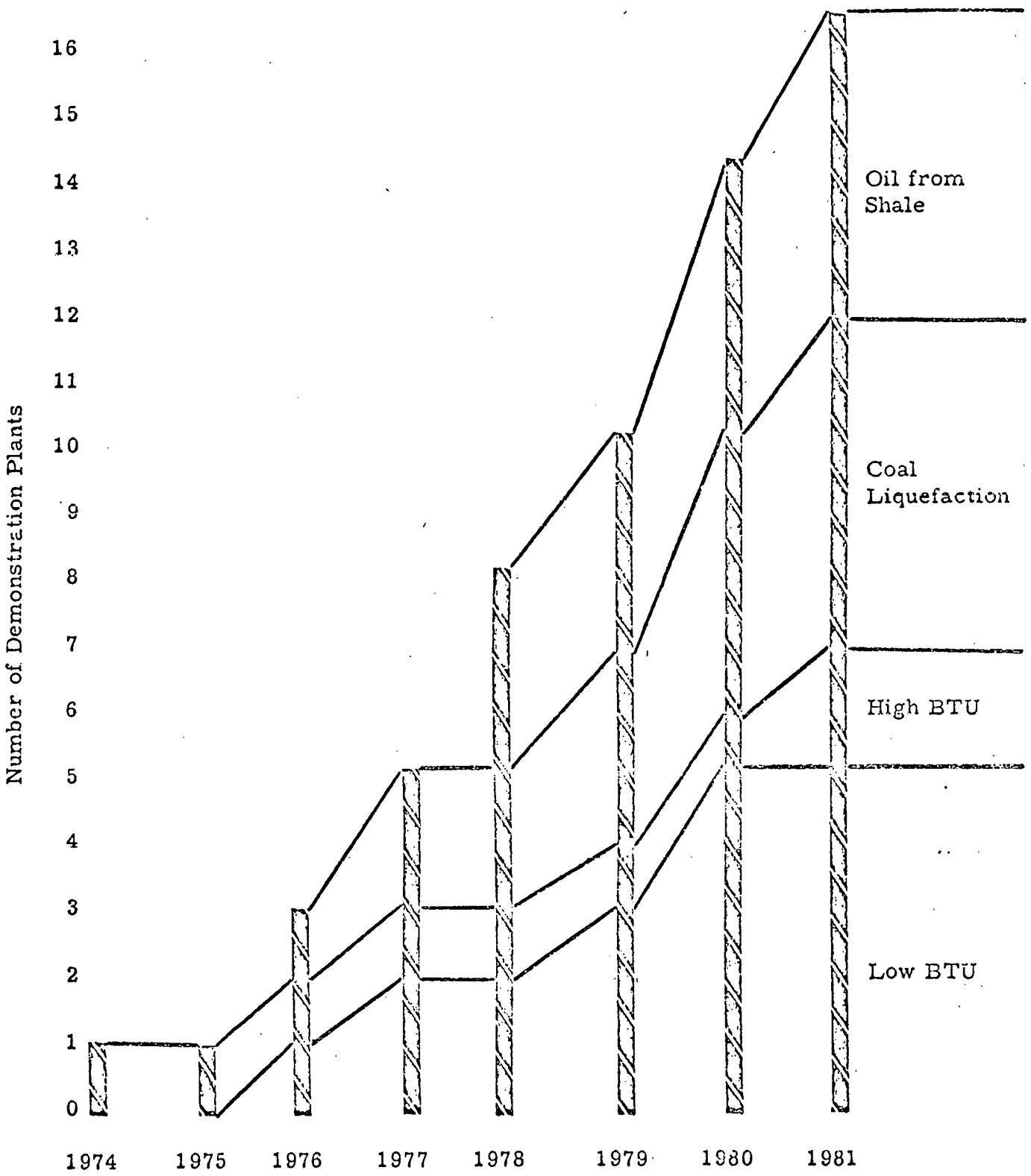
[3] "Synthetic Fuels Incentives Study," Contract C-856, November 13, 1974.



Expected Number of Synthetic Fuel Demonstration Plants, 1974-81
(Based on Four Implicit Assumptions)

(Source: "Synthetic Fuels Incentives Study," National Science Foundation Contract C-856, November 13, 1974.)

nologies anticipated by industry, ostensibly in the absence of government incentives. Chart 3 shows the most optimistic schedule of pilot, demonstration, first commercial, and subsequent commercial scale plants, for the same four technologies, planned in 1974 by a variety of companies, again in the presumed absence of federal incentives.

This information was actually based on four implicit industry assumptions; that is, the government would: (1) not institute price controls on synthetic crude or gas, (2) act to expedite processing of environmental impact statements, (3) make available the necessary federal coal and oil shale lands, and (4) adopt an effective anti-inflation program. The existence of these four implicit assumptions illustrates an important caveat for personal interviews: they must be conducted in such a way as to uncover such implicit factors which may not even be recognized as such by the interviewees themselves. In the case in point, when the interviewees were advised to ignore these four implicit assumptions after they were identified, the result was to introduce delays of from one to five years in projects already begun, and to postpone indefinitely others not yet initiated. Actual subsequent experience substantiates these corrected predictions.

Chart 4 illustrates the second kind of prospective program evaluation. These interviews, undertaken by IPMC on behalf of FEA,[4] were designed to determine probable industry reaction to a set of proposed federal incentives designed to accelerate the commercial introduction of the same four synthetic fuel technologies considered in the earlier NSF study.

It will be seen from Chart 4 that the most popular federal incentive was the loan guarantee. But once again, in light of subsequent

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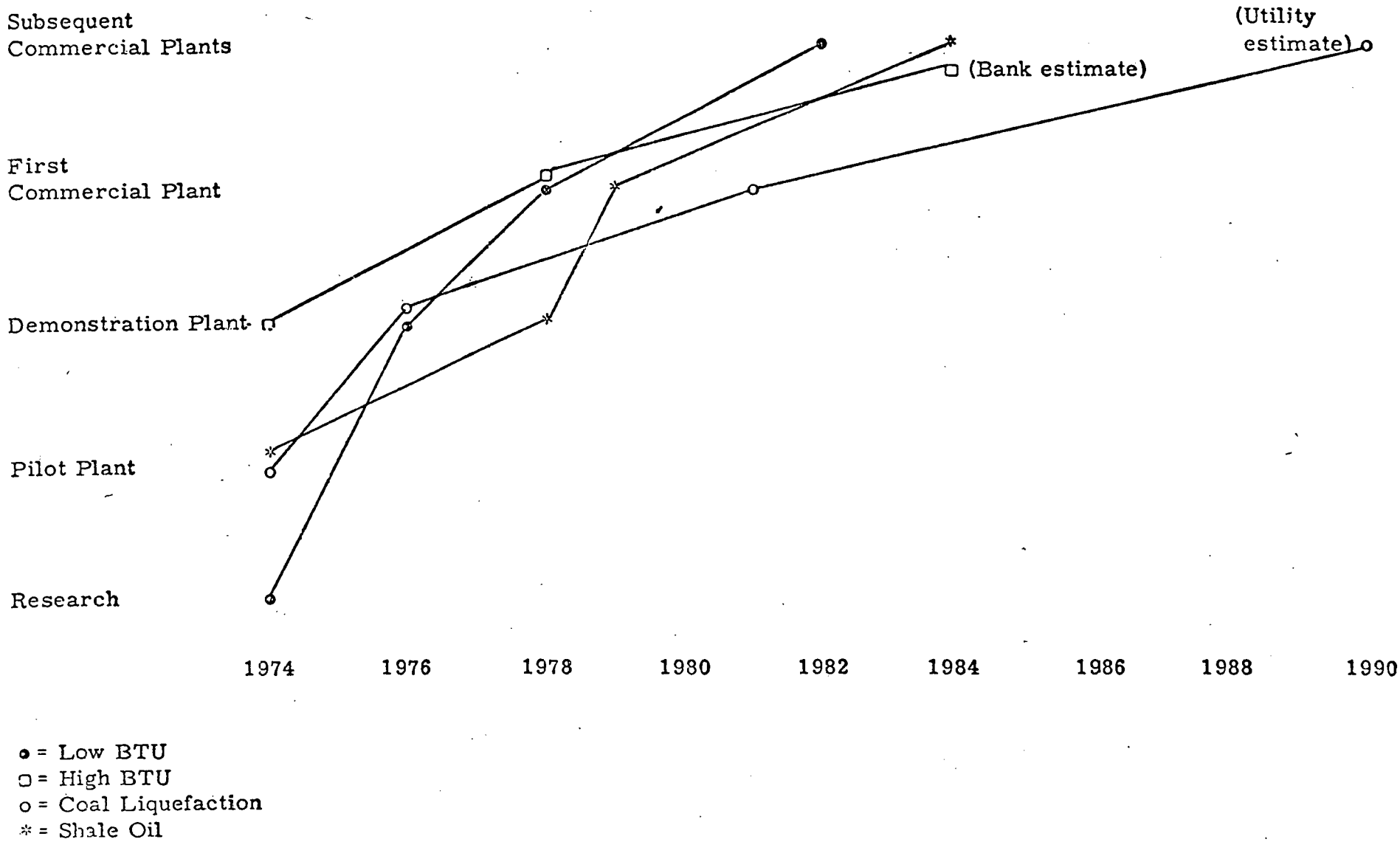
[4]"Incentives for Synthetic Fuels," Contract CO-05-50216-00, July 31, 1975.



Most Optimistic Schedules of Synthetic Fuel Programs
(Based on Four Implicit Assumptions)

(Source: "Synthetic Fuels Incentives Study," National Science Foundation Contract C-856, November 13, 1974.)

OVERALL PREFERENCE RANKING+

Rank	Incentive Number and Title	"For" Minus "Against" (Net)*	+/0/-*
**1	4 - Loan Guarantee	+4	(9/2/5)
2#	3 - Convertible Grant	+2	(8/2/6)
**3#	6 - Guaranteed Purchase/CPFF	+2	(8/2/6)
4	7b - Guaranteed Price with Loan Guarantee	-1	(4/7/5)
5	1 - Direct Grant (2/3—1/3) for Pilot Plant	-3	(5/3/8)
6	7a - Guaranteed Price	-4	(2/8/6)
7	2 - Direct Grant (1/2--1/2) for Demonstration Plant	-5	(4/3/9)
8	7d - Guaranteed Price (Alternative with Loan Guarantee)	-5	(1/9/6)
9	7c - Guaranteed Price (Alternative)	-6	(1/8/7)
10	5 - Guaranteed Purchase/Fixed Price	-8	(3/2/11)
11	8b - Limited Price Guarantee/Advance Payments	-8	(1/6/9)
12#	8a - Limited Price and Loan Guarantee	-9	(0/7/9)
13#	9 - Sale of Options/Guaranteed Price	-9	(0/7/9)

+Source: Incentives for Synthetic Fuels, FEA Contract CO-05-50216-00, July 31, 1975.

*Weights: For = +1, Undecided or No Opinion = 0, Against = -1.

**Most companies favored a combination of these two incentives.

#Tied Ranking

NOTE: Not ranked, but supported positively by all but one company: 100 percent government financing a la World War II synthetic rubber program. Not ranked, but suggested positively by several companies: 100 percent government risk insurance.

history, an interesting discovery was made. All but one of the industry interviewees stated emphatically that a minimum 90 percent loan guarantee was necessary to gain their participation in the federal synthetic fuel program. One comparatively small entrepreneurial corporation said they would accept a 75 percent guarantee. The government program adopted the 75 percent level despite our repeated warnings that the lower level was unsatisfactory with the overwhelming majority of companies interviewed. Since promulgation of the federal program it has been discovered that the 75 percent level is in fact unpopular. The lesson is that candid industry advice may not be believed if it conflicts with government preconceptions.

The application of the personal interview methodology to assist in planning commercial demonstrations is based on the presumption that one of the best sources of planning information is the individuals potentially involved in the programs. The identification of those institutions in turn demands the definition of a so-called technology delivery system,[5] relating R&D performers, product development companies, architect and engineer firms, construction companies, investment organizations, utilities, local governments, state and federal regulators, and markets. This identification requires some imagination; the personal interview methodology can be of help in this process by identifying unsuspected TDS members and by delineating institutional inter-relationships.

This identification is facilitated by the unstructured nature of the interviews. The interviews are unstructured in the sense that the discussions are allowed to follow their natural course under the guidance of the interviewer, who nevertheless assures that the desired information specified by the interview protocol is attained at some point during

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[5] Committee on Public Engineering Policy, "Priorities for Research Applicable to National Needs," Washington, D.C.: National Academy of Engineering, 1973.

the conversation. This unstructured approach can uncover valuable information which was not anticipated in preparing the protocol, as well as facilitating a friendly and informal interview, more conducive to the disclosure of both desired and unanticipated information.

The unstructured approach is particularly appropriate in planning ERDA's commercialization demonstration programs, since a major objective is to identify obscure but important information that may not have been considered in the original planning process. Furthermore, the interview methodology helps in identifying and reaching the most knowledgeable people for assistance in planning the demonstration programs.

Under the terms of Public Law 831, prior approval of a written survey must be obtained from the Office of Management and Budget when ten or more persons are to be interviewed for any study conducted or sponsored by a federal agency. To avoid complications, investigators therefore may decide to interview a maximum of nine representative companies in a particular industry. Or somewhat different information may be collected from interviews with sets of up to nine representatives in different industries. In any event, the unstructured nature of the personal interviews aids compliance with the OMB directive, which relates particularly to the completion of written questionnaires.

In designing the interview protocol, particular care must be taken to assure that the meaning of the questions is clear and consistent, and that the premise on which a particular answer is based is understood, consistent between interviews, and consistent with the intent of the question.

The personal interview methodology demands knowledgeable and capable interviewers. They must be thoroughly familiar with all aspects of the programs under discussion; they must withhold personal judgments and resist the temptation to lead the discussion; rather, they must guide the discussion to assure that the desired information is developed without

prejudicing that information. The knowledge, tact and sensitivity required normally can only be developed through years of experience. This professional seniority is also needed to gain entree to the chief executives, who would generally be unwilling to enter into lengthy, detailed conversations with interviewers who are not in some sense their professional, if not organizational, peers. The interviewers must therefore be mature, objective, and intelligent, pleasant but noncommital, poised, and intimately familiar with the subject under discussion. Most importantly, they must have the ability to keep the conversation productive.

There are two ways to prevent interviewer bias. The first is to employ two interviewers, each of whom independently prepares an interview report. Those reports are subsequently compared and any differences resolved by the two interviewers. The second technique is to recycle the interview report to the interviewees, permitting them to modify, extend or correct the interviewer's understanding of their remarks, and assuring them that the information has been thoroughly and accurately reported.

It is also useful and courteous to send a copy of the draft final report to the interviewees. This practice not only assures the interviewees that their anonymity has been preserved but also offers them a final opportunity to modify their positions, if they so desire.

The analysis of the aggregated interviews should identify common views held by the various executives interviewed. It is incumbent upon the analyst to construct positions that recognize and reflect the positions of the aggregated interviews, a particularly difficult task with unstructured in-depth interviews. This identification of trends and common opinions is perhaps the most important output of the personal interview methodology, one requiring painstaking analysis.

A second objective of the aggregate analysis is to identify important

unique opinions to be included in the final report (without, of course, identifying the particular interviewee by name or institution, unless prior permission was given in writing).

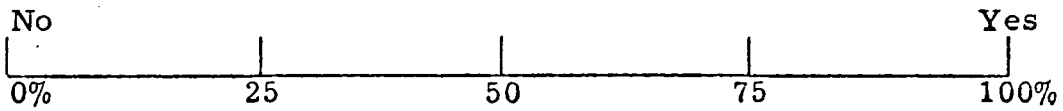
Internal consistency of the interview responses must also be checked: in particular, solutions proposed by the interviewees should be compared with the problems to which they are directed to assure their consistency.

An analytical method of particular interest involves interviewee estimates of the subjective probability with which they would undertake a certain action. In such cases, it has been IPMC's practice to ask the interviewee to note his probability on a scale (such as that shown on Chart 5). It is then possible to combine the probabilities (in the particular illustration, for the effect of combined federal incentives) in response to hypothetical policy combinations. Probability scales are controversial; their least controversial aspect is to assist in the relative evaluation of different future actions. Thus, it may not be that aggregates of institutions or persons will in fact demonstrate a 75 per cent probable reaction to some policy alternative, but certainly one could compare alternative policies, noting that one resulting in an average 75 percent action probability is superior to one rated at an average 25 percent. But the probability scales may also be interpreted absolutely. For example, a particular application of the probability combination formulae of Chart 5 has shown that the projected effect of combined incentives was in fact reflected in actual Army reserve enlistments and re-enlistments. This is the more controversial aspect of subjective probability evaluation; one can dispute the predictive accuracy of such subjective probability estimates, but the relative value of predicted policy combinations, using such formulae, are less controversial and are of genuine value to planners.

Probably the most useful personal interview analytical technique

SUBJECTIVE PROBABILITIES

Scale:



Incentive-Combination Probability:

$$p_o + (1 - p_o)\left[1 - \prod_{i=1}^{n}\left(\frac{1 - p_i}{1 - p_o}\right)\right]$$

where p_o = probability with no incentives

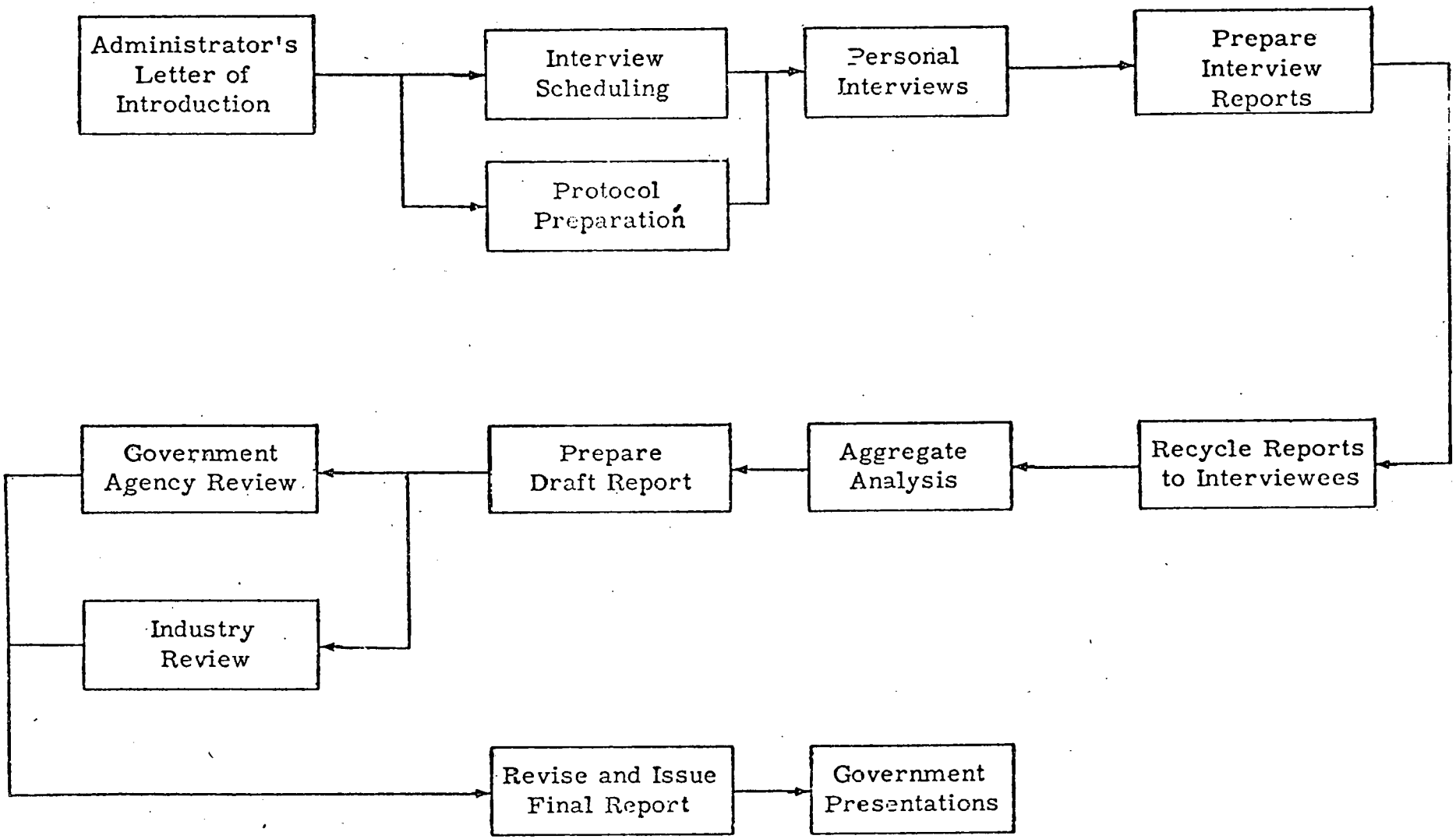
p_i = probability with i^{th} incentive

is simply reasoned or logical argument. Most of the information collected in unstructured in-depth interviews is not quantitative. It is incumbent upon the interviewer and analyst, therefore, to draw appropriate conclusions and recommendations and to support those positions with rational arguments that rely upon and derive from the interview results. Reasoned argument is perhaps the most common form of analysis employed in the personal interview methodology.

The steps to be taken in the personal interview methodology are illustrated on Chart 6.

The first step is a letter of introduction from the chief administrator of the sponsoring government agency to the chief executive officers of the industrial concerns to be interviewed. This introductory letter sets forth the reason for the intended interview; requests the cooperation of the company addressed; and assures that company of the federal agency's commitment to the interviewer that individual responses will remain anonymous, that the interview will be held in conditions of confidentiality, and that the only information provided the federal agency (unless otherwise authorized by the individual company) will be in aggregate form and reported anonymously.

After the letter of introduction has been received and sufficient time has elapsed for its distribution within the company, the interviewer telephones the chief executive (as he should have been advised by the introductory letter to expect) to arrange the time and place for the interview. A personal telephone call rather than a letter is preferable for this follow-up, since possible industry questions can be discussed and answered immediately. The interviewer will advise the company official that a letter will be mailed outlining the details of the proposed interview, the topics to be discussed, and providing the necessary background information or so-called interview protocol. (In cases where possible future federal policies are under consideration, that information may be exten-



Personal Interview Methodology Procedures

sive, and sufficient time must be allowed after receipt to prepare a detailed response prior to the meeting.)

The interview itself is typically 2-1/2 hours in duration, is held at the executive offices of the corporation concerned, and involves a selection of the top executives of the corporation (assuming a group interview is desired rather than individual executive opinions[6]). It is most desirable that the chief executive himself be present in a group interview, as experience has shown that many executives are reticent to express corporate positions in his absence. It is also important that all appropriate industry executives participate (for example, the financial vice president, the director of research, the executive vice president in charge of operations, and so forth). The meeting should not be too large, however, since it should be undertaken in an informal and unstructured fashion. The interviews are in a sense led by the interviewer, who introduces appropriate topics, but his objective is only to assure that the necessary information is gained at some point during the interview; most of the talking should, of course, be left to the interviewees. In some instances the interviewer may be asked to explain proposed federal policies; in such cases he will report his understanding of the government's position (which should have been discussed previously with federal officials in preparation for the interviews), but emphasize that it is only his own understanding of those policies.

Generally the interviewer takes written notes in full view of the interviewees. Electronic recording is not recommended since interviewees are frequently less frank if their remarks are so recorded. The interview should also be prefaced by an assurance that the inter-

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[6] An additional benefit can be gained if the respondents are interviewed individually rather than as a group. Such individual interviews can "protect" the executives from their own institution, and should be used when personal rather than institutional responses are desired.

viewer's trip report will be recycled to the interviewees for their review, modification and approval prior to analysis in preparation for the final report.

The interviewer should prepare a trip report as soon as possible following the interview to assure that the details are fresh. When completed, this report is returned to the interviewee, who is encouraged to make whatever changes he desires, with complete freedom to modify or extend any of the reported data. He should also be assured that the resulting report will be held confidentially in the interviewer's files, and not be made available to the government without prior written consent.

The final report itself primarily reflects the analysis of the aggregated trip reports. The analyst must identify common views of the interviewees, reflecting their positions in appropriately chosen words and supporting those positions with anonymous quotes where possible. (A section of broad, selected excerpts from the trip reports--edited to remove identification--should be incorporated in an appendix supporting the analysis.) Analysis of the individual trip reports is the most demanding and perhaps most important aspect of the entire personal interview methodology. Its objective is to reflect clearly, accurately and completely industry reaction to government questions, as well as related industry advice and comments. Conclusions and recommendations clearly based upon identified industry positions should be drawn to assist the government in its own policy analysis and decisions.

In order that the final report will indeed be of value to the government, the sponsoring federal agency is given a review copy of the final draft from which they may suggest areas where additional information is desired (if available), request further argument, or make other corresponding changes. Such additional information may be gained by follow-up telephone calls to the interviewees, or the analysis may be appropriately extended using other information.

By prefacing its demonstration program planning with selected personal interviews of industry personnel potentially involved in the subsequent commercial technology utilization, ERDA can assure itself a more successful demonstration program. Personal interviews thus offer an excellent methodology to assist in planning ERDA's future commercialization demonstration programs.

APPENDIX D

MANAGEMENT ISSUES IN

SELECTED DEMONSTRATION PROGRAMS

Final Report

Energy Research and Development Administration
Purchase Order No. WA-76-3775

by

George C. Sponsler, President
International Planning Management Corporation
7910 Woodmont Avenue, Suite 1103
Bethesda, Maryland 20014

May 11, 1976

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MANAGEMENT ISSUES IN SELECTED DEMONSTRATION PROGRAMS

by

George C. Sponsler, President
International Planning Management Corporation

I. EXECUTIVE SUMMARY

A. Introduction

This report presents the results of a series of personal interviews with six selected companies involved in four ERDA-sponsored demonstration programs: Coalcon, the Clinch River breeder reactor plant, solar heating and cooling of buildings, and an automobile gasoline turbine. The purpose of the interviews, undertaken under ERDA Purchase Order No. WA-76-3775, was to assist the ERDA Task Force on Demonstration Projects as a Commercialization Incentive in their study of the circumstances under which an ERDA demonstration project should be undertaken, and, when it is, how it should be designed and administered so as to be most productive in "resolving technical, economic and social undertainties." In order to better understand the problem and correspondingly to advise the ERDA Administrator, the Task Force commissioned the interviews reported here to gain detailed information on the selected four demonstration projects to complement their own hearings and deliberations.

Study Objectives

As the term is employed by the ERDA Task Force, a "demonstration project" is defined to involve the operation of a complete energy system in the expected commercial environment for the purpose of resolving the associated technical, economic and social uncertainties. The objective of the ERDA demonstration program is to encourage the early commercial adoption by the private sector of energy technology developed under ERDA auspices. Thus, ERDA's responsibilities are quite different from those of the other major government technical agencies, for example, DOD and NASA, in that ERDA is not its own customer; rather, ERDA must in a sense become a promoter of technology which will be developed under government auspices, but which will be implemented by private industry in the commercial marketplace.

ERDA's problem is thus one of technology transfer. And the purpose of these interviews was to facilitate the transfer, or commercialization, as it has come to be known, of new energy technology by collecting information and advice from experienced contractors who are currently involved in selected ERDA demonstration programs. Since ERDA is developing R&D for industrial commercialization, ERDA must become increasingly cost conscious; and so their basic problem might better be defined as cost-effective technology transfer.

ERDA plans some 116 demonstration programs. The particular four selected for these interviews were chosen by ERDA executives as representative of the larger number.

Four Technologies

By way of brief description for those who may not be familiar with the four selected demonstration programs, Coalcon is a $237 million demonstration plant in Illinois near the St. Clair County town of New Athens. The plant's basic function will be to produce synthetic gas and oil from coal mined in Illinois. Coalcon Company, the prime contractor, is a subsidiary of Union Carbide and Chemical Construction Corporation. The state of Illinois will provide $25 million in Illinois coal development bond funds to furnish the remainder of the needed investment.

The Clinch River breeder reactor plant, located, as the name suggests, on the Clinch River at a site provided by the Tennessee Valley Authority in the state of Tennessee, is to demonstrate the feasibility of the liquid-metal fast-breeder reactor (LMFBR). The Clinch River project has been subject to a variety of delays and other problems which have resulted in a cost growth reflected by the prime contractor's (Westinghouse') present estimate of a total investment of $1.5 billion. The breeder reactor concept reflects an Administration decision under which major reliance is placed upon the nuclear breeder to gain the nation a degree of energy independence in the latter 1980s.

Solar energy for the heating and cooling of buildings is a major long-term goal of both ERDA and the nation. Unlike Coalcon and the LMFBR, the successful commercial introduction of solar heating and cooling units must necessarily involve the efforts of a wide variety of

primarily small businesses, in contrast with the huge capital investment by a few large businesses in the case of Coalcon and LMFBR type projects. Although advanced technology, particularly in the form of solid-state solar photovoltaic cells, plays a role in the solar heating and cooling of buildings, the associated technology primarily is relatively simple, involving the collection of incident solar energy upon blackened metal plates, which transfer the absorbed heat energy to a circulating cooling fluid.

Finally, the gasoline-fired automobile turbine engine, currently under development by the Chrysler Corporation under contract with ERDA, is representative of demonstration projects designed to conserve energy. In this case, it is believed that after development the gasoline turbine should prove more efficient in the use of gasoline than more conventional internal combustion engines. There might also be weight savings which would in turn be reflected in reduced automobile gasoline consumption.

Policy Considerations

DOD and NASA offer precedents where research and development have been particularly effective in solving national problems. But it must always be borne in mind that those agencies are their own customers. Commercialization is a different matter; ERDA is developing new technology for industry use. Because of the DOD/NASA precedent, Congress has come to believe that massive R&D is the solution to the

nation's energy problem. R&D appears to offer an easy solution as an alternative to the development of a comprehensive and coherent national energy policy; but in the case of commercialization, it may not prove as effective as it was with DOD and NASA.

One of the companies interviewed foresaw two possible scenarios for national energy development. In the first, it saw Congress appropriating great sums of government R&D money which, in actuality, would have little substantive effect and might only be a transient phenomenon.

In the second scenario, it saw a transition to a new and fundamentally different national approach to developing R&D for energy, particularly in the development of large energy generators for utilities. In importance, this latter scenario would correspond to the impact of R&D upon DOD and NASA following World War II.

Under this second scenario, to the extent that industry did not perform, the government would itself enter and solve the problem. Nevertheless, the same institutionalization and product development cycle would be anticipated to result as was witnessed in DOD; namely, identification of requirements, development, procurement, production, etc., but with industry as the ultimate customer, whose procurement is dominated by the government. It is hoped and believed that ERDA's responsibilities, as expressed through its demonstration programs, will lead to the realization of this second scenario.

Nevertheless, there is some industry doubt as to the efficacy of the ERDA demonstration projects and, indeed, as to the demonstration

project approach insofar as ultimate commercialization success is concerned. Part of this doubt arises from the concern that the demonstration projects as presently planned will not eliminate or even substantially reduce the real risk which is industry's primary fear in the commercialization process. That risk is economic and financial rather than technical.

It is feared the demonstration projects may be directed to the wrong (primarily, technical) objectives. Certainly one must demonstrate technical feasibility before one becomes concerned with economic and financial factors, and the three areas are inter-related, as is obvious. Nonetheless, capital investment risks are enormous, even if the technology is successfully demonstrated. Demonstration projects as presently planned do not address this latter problem. Indeed, the economic and financial risks may be so great that the technology, no matter how successful, may never be used.

Industry too often sees technically questionable projects with uncertain paybacks. Why should the utilities, for example, invest enormous quantities of money on such questionable projects? The discounted cash flow analyses which are called for often embody time horizons greater than ten years, which are far too long for most financial analysts, who need a quicker return on their investment. The payoff is so far in the future that the mathematics of discounted cash flow and the mathematics of competitive markets offer a very dubious prospect.

(Speaking of utilities, another old problem probably will rear its head in attempts to commercialize ERDA technology: namely, the public utility vs. private power problem. Sooner or later any policy connected with the demonstration of utility-like power systems will have to confront this public vs. private problem.)

Procedures

The procedures followed in this present study were the same for each of the six companies interviewed. With the assistance of ERDA executives, a protocol was prepared, presented in Appendix A, which asked specific questions, the answers to which were desired in the course of the interviews. The protocol was mailed prior to the interviews to each of the six companies: Coalcon and Union Carbide (Coalcon demonstration project); Westinghouse Electric (LMFBR and solar heating and cooling of buildings); Honeywell (solar heating and cooling of buildings); and Chrysler Corporation (automobile turbine project). The protocol accompanied a letter of introduction to the companies interviewed from the Chairman of the ERDA Task Force on Demonstration Projects as a Commercialization Incentive. That letter outlined the reasons for the interviews and requested the assistance of the chief executives of the corporations contacted to assure that the interviews were productive. The Chairman's letter is presented in Appendix B.

The week after the Chairman's letter had been mailed, International Planning Management Corporation (IPMC) telephoned the addressees to arrange a specific time for the desired interviews. Those arrangements were confirmed by a subsequent letter from IPMC, which also introduced the interviewer and the company.

The interviews lasted approximately two and one-half hours each. The general approach in each was to review the reasons for the interview, to explain the objectives of the Task Force, and then to address each specific question of the protocol (c.f. Appendix A) in turn. Each question was discussed in depth and often led to other matters not foreseen by the protocol. Following completion of the entire set of protocol questions, the discussion then extended into other areas of particular interest or concern to the interviewees. These latter discussions proved quite fruitful, and their results have been incorporated in the following section under the heading "Additional Comments."

A detailed trip report was prepared following each visit and returned to the particular interviewee for his comment, correction, extension or other modification. In accord with the promise of anonymity offered by the Task Force Chairman in his letter (c.f. Appendix B), each interviewee was assured of anonymity for himself and his company and advised that the individual trip reports would not be shown or offered to ERDA, but rather would be retained in the IPMC files to form the basis of this present report. In every case, the interviewees specifically

requested that anonymity be preserved. Consequently, other than identifying the companies interviewed, as previously has been done, the following remarks will not be associated with any particular individual or company.

In the analysis of the six trip reports, every attempt was made to determine the existence of a consensus of opinion or a majority opinion. Where such was not possible, as will be seen from the following Section II on Interview Results, individual comments have been incorporated in this report (in slightly modified fashion to eliminate any means of identifying the particular source).

B. Principal Findings and Recommendations

Table 1 presents an overall summary of the answers to all of the protocol questions, together with an appraisal of project factors, presented at the end of the table, of each demonstration project, as seen in the eyes of its principal contractor, regarding the four factors noted, namely: familiarity with critical issues, permanence of the government role, relative size of the government contribution, and the nature of the demonstration. As will be seen from that summary table, only three of the companies interviewed felt themselves qualified or their project appropriate for comparison as requested by the protocol with similar practices of DOD and NASA. All six companies preferred to discuss each protocol question individually; and, in the case of the three companies not reported in Table 1, without regard to DOD and NASA practices.

Table 1

SUMMARY OF RESULTS

In the opinion of the sample of ERDA's participating contractors, ERDA's management practices are, in relation to those of DOD and NASA:

	MANAGEMENT PRACTICES (In Relation to DOD and NASA Practices)		
	MORE RESTRICTIVE	ABOUT THE SAME	LESS RESTRICTIVE
I. TECHNICAL DESIGN			
I-1. Level of technical direction	1	2	
I-2. Specify particular technology	1	1	1
I-3. Approval of drawings, etc.	1	1	1
I-4. Approval of project personnel		2	1
I-5. Approval of subcontractors		2	1
I-6. Approve change orders	3		
I-7. Rights to patents and proprietary data	2	1	
I-8. Demand royalty-free licenses	2	1	
I-9. Access to contractor records		3	
II. SITE SELECTION -- Not applicable to DOD/NASA Comparison			
II-1. Extent of site selection determination			
II-2. Offer federal land			
II-3. Financial protection for public liability			
II-4. Environmental impact statement preparation			
II-5. Facilitate procurement and permits			
II-6. Reimburse public for demonstration operations			
II-7. Ownership or leasing procedures			
II-8. Participation in hearings with concerned citizens			

Table 1 (continued)

	MORE RESTRICTIVE	ABOUT THE SAME	LESS RESTRICTIVE
III. RESOLUTION OF DEVELOPMENTAL PROBLEMS			
III-1. Role in resolution of development problems		2	1
III-2. Inspection and acceptance rights		2	1
III-3. Monitor development tests		2	1
III-4. Approval over price adjustments		3	
III-5. Demand royalty-free use	1	2	
III-6. Approval of change of scope		3	
III-7. Schedule and performance criteria control		3	
III-8. Access during development		3	
III-9. Progress report stipulations		2	1
IV. OPERATIONS			
IV-1. Role during operational phase		3	
IV-2. Access during demonstration operations		3	
IV-3. Recourse in default		3	
IV-4. Termination rights		3	
IV-5. Policy regarding follow-on use		2	1 (Undecided)
IV-6. Indemnify contractor during operations		3	
IV-7. Monitor environmental aspects	1	2	
IV-8. Interface between public and contractor	1	2	
IV-9. Specify operating procedures		3	

Table 1 (continued)

	MORE RESTRICTIVE	ABOUT THE SAME	LESS RESTRICTIVE
V. EVALUATION			
V-1. Insure results accurately reported		3	
V-2. Design evaluation tests		3	
V-3. Access to evaluation data		3	
V-4. Direct particular tests		3	
V-5. Evaluation duration		3	
V-6. Termination rights		3	
V-7. Publicity procedures		3	
V-8. Dissemination of data	1	2	

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PROJECT FACTORS

Demonstration Project	Primary Familiarity With Critical Issue	Permanence of Government Role	Relative Size of Government Contribution	Nature of Demonstration
CoalCon (Union Carbide and CoalCon)	Extremely	Through entire scope of program (8 years); disengage	Fully funded design phase; 50/50 for demo. construction and oper.	Trying to demonstrate commercial viability of coal conversion as an industry.
Solar Heating (Honeywell)	Limited; critical issue is degree of private investment required before market is well established.	As long as it represents a viable and necessary incentive for commercialization.	Major - all phases.	Accelerate commercialization of solar heating and cooling systems for buildings.
LMFBR (Westinghouse)	Will a fast breeder be licensable and useful in utility network?	Government role will last through 1990s (fuel cycle, development of comm. size co.	$1.95 billion est. $260M utilities $20M mfr. & reg. Govt. = 80%	Same as Critical Issue
Georgia Solar School (Westinghouse)	Difficulty with procurement of goods and services (not commercially available).	Government continues to monitor operations.	100% government	Prove technical feasibility and utility; data base for others; responsive to the Congress

Selected individual responses are incorporated in the following Section II on Interview Results.

In this Executive Summary only the consensus or majority view, appropriately modified where necessary, is summarized for each major section of the protocol. In addition, in each instance, all related recommendations, specifically proposed during the course of the six interviews, are incorporated because of their potential importance to the deliberations of the ERDA Task Force on Demonstration Projects as a Commercialization Incentive.

As will be seen from the summary Table 1, in most instances the three respondents who felt qualified or believed it appropriate to compare ERDA with DOD and NASA practices felt that there were substantially no differences. Such result was to be anticipated, since in most cases the ERDA practices have evolved from those of AEC, which in turn frequently have employed DOD precedents. In other cases ERDA has followed both DOD and NASA precedents.

Technical Design Majority Opinions

The principal differences of opinion shown by Table 1 occurred in the area of technical design. One of the three respondents felt that generally, "In contractual matters, ERDA is loose and flexible vis-a-vis DOD and NASA practices; however, in the technical context ERDA's practices are decidedly more rigid." In the view of this interviewee, the level

of technical direction exercised by ERDA "is distinctly more restrictive than either DOD or NASA."

A second respondent who felt qualified to compare ERDA practices with those of DOD and NASA stated that "The level of technical direction exercised by ERDA is about right." However, he reported an anomalous situation in which one ERDA individual was exercising excessive technical direction over one particular subsystem for which he has oversight responsibility.

The third respondent who felt qualified to compare ERDA with DOD and NASA, as noted by Table 1, felt that ERDA's practices were rather more lax than those of DOD and NASA, except for the area of patents, in which he said that ERDA's procedures were more rigid than those of DOD or NASA.

In only one area, that of approval of change orders, did all three respondents feel that ERDA's practices were always more restrictive than those of DOD/NASA.

When one incorporates the views of the three companies who felt unqualified or preferred not to compare ERDA with DOD and NASA, the majority opinion emerges that in general government direction over technical design should be held to a minimum except in the initial selection of project design and contractor. What direction there is should primarily be in the area of incentives to push the state of the art. This encouragement is particularly needed when one recognizes that the ERDA objective

is to encourage the ultimate commercialization, not just prove technical feasibility, of a particular demonstration project.

There was unanimity of opinion that ERDA should not demand background patent rights for a demonstration project.

The following specific recommendations were collected during the interviews regarding the government role in the technical direction and design of a demonstration project:

Technical Design Recommendations

- Broader participation by industry should be encouraged in ERDA demonstration projects. The Mellon Institute's fellowship system of cooperative laboratories provides an interesting precedent, as does the FEA center for construction technology. ERDA must motivate a wide variety of diverse types of people in industry in order to commercialize their new technology. Trade associations involved with the particular technology might sponsor a Mellon Institute type fellowship, for example. Antitrust and related aspects of such possibilities must be reviewed in advance, however, before implementing this recommendation.

- The government should specify basic technology because those decisions determine basic project risks. However, the design organization should be consulted in that decision, and the government should not exercise specific detailed design approval.

- To expedite and facilitate project management, ERDA should

authorize the project officer to approve subcontractors and should raise the level which requires headquarters approval to, say, $10 to $20 million.

- Contractors should have the right to file patents for exclusive use as an incentive for their participation in a demonstration project. The government should not have the right to disseminate patent information to contractor competitors, but rather should be granted a royalty-free license for its own purposes. However, the government must be careful not to permit itself to be accused of favoritism and must otherwise assure fair competition, particularly in industries where there may be only one or two large demonstration projects.

- Insofar as determination as to project marketability is concerned, however, the industry contractors must be permitted to make their own decisions free of government intervention, subject only to incentives offered by the government.

- The government should raise the level above which they require prior approval authority on tooling and orders to at least $25,000, or, more generally, to one or two percent of the contract.

- Patents in the public domain should be licensed to the government in proportion to the government's cost sharing and should pertain only to foreground patents. Background patents should remain entirely the property of the contractor.

- Since no private company will allow another private company (e.g., a subcontractor/contractor relationship) to audit their records,

ERDA contract provisions should clearly indicate provision for the government to audit subcontractors.

- The scope and number of required reports should be clarified and held to an absolute minimum by the terms of the original contract for the demonstration project. The government should be flexible in demanding periodic reports and should permit reporting periods to be adapted to company accounting procedures and practices.

Site Selection Majority Opinions

None of the six companies interviewed felt that it was appropriate or possible in many instances to contrast ERDA practices with those of DOD and NASA in the matter of selection of demonstration project sites. The reason for this view was that DOD and NASA generally do not operate demonstration projects, and certainly do not have the commercialization requirement incumbent upon ERDA's demonstration projects. Consequently no company offered a comparison between ERDA and DOD/NASA in the area of site selection criteria.

All companies concurred in the belief that site selection is a political problem; since "politics is the art of government" site selection necessarily becomes the prerogative and responsibility of the government. However, that selection by the government should be in accord with technical specifications stipulated by the contractor. Private contractors cannot afford to antagonize unsuccessful site proponents.

Site Selection Recommendations

- The government should have the decision as to site selection, but the particular site or sites must meet the contractor's specifications.

- The government presently prefers to be self-insured, rather than to allow insurance premiums to qualify as contract costs.

- Comprehensive insurance programs, private or government supported, will be needed in future major demonstration projects and in their subsequent commercialization.

- Payments in lieu of taxes are needed to aid impacted local areas in government demonstration projects, since such projects are not generally subject to local taxes.

- Since the government must approve the environmental impact statements for a particular demonstration project, it is inappropriate for the government to assist in their preparation, and the government should not do so.

- Whereas the contractor is responsible for procuring his own construction and other permits, the government should be totally responsible for long lead time procurement.

Developmental Problems Majority Opinion

As will be seen from the summary Table 1, for the most part the three companies who felt qualified to compare ERDA with DOD/NASA agreed that there was little difference between those three government

agencies in the majority of the areas concerned or involved in this heading. Principal exceptions occurred in the proper role for the government in the resolution of developmental problems, in inspection and acceptance rights, and monitoring of development tests. One of the three companies felt that ERDA was considerably less restrictive, whereas the others felt that ERDA was about the same as DOD/NASA in these regards.

The only area in which ERDA was thought to be possible more restrictive was in its policy regarding royalty-free use and other patent rights.

Developmental Recommendations

- Presently every cost-type contract change greater than $500 requires government approval. This figure should be raised to $25,000 to $100,000.

- Presently ERDA requires approval of fixed-price contract changes of scope greater than $100,000; with present inflation this figure is too low. The figure should be increased to, say, $200,000 to $1 million.

- Technical reports should be required by the government less frequently than is customary. Topical reports are easier to prepare and often more useful to the government, and should be employed more generally.

- The government should not involve itself directly in development problems, as distinguished from acceptance tests.

- As a matter of policy ERDA should be permitted to grant contractors title to inventions made in accord with the performance of ERDA contracts. By doing so, ERDA would help fulfill its mission, as outlined in the Energy Reorganization Act, of having a patent policy which would provide an incentive to stimulate commercial industrial development in energy fields, as well as protection of the public interest. The public could be protected, under a policy leaving title to inventions to the contractor, by being provided the best possible chance to have the invention brought to the marketplace. Further protection could be provided by reserving to the ERDA Administrator certain "march-in" rights to assure that, if the contractor did not exploit the invention within a reasonable period of time, title to the invention could be obtained by the government so that it could be licensed to another. Such a policy would, of course, preserve to the government a royalty-free, non-exclusive license for government purposes.

- As a matter of policy ERDA should not obtain any free license under background patents or data. Such licenses should be left to negotiation on a case-by-case basis.

- The government should demand royalty-free or other patent rights in proportion to the degree of government financial participation.

Operations Majority Opinion

As will be seen from the summary Table 1, all three responding companies felt there was little difference between ERDA and DOD/NASA

practices insofar as the operational phase of a demonstration project was concerned.

One company was undecided regarding ERDA policy pertaining to follow-on use of technology. But the same company also felt that ERDA was more restrictive in its policies and practices regarding the monitoring of environmental aspects of demonstration projects and in its role as an interface between the public and the contractor on such projects.

Operations Recommendations

- The government should not itself in general operate demonstration projects, but should employ appropriate private contractors.
- Operating procedures should not be specified by the government, but rather by the contractor, since detailed project knowledge is the contractor's and not the government's.
- The government should interface between the public and its demonstration project contractors in such a manner as to influence the market in favor of the new technology.

Evaluation Majority Opinion

With but one exception, all three companies who felt themselves qualified or who desired to compare ERDA with DOD/NASA practices felt there was no substantial difference among those three government agencies. The one exception referred to ERDA policies regarding dissemination of data, which one company felt to be more restrictive than similar practices of DOD/NASA.

Evaluation Recommendation

- In most instances the government should permit the demonstration project contractor to prepare his own evaluation; however, where an independent third-party evaluation is required for whatever reason, the government should adopt the following three policies:

  (1) The contractor should be given approval of the proposed evaluator as to the latter's competence, etc.;

  (2) The evaluation should be conducted in such a fashion that it would not compromise the demonstration project contractor's proprietary rights; and

  (3) The contractor should have the right of approval of the evaluator's proposed test procedures.

Overall Comparison

In order to permit an overall comparison of the views of all six respondents regarding ERDA's management practices, a second table was prepared based upon the interviewer's interpretations of the responses of each company to the protocol questions of Appendix A. In essence, Table 2 is an inferential analysis of the views of the companies interviewed concerning their appraisal of ERDA's management practices as the latter pertain specifically to the respondents' particular demonstration projects.

The column headings of Table 2 have been interpreted from Table 1 as: "Too Strict," "About Right," or "Too Lax," insofar as ERDA's

Table 2

SUMMARY OF RESULTS

Interpreting the responses of ERDA's participating contractors, ERDA's management practices are considered to be:

	MANAGEMENT PRACTICES		
	TOO STRICT	ABOUT RIGHT	TOO LAX
I. TECHNICAL DESIGN			
I-1. Level of technical direction	2	4	
I-2. Specify particular technology	1	4	1
I-3. Approval of drawings, etc.	1	4	1
I-4. Approval of project personnel	1	4	1
I-5. Approval of subcontractors		4	2
I-6. Approve change orders	6		
I-7. Rights to patents and proprietary data	4	2	
I-8. Demand royalty-free licenses	4	2	
I-9. Access to contractor records		6	
II. SITE SELECTION			
II-1. Extent of site selection determination		6	
II-2. Offer federal land		6	
II-3. Financial protection for public liability		6	
II-4. Environmental impact statement preparation		6	
II-5. Facilitate procurement and permits		6	
II-6. Reimburse public for demonstration operations		6	
II-7. Ownership or leasing procedures		6	
II-8. Participation in hearings with concerned citizens		6	

Table 2 (continued)

	TOO STRICT	ABOUT RIGHT	TOO LAX
III. RESOLUTION OF DEVELOPMENTAL PROBLEMS			
III-1. Role in resolution of development problems		5	1
III-2. Inspection and acceptance rights		5	1
III-3. Monitor development tests		5	1
III-4. Approval over price adjustments		6	
III-5. Demand royalty-free use	2	4	
III-6. Approval of change of scope		6	
III-7. Schedule and performance criteria control		6	
III-8. Access during development		6	
III-9. Progress report stipulations	2	3	1
IV. OPERATIONS			
IV-1. Role during operational phase		6	
IV-2. Access during demonstration operations		6	
IV-3. Recourse in default		6	
IV-4. Termination rights		6	
IV-5. Policy regarding follow-on use	1	4	1 (Undecided)
IV-6. Indemnify contractor during operations		6	
IV-7. Monitor environmental aspects	1	5	
IV-8. Interface between public and contractor	1	5	
IV-9. Specify operating procedures		6	

Table 2 (continued)

	TOO STRICT	ABOUT RIGHT	TOO LAX
V. EVALUATION			
V-1. Insure results accurately reported		6	
V-2. Design evaluation tests		6	
V-3. Access to evaluation data		6	
V-4. Direct particular tests		6	
V-5. Evaluation duration		5	1
V-6. Termination rights		6	
V-7. Publicity procedures		6	
V-8. Dissemination of data	1	5	

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management practices contribute to the satisfactory conduct of the companies' demonstration projects. The previous data of Table 1 have also been included in Table 2, identifying "More Restrictive" with "Too Strict," "About the Same," with "About Right," and "Less Restrictive" with "Too Lax."

Comparing Tables 1 and 2, it will be seen that there are few significant differences. Overall, we conclude that ERDA's management practices, as seen by the six contractors interviewed, are for the most part satisfactory.

What differences there are appear primarily in technical design concerns. It was the unanimous opinion of all six companies interviewed that ERDA's change order management practice is too strict. Similarly, the majority opinion was that ERDA's patent management practices are too strict, particularly as they concern background rights.

There are no significant problems in ERDA's site selection procedures.

Insofar as the resolution of developmental problems is concerned, the only differences between Tables 1 and 2 appear: in Question III-5, the demand for royalty-free use, again reflecting concern with ERDA's patent practices; and in the demand for project report information, Question III-9.

The concern with ERDA patent regulations also explains the one deviation between Tables 1 and 2 insofar as operations are concerned:

namely, a concern regarding patent rights in the follow-on use of technology, reflected by Question IV-5.

The patent problem also arose in the one difference between Table 1 and Table 2 in Section V, Evaluation. An additional concern was raised in the same section relating to the dissemination of data, Question V-8, which again reflected the particular respondent's concern with ERDA patent restrictions.

Conclusions and General Recommendations

There was a divergence of opinions and conclusions regarding the four different types of demonstration projects discussed during the interviews.

In the case of the large capital-intensive projects (Coalcon and LMFBR) the principal conclusion was that ERDA should recognize that the primary problem to be solved in commercialization is the making available of the necessary funds, i.e., financing.

Financing was also anticipated to be the major commercialization problem in the adoption of a new technology such as that of the automobile turbine. Here the problem of commercial introduction is not that of technical feasibility but rather that of financing the huge retooling of the entire automobile industry which would be needed to produce the turbine.

In the case of the solar heating and cooling demonstration projects, financial considerations of a different nature predominate. Namely,

industry presently projects return on sales of much less than five percent, and return on investment of less than ten percent. Commercial attractiveness is therefore in doubt. As with the automobile turbine, to encourage commercialization of solar heating and cooling technology, reduced production costs are required; however, at the moment improved production methods do not look particularly promising. Indeed, the cost of production presently is about ten times what would be considered economical.

Another problem with the solar area--which in different ways is reflected in the other three areas as well--is that of public acceptance. Frequently solar installations are esthetically unattractive and there is a built-in market resistance. Market resistance might also be found in automobile turbines, although such is not anticipated to be the case. Environmental and safety aspects of the large projects, such as Coalcon and the LMFBR, may jeopardize the public acceptance of those projects as well.

Historically it was felt that demonstration projects, such as those planned by ERDA, have not been particularly successful in commercializing a new technology. It was thought by one respondent that the Bureau of Mines demonstration projects were the precedent for the ERDA program, as the BuMines projects were also cost shared and exhibited other characteristics typical of the ERDA approach. The principal problem of such demonstration projects is that they have not illustrated economic feasibility.

On the other hand, certain AEC-sponsored demonstration projects, such as that at Shippingport, have been quite successful. In these latter cases, however, the government paid 100 percent of the demonstration project cost, and in the case of Shippingport sold the resulting steam at competitive prices to private industry.

One respondent said that today ERDA is being forced by Congress to produce results. What is needed is a commercialization program which looks at all pertinent political, economic, technical and social realities and recommends a plan for a more promising commercialization approach than is offered by current demonstration projects.

Similar recommendations were made by other respondents:

- ERDA should itself plan the commercialization phase in detail or else should give clear-cut responsibility to someone else to write such a strategic plan so as to know how and when to involve the industrial community in encouraging future commercialization of its new energy technology. Thus ERDA should become a promoter as well as a developer of new energy technology. (Appendix C presents an example of such a commercialization plan, drawn for the Clinch River Breeder Reactor Plant and made available to the general public by the Westinghouse Electric Corporation.)

- In planning technology commercialization, ERDA might be wise to develop industry committees in each technical area, which would recommend how commercialization could best be brought about in that

area. Such an approach would guarantee industry involvement and would accelerate the commercialization process. It must be recognized that such a committee approach would differ from project to project, as the problems themselves are drastically different between, say, the LMFBR and the solar area. For example, LMFBR or Coalcon commercialization will involve a very small number of large businesses, whereas in the solar projects a very large number of small businesses will be involved. Each technical area has different problems and requires its own specialized commercialization plan (e.g., see Appendix C).

- In its approach to planning the commercialization phase, ERDA should, first, get the appropriate people together from industry and government in discussion to decide what technology should be used and to identify what engineering approaches should be employed. Second, the government and industry would then determine what appropriate funding is required. Third, and most important, the government must then figure out an equitable method of funding the production phase, or of assuring that adequate financing for the commercial introduction of the new technology is otherwise available.

- As part of its commercialization strategic planning, the government should develop and publish a national energy policy which should be integrated in the sense that it stimulates the economy, provides energy, permits people to work, and assures national oil independence from foreign producers at some reasonable time in the future.

- Perhaps the demonstration plant phase should be eliminated altogether, with ERDA going directly to the first commercial plant stage on a risk basis with government insurance of reasonable return on investment. The World War II synthetic rubber plant precedent might be most appropriate in this regard.

- ERDA must decide whether it will manage a demonstration project itself or will contract with a private company to do so. The latter course is recommended by industry.

- A number of vacancies exist in ERDA which they are trying to fill from industry in order to gain experienced management talent. This is a good policy and should be encouraged.

- Finally, there are many costs of demonstration plants which are not involved in a commercial-scale project, and which further degrade their financial attractiveness. In general, private financiers are unwilling to contribute, say, $150 million toward a demonstration project with its associated risk. Fifty/fifty funding for demonstration projects is often too severe for industry. The share proportion of project funding should be based on a situational assessment of demonstration risk. Not all pilot plants should be funded on a 70/30 basis, nor all demonstration plants on a 50/50 basis. It might be unbalanced one way or the other, depending on risk. The actual sharing proportion could be part of the original proposal for a demonstration project. The government might consider bearing all costs of a new demonstration

plant with possible resale to industry on a bid basis, a la the World War II synthetic rubber industry precedent.

II. INTERVIEW RESULTS

This section presents selected (edited) comments offered by the various interviewees in response to the protocol questions presented in Appendix A. For convenience, the comments are presented in the same order as the protocol questions, and the questions themselves are repeated at the beginning of each corresponding series of interviewee responses.

All of the recommendations gathered during the interviews have been quoted verbatim in the preceding Executive Summary, and therefore will not be repeated hereafter.

Technical Design Comments

I-1. The principal question to be answered is: What level of direction should the government exercise over demonstration project technical design?

- Government direction over technical design should be kept at a minimum and then primarily held to the area of incentives in order to push the state of the art. This is particularly so in fields of commercialization where the government is buying the design, not just the manpower.

- The government has a right to "early signals" if the demonstration project were in difficulty. However, the government might be tempted to become a "creeping monitor" under whom enforcement might be replaced by regulation, which would be intolerable.

- In contractual matters, ERDA is loose and flexible vis-a-vis DOD and NASA practices; however, in the technical context ERDA's practices are decidedly more rigid. The level of technical direction exerted by ERDA is distinctly more restrictive than either DOD or NASA.

- ERDA is presently toying with the $(CS)^2$ management concept a la DOD. This would be a most unwelcome development. The most successfully managed DOD projects did not employ $(CS)^2$.

- Informal government guidance, particularly with respect to technical feasibility considerations, is welcome; however, in the case of marketability, the contractor must decide.

- The level of technical direction exercised by ERDA in its demonstration projects is "about right."

- The government should select the contractor, but the contractor should then be left to do the work. The government should also have the right to inspection and veto.

I-2. To what extent should the government specify the particular technology to be employed in achieving the desired performance?

. The contractor should work with A&E firms at an early stage of the demonstration in the definition of the system as a whole to encourage the proper development of the project, and to assure optimal use of the existing industrial infrastructure.

. It would not be wise to relax government specification control. To do so would permit undesirable duplication of effort.

. The government should only specify technology in the initial selection of the contractor. Afterward its role should be that of maintaining cognizance.

. The contractor selected should be among the best judges of commercialization. Additional commercialization considerations may need to be exercised in a step following the demonstration project, in which the contractor could be of great use.

. ERDA's technology selection specifications are too rigid, and frequently suffer from design by committees. Thus the design organization, with their detailed knowledge of the implications and costs of technology selection, do not have a chance to participate in the original selection.

. The layers upon layers of government management review and approval commonly experienced in the U.S. and particularly as required by ERDA result in serious delays and cost growth of demonstration projects.

I-3. To what extent should the government exercise approval rights on drawings, materials, and/or procedures?

. It is unnecessary for the government to exercise approval rights on drawings, materials, or procedures.

. The government should provide any information at its disposal, beyond that which the contractor is using or knows about, regarding materials, processes, etc. However, commercial good judgment is most likely to rest with the contractor.

. The government should exercise their legal approval rights, except in the area in which the product/system must meet performance requirements as specified.

. The government as a whole is much too restrictive.

I-4. To what extent should the government exercise approval rights on project personnel?

. Most contractors are capable of selecting their own people and do not welcome government intrusion in the process.

- Some contractors are concerned that the government laboratories may take over certain energy R&D areas to the exclusion of private companies, who may have done the original work.

- It is not appropriate for the government to exercise approval of personnel once a contractor has been selected. It is appropriate in the initial selection of the contractor.

- The government should not exercise approval rights on project personnel. Presumably the contractor has been selected because of past experience in his field and in selecting personnel. In that initial selection, the government should of course determine relative capabilities of the various personnel proposed. Key personnel changes subsequent to contract award should be reported, of course; however, if blanket government approval of personnel were required, it would interfere with union agreements, create conflicts of interest, and lead to prejudgment of the project.

I-5. To what extent should the government exercise approval rights on subcontractors?

- The government should exercise its approval of subcontractors only as regards their financial credibility, except in the initial award of the contract, when the subcontractor would be considered a team member.

. Preferably, the government should exercise its determination in the original RFP rather than after the contract award. "Negotiate is preferred to "approval." ERDA should exercise no more approval rights than other governmental bodies.

. The government should only exercise approval rights on subcontracts to a very limited extent. The government is buying the contractor's services in this area. However, large R&D subcontracting or unusual large procurement should be a subject for negotiation and approval by the government.

I-6. To what extent should the government approve necessary change orders?

. Typical DOD/NASA change order procedures relating to form, fit and function, etc. are less applicable in ERDA contracts. A DOD/NASA approach would be too restrictive.

. Misunderstanding and confusion arise because of the level at which changes must be approved by the government. Too much control exists under the present contract mode.

. Change orders have a negative impact upon cost and performance, but when they are necessary they should be processed promptly. ERDA approves or requires approval of changes at too low a level.

. Government approvals should only apply to large change orders.

. Change orders should be negotiated mutually between the government and the contractor, and should require proper reimbursement to the contractor. Change orders to subcontractors are prime contractor responsibility, unless the costs are unusual and therefore require explanation to the government. ERDA's procurement restrictions significantly hamper purchasing schedules. Such restrictions include prior approval on tooling over $2,000 and orders over $10,000. Such levels result in many orders being delayed unnecessarily. The limits are too low.

I-7. To what extent should the government exercise rights as to patents and proprietary data?

. The DOD practice of the contractor retaining title is preferred. With reference to background patent rights, no government access is desired. On occasion background patent position has been relaxed, but it is an unpopular practice and is not preferred. Patents and data developed prior to contract should become government property in terms of license rights but not patent rights.

. Present patent and proprietary data clauses make sense, both as regards background and foreground patents, data ownership, etc.

. There should be a good patent incentive for the contractor. The background patent area has been a particular problem. ERDA is much more demanding of background rights than either DOD or NASA.

. Patent rights should not be decided as a matter of policy. In all cases they should be determined on a case-by-case basis, subject to certain guidelines. In any event, background rights should be eliminated from government control.

. If inventions are made using public funds, then those patents should remain in the public domain. Patents are far less important than "momentum." The adage "Never try to root out an incumbent" implies the advantage afforded by a leading industrial position.

I-8. To what extent should the government demand royalty-free licenses for government purposes to inventions, patents and discoveries developed prior to or in the course of the technical design?

. Again in the background area, ERDA is much too restrictive.

. Background, no; foreground, possibly, via a license. We would like to see the license granted only if the specific development company cannot fulfill the market need; and royalty-free only if developed in the course of the technical design, with the contractor having no prior related background experience.

. The practice under which the contractor owns a title but issues a royalty-bearing license is unpopular. Royalty-free licenses to the government for background patents are not appropriate, but are entirely appropriate for foreground rights.

. Much of the success of a demonstration project derives from the contractor's prior experience. That experience is reflected in background patent rights, which should not be made available to the government on a royalty-free basis.

I-9. To what extent should the government be authorized access to contractor records?

. All records relating to activities for which the government pays or in which the government shares the cost should be and are totally accessible to government review. Financial records must be consistent with the type of contract, and in accord with government procurement regulations. Some subcontractors are concerned by the government's access rights, as they fear they may lose considerable advantage to their competitors who may gain information by the government's access to their records.

. The government has complete access except for personnel files. We feel they should have no access to contractor records on fixed price; on cost plus, present audit procedures are suitable.

. In a cost-reimbursable contract standard catalog items are not audited in detail. However, what should be done about future catalog items which may be required for cost disclosure, but which are intended for future commercial sale? This is a problem area requiring government resolution.

- Experience with the Corps of Engineers, who have demanded excessive access to reports, has proved cumbersome in practice and has been negative.

- There is currently a tremendous paper burden on contractors meeting government requirements.

Site Selection Comments

II-1. Under what conditions and to what extent should the government make site selection determination?

- The site selection problem involves a myriad of factors, including: unions, local government, local populace, and many additional questions. It is best handled by the government. The contractor should develop a "technical data bank"--that is, specifications for a site--but the actual selection should be left to the government because of the political implications.

- "Politics is the art of government." Site selection is primarily a political problem and should be left to the government, providing the technical specifications are met as stipulated by the contractor.

- This is a "political football."

II-2. Under what circumstances should the government offer federal land for such purposes, and under what conditions?

. The land cost is a relatively minor part of a demonstration project. Unless there is some overriding reason for choosing federal lands, there is no need for their use.

. The government should consider offering federal land only as a matter of cost effectiveness.

. A policy of exclusive use of federal lands could compromise the best site selection from a technical standpoint.

II-3. Should the government offer or furnish financial protection or indemnification for public liability claims arising from demonstration operations on government lands?

. There is no difference between federal and private land, and there should be no government protection, unless the government restricts the selection to federal lands when it might be needed for unknown reasons.

. Financial protection or indemnification in large projects should be and is required by all participants. Government insurance might be useful.

. Not a major factor.

. The government should provide this protection.

. The government should act only as an insurer of last resort, since most private contractors have their own insurance agents.

II-4. To what extent should the government assist in the preparation of needed environmental impact statements for the particular site selected?

. Perhaps the government should fund EISs, but not do them. In any case the government should approve them.

. EISs should be prepared by contractors and approved by ERDA.

II-5. To what extent should the government facilitate procurement necessary for construction and other permits relating to the particular site selected?

. In general, procurement of permits is the responsibility of the contractor. However, any government assistance is welcome.

. Governmental help would be appreciated. Insofar as building permits are involved relating to performance standards, we prefer working with local rather than federal government bodies. However, special cases might require government involvement to help meet difficult local building codes.

II-6. What arrangements should be made to reimburse the public for demonstration project operations on federally-owned land?

. Land is a nominal part of the project cost.

. Reimbursement is not necessary; however, exceptions arise in strip mining of coal and similarly in the mining and processing of oil shale.

. This is a government problem, not the contractor's.

II-7. Correspondingly, what particular ownership or leasing procedures are recommended for construction of plants on the site selected?

. If new construction is involved, timing problems may arise. On occasion the construction phase might actually precede ERDA final decision and approval. A policy should be developed under which the government would not interpret a company's initiation of construction prior to final approval as a prima facie indication that the company would be willing to fund the project alone without government assistance.

. Arrangements depend upon how commercially attractive the project may be. The operator may wish to have an option to purchase, if the demonstration is successful. Fusion power demonstration projects of the future may be particularly concerned with this problem.

. Ownership and leasing procedures should be part of the contractor's obligations. The government role should be one of stimulus and standby assistance.

II-8. To what extent should the government participate in hearings and meetings with concerned citizen groups in the vicinity of the selected site?

. The government should adopt a responsive posture for local problems, but in general such problems are the problem of the contractor.

. Clearly the government should do so.

. The government should participate since it is a partner in the cost-shared demonstration project.

. The government should not normally "participate" but should lead the response or be the only respondent to concerned citizen groups. The action should be taken prior to granting of an award.

Developmental Problem Comments

III-1. What role should the government play in the resolution of development problems in general?

. In general the government should make available all its technology to help solve developmental problems. The resources of the national laboratories particularly should be made available in this regard.

. The government should provide any technology at its disposal that is required, but the government should not attempt to provide technical solutions to developmental problems per se, which is the responsibility of the contractor.

. The government should have approval rights to technical solutions to a major unplanned technical problem encountered during development. One needs flexibility to cope with unplanned problems, both technical and financial.

. The government should play a supportive role in the solution of developmental problems.

. The government must protect itself and the public interest in all respects.

III-2. To what extent should the government demand inspection and acceptance rights?

. The question should be one of specification by the contract. If it is contracted, the government has complete rights. Difficulties arise in cases not covered by the contract or for which there is not sufficient or adequate specification.

. It is reasonable for the government to have these rights. This is the name of the game; that's the way life is.

. Acceptance matters are a moot matter in research and development projects. Specifications are not necessarily appropriate; rather they should be replaced by goals which could be reached on a best-effort basis. Misfeasance, of course, must remain reprehensible.

. The government is always entitled to inspect the end product it is financing. Yet acceptance rights on a complex R&D program can be relatively moot.

. Establishing the possible degree of success is the purpose of a "best-effort" R&D project.

III-3. To what extent should the government demand or monitor development tests?

. The government should demand or monitor development tests only to assure that the results will be successful and useful to others.

. The contractor is more qualified to judge the testing required for commercialization than is the government.

. Government should always monitor, but development tests should be specified and written into the original contract.

. The word "demand" should be changed to "specify." Practically any reasonable degree thereof is acceptable.

. The contractor is generally in a better position to specify; ERDA is relatively flexible in this regard.

. Government involvement in development, as distinguished from acceptance tests, is not welcome. This area should be called out in the contract.

III-4. To what extent should the government exercise approval over price adjustments or cost over-runs on specific items during construction?

. None on fixed price construction contracts.

. The government should approve changes in cost estimate of a significant size.

. On specific items, no; however, it would be alright in a general cost-overrun situation. Beyond that, this problem falls into the usual government auditing procedures.

. Government approval over price adjustments or cost overruns should be primarily on the overall or major cost segments, because the contractor's estimating may balance out one task against another within a total cost limit.

III-5. To what extent should the government demand royalty-free use or other patent rights to processes evolved in solution to developmental problems?

. Commercial utilization of inventions requires a great deal of work and risk capital beyond the initial making of the invention under an ERDA contract. The contractor is the party most likely to invest this effort and capital to exploit the invention, since he has the background expertise in the field of the invention. Without the right to patent the invention, he cannot justify the investment needed to bring the invention into

the marketplace, because anyone could take advantage of his work and capital investment and immediately bring out competing copy, thus denying him the recoupment of his investment.

. The government should have such royalty-free use, but not industry at large in order to provide incentive to the demonstration project contractor.

. To whatever degree the government needs.

III-6. To what extent should the government exercise approval and control of change of scope orders?

. Change of scope orders are handled as per the contract and for the most part are acceptable.

. It all depends on the level of dollar approval. Presently every cost-type change greater than $500 requires government approval and fixed price contract changes of scope greater than $100,000. These figures are too low.

. It is customary for the government to exercise total approval and control of change of scope orders, since change of scope is an actual amendment to the contract. If the contracts are cost reimbursable, they are totally a government responsibility. If the contract is cost shared, then one must have both government and industry agreement

and changes should be conducted on the same basis as the original financial participation.

. Government has full approval and control of change of scope orders by negotiation processes which resolve the effects on the end product and costs involved.

III-7. To what extent should the government exercise control over changes of schedule and performance criteria?

. Government control over changes of schedule and performance criteria should be via negotiation on the prime contract. Subcontracts under agreed unusual cost limits should not have controls other than conventional audit.

. Schedule and performance criteria should be subject only if critical to the overall project, not for any specific problem.

. Clearly the government needs this right as a participant.

. Performance criteria, in terms of changes, are subject to contract terms and can be made by mutual agreement. We take a liberal view of this problem.

III-8. To what extent should the government demand inspection rights and access during the development period?

. The government should have total access and inspection rights,

subject to the terms of the contract and assuring that commercial proprietary information is held confidentially.

. The government should be given reasonable rights of access as specified by the contract.

. The government access and inspection rights should be to the extent of assurance that efforts and progress reported are reasonable and accurate.

III-9. How frequently and how detailed should progress reports be required of the contractor for government review?

. Topical reports are often more useful and easier to prepare than technical reports. ERDA is flexible in this area.

. ERDA proposes to follow DOD $(CS)^2$ procedures in this area, with problems expected to result.

. Contractors generally experience too much effort in preparing too frequent and overly detailed reports. The frequency and level of detail should be reduced.

. Less frequent or less detailed progress reports might facilitate progress.

. As specified by the actual contract and adhered to thereafter, but with an anticipated frequency not greater than once a month.

. Progress reports should be provided for government review not less than monthly and detailed to cover milestones, cost position, and technical information, such that other parts of industry and government need not duplicate the same efforts. Some technical data cannot be reported more frequently than quarterly or annually. The government should be flexible in melding their requirements with the contractor's practices.

Operations Comments

IV-1. In general, what role should the government play during the operational phase of the demonstration?

. There is an old adage that "No government employee makes a mistake and no government project is ever a failure." Close contact between the government and the contractor on technical matters, particularly during the operational phase of a demonstration project, is essential. The government in its role as "sovereign" has responsibility for regulation of these matters.

. Contractors should be insured by private investors, using the government only as an investor of last resort.

. The government should play an active role and should understand the problems intimately, but they should not call all the shots.

. The present government role is appropriate and reasonable.

. Private commercial or industrial operators who are experienced in similar business should operate demonstration projects, rather than government employees, in order to maximize the transfer of technology and confidence to the ultimate users.

. Ultimate commercial success is the government's responsibility, but operation of the demonstration project is the contractor's.

IV-2. What should be the government's access and audit rights during the course of the demonstration project operation?

. The government must have total access and audit rights as specified by the contract.

. Minimal, but that necessary to assure success.

IV-3. What should be government recourse in case of default?

. This right should be clearly negotiated in the original contract. Recourse should not extend beyond government financial participation. A major problem is the risk of termination damages.

. The government can unilaterally cease operations at any time under the termination clause, with corresponding termination liabilities. Definition of default has to be determined in a court of law.

. The government has the right to terminate for convenience or default, although the latter is seldom encountered. Often termination

for convenience is used in place of default in order to avoid litigation. Particulars of termination should be and are part of the contract.

IV-4. What should be the government termination rights?

. Termination for convenience is unfair in cost-shared demonstration projects, unless provision is made for residual damages to the end owner.

. The government must be permitted to terminate a project at the end of any phase, or indeed in the middle, subject to certain liabilities and termination costs.

IV-5. What should be the government's policy regarding follow-on use of technology and technical changes during the course of the demonstration plant operation?

. The government's rights regarding follow-on use during the demonstration plant operation should be on the basis of financial participation.

. Contract must specify, otherwise hands off. It would actually be the same as during the development period, that is, on the same basis as the cost sharing.

. Again the problem of free access to competing contractors of patents developed under ERDA sponsorship arises. ERDA generally does not allow contractors to retain patent protection to the extent that DOD does.

IV-6. To what extent should the government indemnify the contractor during the course of operations?

. The intent was interpreted to mean indemnification against secondary damages, in which case government participation is not appropriate.

. The government should indemnify contractor thoroughly.

. Most contractors would require such indemnification.

. This protection should be worked out in the original contract relating to casualty liability.

IV-7. To what extent should the government monitor environmental aspects of operations?

. Here indemnification is important. If the government approves environmental impact statements, it should then indemnify against suits. The key restriction must be a ceiling upon the contractor's liability. It is the government's responsibility to monitor environmental aspects of operations under EPA regulations, and it is therefore appropriate here as well.

. "The government monitors the hell out of it."

IV-8. To what extent should the government act as an interface between concerned public groups and the contractor during the course of operations?

. Usually the contractor is the actual contact point with the public,

although government participation and support is of course welcome. ERDA arranges for the contractor to have access to the public, but exercises the right of prior approval more frequently than DOD or NASA.

. Most of the interface should be prior to award. However, the government interface should continue if required. The government should lead. If handled properly (this is probably an atomic energy question), the problem would exist at the onset with known lead during the contract.

. It is entirely the contractor's responsibility to act as an interface with public groups; however, should they fail, the government could step in to protect its investment.

. The government should always be willing to respond; that is, to step in when requested by the contractor. The contractor should share responsibility as a member of the project.

Evaluation Comments

V-1. In general, what procedure should the government employ to insure that the results of the demonstration are accurately reported and fairly evaluated?

. Clearly ERDA does not have many "on the scene" people and therefore does not have the ability to evaluate a demonstration project itself

to the extent and depth needed. In any event, it is best to leave evaluation to the private sector.

- The testing of the end product against contract specifications is a major evaluation, and is the contractor's responsibility. Normally the contractor is very aggressive in evaluating its own products.

- The government should make its own evaluation, engaging a third party if necessary.

- Procedures are very adequate as they stand and are defined in the contract.

- The situation with ERDA is almost completely different from that with DOD and NASA, who are their own customers. ERDA is trying to get technology into the private sector; they are not their own customer.

- ERDA's big problem is technology transfer. They need some vehicle to encourage industry participation in the commercialization phase. Potential industry users should be involved on a broad basis in a demonstration project to encourage their participation in that phase. At a minimum information should be exchanged, but it would be better to have the potential users directly involved in the demonstration project itself.

. The government has responsibility; it can establish the test standards to be followed and a test period. The government should employ companies who clearly have an interest in the ultimate commercial marketplace for project evaluation. Usually the initial prime contractor should have this responsibility.

V-2. More specifically, should the government design the evaluation tests, or exercise approval rights over test design by the contractor?

. Consumer products can best be tested using the contractor's own experience. In general, contractors do not like the idea of the government employing a third party for test and evaluation; they prefer to do their own evaluation.

. The role of the private firm is to optimize decisions and performance, especially from a financial standpoint. The government should be willing to pay for the additional costs.

. The situation is fine as it is; the government does exercise approval rights, but they do not and should not design tests.

. This question leads to the problem of certification. Government and industry actions should be resolved to establish independent certification.

V-3. To what extent should the government have access to basic evaluation data prior to incorporation in evaluation reports?

. The government should always have access to data to protect the industry. Whether the government has the necessary manpower and other capabilities required for analysis of that data is another matter.

. Access by the government to basic evaluation data prior to incorporation in evaluation reports can be done by analysis of progress reports and draft reports and the government's own data from the testing of the end product.

V-4. To what extent should the government itself direct particular evaluation tests?

. The government iself should direct particular evaluation tests to the extent of their knowledge and to the extent the government is assured they are obtaining reasonable results. The contractor is presumed to be selected for this talent and is better equipped to establish the commercialization by tests.

. If the government pays for it, the contractor will do it. The government should not direct specific evaluations; rather, it may specify certain tests.

. The government should do so very sparingly.

. The government should specify ends but not means.

V-5. For what period of time should the evaluation continue?

. Should be as specified by the contract; the longer the period the better. It should be at least one year.

. More thought is needed by the government to determine the most appropriate period. If you are trying to encourage industry acceptance, several years of evaluation is required.

. The period of time for government evaluation is negotiable. Performance testing is short compared to expensive endurance testing. Commercial success is better measured by industry than by government.

V-6. What termination rights should the government demand?

. Full termination rights can be demanded by the government, but it must recognize the termination costs. The contractor should be entitled to have the usual broad form Authorization and Consent clause included as part of the general provisions of the contract.

. The government should have this right, provided they are willing to pay termination damages, as specified by the contract.

V-7. What publicity procedures should the government employ?

. Publicity should be planned or structured in advance. ERDA must decide the extent to which it wants to exploit the technology and

should then proceed to do so. Once again ERDA must take on the role of a promoter in its public relations. ERDA is exercising very extensive control in most of its demonstration projects, perhaps more than is needed.

- Government permission should be required prior to publication.

- The government issues all press releases relevant to ERDA's programs and policies, and any such information for the public must have prior government approval before release.

- Any publicity should be the joint responsibility of the contractor and the government to avoid any possibility of embarrassment.

V-8. What control over dissemination of data should the government demand?

- The government should have no control over the dissemination of data; rather the government should aid in making the data available unless contra-indicated by patent requirements. Data should be fully disseminated to the public as a general rule, subject of course to restrictions on the use of such data as covered by the contractor's or subcontractor's patents. There should be a suitable delay before such dissemination to enable the contractor or the government, as the case may be, to file patent applications on inventions disclosed in such data. Further, whatever restrictive clauses were included in the contract as to the dissemination

of contracted data would have to be taken into consideration.

- The contractor will demand all data for himself, but with limited distribution until the final report, and with government approval. Interim data should be limited to statements of fact without interpretation to avoid premature disclosure.

- The government has total control over data dissemination.

- Data cannot be disclosed prior to determination of new patents under the terms of the contract.

Additional Comments

In addition to the preceding comments regarding specific questions in the protocol, the interviews went into various subjects of particular interest and concern to the parties interviewed. In that regard, the following comments are particularly worthy.

- One contractor has experienced problems in the transition from DOD IR&D and B&P type proposals to ERDA requirements. ERDA proposes to take a three-year backward look, which would make this contractor's B&P remuneration about one-third or one-fourth of its projections. The approach is the same as that followed by DOD, but the particular demonstration technology lies in a growth area in which business is anticipated to expand in the future, with corresponding B&P cost growth.

Also, ERDA IR&D policy presently demands ERDA ownership rights; DOD lets the contractor keep those rights. The contractor would prefer the DOD procedure.

. Private financial sources tend to shy away from new technology. They prefer to fund safe or known state-of-the-art technology. If the government must support untried technology, it must be prepared to pay a greater percentage of the cost of new technology demonstration programs, rather than the current 50 percent.

. Two common problems of demonstration projects are: their size, which does not permit a return on investment similar to that of a commercial scale plant; and the technical risk accompanying the new technology. As a compensating incentive, the government might consider offering contractors exclusive patent rights at some nominal royalty.

. In many instances, 50/50 cost sharing of demonstration projects is too severe from the industry standpoint. The actual proportion of project funding should be based on a situational assessment of demonstration risk. Not all pilot plants should be funded on a 70/30 basis, nor all demonstration plants on a 50/50 basis. The ratio might be unbalanced one way or the other, depending on risk. The actual sharing proportion could be part of the original proposal. One view is that the present 50/50 cost sharing is on the ragged edge of many, if not most, demonstration projects.

- There is a basic conflict in philosophy between ERDA, which is high-risk oriented in its technical development projects, employing unproved (that is, not state of the art) technology, and the private financial interests, which are accustomed to low-risk projects, well within the state of the art.

- The term "loan guarantee" is terribly unfortunate. It has the wrong association; for example, it reminds the public of the Lockheed situation, with connotations of a give-away program. This is bad publicity. It does not help the project in the public's eyes. The loan guarantee program does not help the short-term availability of capital either, but most ERDA programs are long term and should be viewed not as general programs to bail out failures, but to reward performance; that is, to provide adequate return on investment.

- A possible approach might be to offer a guarantee as to a certain return on investment after a 20-year period--much as DOD offers with its cost-incentive contracts--with an above-average return on investment as an incentive, if the project exceeds government anticipation.

- There are some who say that demonstration programs are unnecessary; rather, what is needed is good planning and better performance monitoring in the old fashion of Red Rayburn at DOD. However, a pilot or demonstration plant is useful in helping to reduce technical risks.

In the opinion of the present author, the Coalcon contract is a model which might well be followed elsewhere in similar large demonstration projects. The Coalcon contract required two weeks for its final intensive negotiation and runs 240 pages. It is very detailed, is quite acceptable to both Coalcon and the government, and appears to have foreseen most problems which have arisen subsequent to its signature.

* * * * *

APPENDIX A

INTERVIEW PROTOCOL

INTRODUCTION

The ERDA Task Force on Demonstration Projects as a Commercialization Incentive has been charged to advise the ERDA Administrator under what circumstances a demonstration project should be undertaken and, when it is, how it should be designed and administered so as to be most productive in "resolving technical, economic and social uncertainties." A "demonstration project" is defined to involve the operation of a complete energy system, in the expected commercial environment, for the purpose of resolving those technical, economic and social uncertainties. The objective of the ERDA demonstration program is to encourage early commercial adoption by the private sector of energy technology developed under ERDA auspices. It is for this reason that the demonstration projects must consider economic and social factors as well as the more conventional technical operations.

To aid its deliberations, the Demonstration Projects Task Force wishes to gain the benefit of private sector experience of contractors presently involved in a selected set of on-going ERDA demonstration projects. The purpose of this protocol is to serve as a guide for interviews intended to collect the desired information.

Because of the often confidential or proprietary nature of the information involved, the ERDA Task Force has assured International Planning Management Corporation (IPMC) that all interview information will be treated anonymously. The Chairman has also asked the IPMC interviewer to report orally to the Task Force any information which the interviewees would permit to be so reported with attribution but informally on an off-the-record basis.

After the interview, a confidential trip report will be prepared and returned to the interviewee for his review, modification and approval. These trip reports will remain the confidential property of IPMC and will not be divulged to the Task Force without prior written approval of the interviewee.

To guide the interview, we shall seek your inputs to the following specific questions which the Task Force has been asked to address. To facilitate our analysis, we ask that you compare your ERDA experience with DOD and NASA practice in answering these questions.

I. TECHNICAL DESIGN

I-1. The principal question to be answered is: What level of direction should the government exercise over demonstration project technical design?

I-2. To what extent should the government specify the particular technology to be employed in achieving the desired performance?

I-3. To what extent should the government exercise approval rights on drawings, materials, and/or procedures?

I-4. To what extent should the government exercise approval rights on project personnel?

I-5. To what extent should the government exercise approval rights on subcontractors?

I-6. To what extent should the government approve necessary change orders?

I-7. To what extent should the government exercise rights as to patents and proprietary data?

I-8. To what extent should the government demand royalty-free licenses for government purposes to inventions, patents and discoveries developed prior to or in the course of the technical design?

I-9. To what extent should the government be authorized access to contractor records?

II. SITE SELECTION

II-1. Under what conditions and to what extent should the government make site selection determination?

II-2. Under what circumstances should the government offer federal land for such purposes, and under what conditions?

II-3. Should the government offer or furnish financial protection or indemnification for public liability claims arising from demonstration operations on government lands?

II-4. To what extent should the government assist in the preparation of needed environmental impact statements for the particular site selected?

II-5. To what extent should the government facilitate procurement necessary for construction and other permits relating to the particular site selected?

II-6. What arrangements should be made to reimburse the public for demonstration project operations on federally-owned land?

II-7. Correspondingly, what particular ownership or leasing procedures are recommended for construction of plants on the site selected?

II-8. To what extent should the government participate in hearings and meetings with concerned citizen groups in the vicinity of the selected site?

III. RESOLUTION OF DEVELOPMENTAL PROBLEMS

III-1. What role should the government play in the resolution of development problems in general?

III-2. To what extent should the government demand inspection and acceptance rights?

III-3. To what extent should the government demand or monitor development tests?

III-4. To what extent should the government exercise approval over price adjustments or cost over-runs on specific items during construction?

III-5. To what extent should the government demand royalty-free use or other patent rights to processes evolved in solution to developmental problems?

III-6. To what extent should the government exercise approval and control of change of scope orders?

III-7. To what extent should the government exercise control over changes of schedule and performance criteria?

III-8. To what extent should the government demand inspection rights and access during the development period?

III-9. How frequently and how detailed should progress reports be required of the contractor for government review?

IV. OPERATIONS

IV-1. In general, what role should the government play during the operational phase of the demonstration?

IV-2. What should be the government's access and audit rights during the course of the demonstration project operation?

IV-3. What should be government recourse in case of default?

IV-4. What should be the government termination rights?

IV-5. What should be the government's policy regarding follow-on use of technology and technical changes during the course of the demonstration plant operation?

IV-6. To what extent should the government indemnify the contractor during the course of operations?

IV-7. To what extent should the government monitor environmental aspects of operations?

IV-8. To what extent should the government act as an interface between concerned public groups and the contractor during the course of operations?

IV-9. To what extent should the government be able to specify operating procedures and changes thereto during the course of operations?

V. EVALUATION

V-1. In general, what procedure should the government employ to insure that the results of the demonstration are accurately reported and fairly evaluated?

V-2. More specifically, should the government design the evaluation tests, or exercise approval rights over test design by the contractor?

V-3. To what extent should the government have access to basic evaluation data prior to incorporation in evaluation reports?

V-4. To what extent should the government itself direct particular evaluation tests?

V-5. For what period of time should the evaluation continue?

V-6. What termination rights should the government demand?

V-7. What publicity procedures should the government employ?

V-8. What control over dissemination of data should the government demand?

As noted earlier, we shall be seeking your answers to the preceding questions in light of your dealings with ERDA in relation to similar practice on DOD and NASA projects. In each instance, we ask that you compare ERDA's management practices as more restrictive, about the same, or less restrictive than those of DOD and NASA.

In addition to these questions, the Task Force will welcome your observations in all domains pertinent to its area of inquiry.

APPENDIX B

MAR 9 1976

Mr. A. Stanley Noss, President
Coalcon Company
One Penn Plaza
New York, New York 10001

Dear Mr. Noss:

I am writing you in my capacity as Chairman of the ERDA Task Force on Demonstration Projects as a Commercialization Incentive to request your company's cooperation in a study of management issues encountered by selected contractors in their conduct of certain ERDA-sponsored demonstration projects.

The Task Force has been charged by Administrator Seamans to advise ERDA as to the circumstances under which a "demonstration project" should be undertaken and, when it is, how it should be designed and administered so as to be most productive in "resolving technical, economic and social uncertainties." As part of our work, we have been briefed by ERDA personnel on four selected demonstration projects (the liquid-metal fast-breeder reactor, the automotive gas turbine, Coalcon, and solar heating and cooling), the histories of which, it is believed, will provide particularly important insights for the Task Force's deliberations.

Having heard the government spokesmen, we would now like to have the benefit of their industry counterparts' views of management issues of particular concern and importance to them which have arisen during the course of the demonstration projects. Because of the need for confidentiality and the desire of many contractors to remain anonymous, ERDA has arranged with a management consulting firm, International Planning Management Corporation (IPMC), to undertake a series of personal interviews with the counterpart companies' project managers to inquire into these management issues. It is in this regard that I am soliciting your assistance.

Because of the importance and corresponding urgency attributed by ERDA to the Task Force deliberations, we wish to complete our counterpart company review within thirty days. In this regard, may I ask your cooperation in making available your project manager for interview by IPMC at his earliest possible convenience. Dr. G. C. Sponsler, President of IPMC, will phone your office within the next week to make specific arrangements.

OFFICE ➤						
SURNAME ➤						
DATE ➤						

To advise you further as to the particular matters of concern to my Task Force, I have asked Dr. Sponsler to prepare the enclosed protocol to guide the interviews. As you will see, we are searching for specific instances of management issues which have arisen during the course of your demonstration project, particularly as they pertain to five issue categories: technical design issues, site selection issues, project development issues, project operation issues, and project evaluation issues. In addition to the specific information detailed by the protocol, I would of course, welcome any other advice you and your project manager might care to offer my Task Force.

I would also welcome your permission for Dr. Sponsler to brief individual Task Force members orally as to specific issues which you believe would be of particular value to us and with regard to which you would permit disclosure with attribution, on an off-the-record basis. Any and all other information will, of course, be held anonymously by IFMC and will be incorporated in their final report in combination with the other interviewees' data without specific source disclosure.

May I thank you personally and on behalf of my Task Force for your cooperation in this matter, which is of great importance to ERDA and the nation.

Sincerely yours,

Robert Charpie
Chairman

Enclosure:
Task Force membership list
Interview Protocol

WPC Job No. 1487-ISL-6
Disc ISL-1

OFFICE ➤						
SURNAME ➤						
DATE ➤						

Energy Research and Development Administration

DEMONSTRATION PROJECT TASK FORCE

MEMBERSHIP BY SECTORS

SECTOR

I. Product Development Companies: 5 members

*Mr. Robert C. Gunness, retired Vice-Chairman of the Board, Standard Oil Co. (Indiana)
*Dr. Edward E. David, Jr., Executive Vice-President, Gould, Inc.
*Dr. Denis M. Robinson, Chairman of the Board, High Voltage Engineering Corporation
Mr. Howard K. Nason, President, Monsanto Research Company
*Dr. Thomas Paine, Sr. Vice-President, General Electric Co.

II. A & E / Design - Construct Firms: 1 member

*Mr. W. Kenneth Davis, Vice-President, Bechtel Power Corporation

III. Investment Companies:

A. Commercial Banks: 1 member

Mr. William Cross, Jr., Executive Vice-President, Morgan Guaranty Ba

B. Investment Bank: 1 member

Mr. George Montgomery, Senior Vice-President, White, Weld & Co.

IV. Delivery Organizations:

A. Utilities: 2 members

Mr. Wallace B. Behnke, Executive Vice-President, Commonwealth Edison Company
*Mr. Robert A. Baker, Sr. - retired Executive Vice-President, Public Service Electric & Gas Company

B. Local Government: 1 member

Mr. Eli Freedman, City Manager, Rochester, New York

V. Regulators:

A. Federal: 1 member

Mr. John Quarles, Jr., Deputy Administrator, Environmental Protection Agency

B. State: 1 member

Dr. Allan Pasternak, Commissioner, California State Energy Resources Conservation and Development Commission

CHAIRMAN: **Dr. Robert Charpie, President, Cabot Corporation

NOTES

* Member, National Academy of Engineering
** Member, National Science Board

ADDRESSEES

Mr. A. Stanley Noss, President
Coalcon Company
One Penn Plaza
New York, New York 10001

Mr. Eugene Cafiero, President
Chrysler Corporation
12000 Lynn Townsend Drive
Detroit, Michigan 48231

Mr. Edward Spencer, President
Honeywell, Inc.
Honeywell Plaza
Minneapolis, Minnesota 55408

Mr. William Sneath, President
Union Carbide Corporation
270 Park Avenue
New York, New York 10017

Mr. Robert E. Kirby, Chairman of the Board
Westinghouse Electric Corporation
Westinghouse Building
Gateway Center
Pittsburgh, Pennsylvania 15222

APPENDIX C

WHAT CONSTITUTES SUCCESSFUL COMMERCIALIZATION OF THE LMFBR? *

We believe that "commercialization" of the LMFBR means achievement of an industry in which the LMFBR is purchased with projected bus bar costs, commitment schedules and warranties similar to those currently offered by the LWR vendors. Commercialization also means achievement of an industry in which LMFBR power plants are purchased in substantial numbers. This will require confidence on behalf of the public utility commissions that the bus bar costs are competitive with alternate concepts.

To achieve this overall goal of LMFBR commercialization, the following major conditions must be met:

1. The reliability of the system for power generation must be clearly established through successful operation of demonstration and prototype plants under practical utility conditions. Since the LMFBR is a relatively high capital cost, base load generator, it will not serve the needs of the utilities if it is subject to significant unanticipated downtime or excessively long maintenance periods. The cost of such lack of availability would quickly erase the basic economic advantages of the LMFBR. Further, by the time of commercial introduction of LMFBRs, the present generation light water reactors will have benefited by another decade of experience involving hundreds of plants, and these systems will be highly reliable.

2. The LMFBR must become an economic option for the utility industry as compared to other base load power generators available in the same period. Thus, the capital costs of the system must not be so much greater than competing systems that the fuel cycle cost advantage is wiped out or exceeded. Hence, the utility will choose the LMFBR because its overall total power costs will be less than other alternatives.

3. The contracting, procurement and financial aspects of the LMFBR must be established to be essentially the same as

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*Excerpt from Westinghouse Recommendations for a National Plan for Commercial Introduction of the Breeder Reactor in the Late 1980s (Oak Ridge, Tennessee: Westinghouse Advanced Reactors Division, n.d.), pp. 1-2.

they are for the alternate commercially available nuclear and fossil power generators. Thus, pricing practices, warranty provisions, and performance standards should all be fully competitive with the alternate systems. There must be a gradual shift of these responsibilities to industry during the pre-commercial development period so the sudden step increases in risk, not comparable with prudent business practice, are avoided.

4. The basic supply of fuel must be assured. The LMFBR is intrinsically the means by which fuel supply is extended for generations. However, for this to be effected practically, fuel fabrication, reprocessing, handling and transportation capability as well as effective waste storage facilities must be made available. Each of these facilities, in turn, must be licensable on a predictable basis so as to meet all safety and environmental requirements. The doubling time of the system must also be such as to sustain the growth of LMFBR capacity.

   Implicit in the requirements for near term economic power costs is the assumption of federal assistance to the fuel cycle comparable to that given to the LWRs. The federal assistance for the LMFBR is expected to take the form of providing fuel fabrication and reprocessing capability. The importance of achieving a fuel supply which does not require significant federal funding for expansion of the enrichment plants must be recognized. In this respect the proper balance between the economic value and achievement of a high breeding ratio must be determined since the lowest power cost may not necessarily be associated with the highest breeding ratio.

5. Adequate standards and design, fabrication and construction criteria must be defined which will assure high reliability and safety in the high temperature sodium environment of the LMFBR. This underlying body of technical standards is an essential foundation to achieving predictable licensability from both a safety and environmental standpoint. They are essential prerequisites to assuring continued reliability and safety as the industry enters the mass production stage.

6. Industrial design competence, manufacturing capability and construction capability must exist to fabricate the plant

components and to construct the plants reliably, predictably and economically. In order that the breeder fulfill its role of extending uranium fuel supplies while supplying electrical generation capacity needs, a large number of plants must be built in the commercial phase. The magnitude of the task is such that a major industrial base must be in place to assure its successful completion. A necessary corollary to this capability will be sufficient availability of the key materials required and sufficient numbers of skilled personnel in the design, fabrication and construction fields.

7. The licensability and environmental compatibility of the LMFBR must be established with the regulatory agencies on the basis of definitive analyses and experimental data and this technical position communicated to gain public acceptance. The utilities must be assured that the plant is licensable and can be licensed on a schedule on which they can depend. By the time the LMFBR is introduced, this problem will have been solved for the present generation nuclear plants or there will be no nuclear industry whose expansion the LMFBR is to serve. Utility executives will therefore not be willing to take major licensing risks on the LMFBR unless they have no other choice for baseload power generation.

8. A nucleus of trained utility operators and management must be available with specific programs for the training of additional personnel to serve the growth of the industry.

Each of the above eight conditions must be represented in the program established to reach successful commercialization. This report summarizes the elements of such a program, placing special emphasis on the reactor aspects on the assumption that the other LMFBR organizations who are also answering these questions will tend to emphasize the areas in which they are actively engaged or taking the lead.

APPENDIX E

PRESENTATION ON DECISION ANALYSIS TO THE DEMONSTRATION PROJECT TASK FORCE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

W. HOWARD COOK
D. WARNER NORTH

Decision Analysis Department
Stanford Research Institute
Menlo Park, California

December 3, 1975

SRI PRESENTATION

AFTERNOON SESSION

(1:15 p.m.)

DR. CHARPIE: To start with, I am now going to call on the Stanford Research group, Dr. North.

DECISION ANALYSIS - APPLICATION TO DEMONSTRATION PROJECT PLANNING

DR. NORTH: We are going to present to you now decision analysis as a methodology that may have application to demonstration project selection and planning.

(Slide: "Overview of Presentation.")

Now in this presentation we're going to start off by spending a few minutes introducing ourselves, talking about what decision analysis is, and how it relates to other quantitative planning methodologies.

Then we are going to present a basic approach to the problem of demonstration project planning. We are then going to illustrate this approach with an example drawn from an actual project carried out by SRI as an application of decision analysis. The project was for a commercial client, and it was not in the energy field. Rather it was a decision involving demonstration of an agricultural chemical. We will use it to illustrate the approach.

Then we will turn our attention to the difficulties that are involved in using a decision analysis approach on energy-related demonstration projects for ERDA and the federal government.

OVERVIEW OF PRESENTATION

I. INTRODUCTION AND BACKGROUND: WHAT IS DECISION ANALYSIS?

II. AN APPROACH TO ANALYSIS OF DEMONSTRATION PROJECT DECISIONS

III. AN APPLICATION OF DECISION ANALYSIS TO A DEMONSTRATION PROJECT DECISION

IV. DIFFICULTIES IN ANALYZING TO ERDA DEMONSTRATION PROJECTS, AND WAYS OF ADDRESSING THESE DIFFICULTIES

V. SUMMARY: A DECISION ANALYSIS APPROACH FOR EVALUATING DEMONSTRATION PROJECTS

We will illustrate possible ways of addressing these difficulties using specific examples from SRI energy-related projects. We will conclude by summarizing the main points of the decision analysis approach that we see as being relevant and helpful on demonstration projects.

(Slide: "Introduction and Background: What Is Decision Analysis.")

First a few words of introduction about decision analysis.

(Slide: "Decision Analysis.")

Decision analysis is a quantitative planning methodology whose objective is to help a decision maker or a decision making authority to gain insight into difficult decision problems.

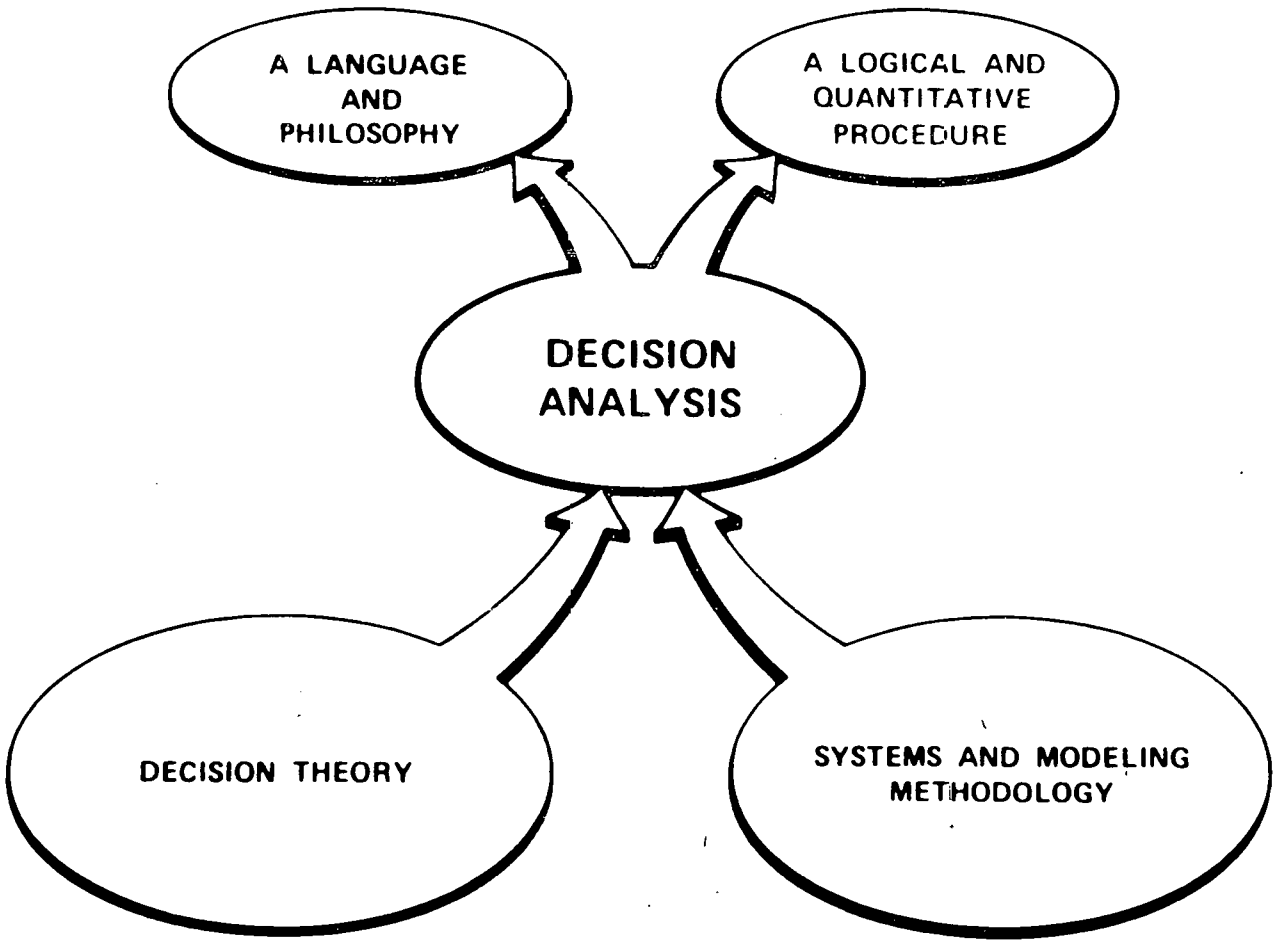
Now what makes decision difficult? Typically one important aspect is complexity. Many factors need to be taken into account, and it is difficult for the decision making authority to do this in a consistent fashion.

One of the techniques that has been found useful in dealing with such complicated situations is to set forth a formal representation of these factors and how they relate to each other. Very often this formalism can be a set of mathematical representations, which act as a summary of the knowledge about the various factors and their relationships. The use of mathematics as a formalism for dealing with complexity goes under many names: operations research, systems engineering, systems analysis, mathematical models, cost-benefit analysis,

I

INTRODUCTION AND BACKGROUND:

WHAT IS DECISION ANALYSIS?


A LANGUAGE AND PHILOSOPHY
A LOGICAL AND QUANTITATIVE PROCEDURE
DECISION ANALYSIS
DECISION THEORY
SYSTEMS AND MODELING METHODOLOGY

Now what does a decision maker gain? What does a decision making agency get from having this sort of planning methodology employed?

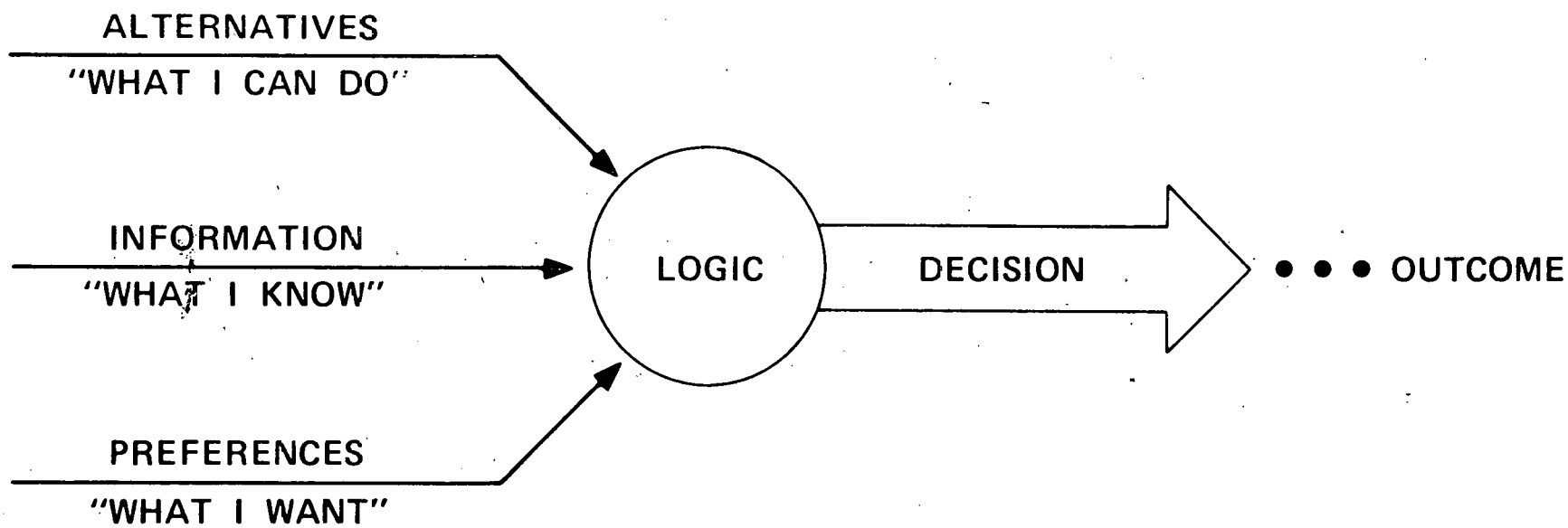
Well, one obvious result is that the methodology provides a way of getting answers: specific recommendations on a course of action to be followed in that specific decision situation. But few decision making individuals or decision making entities are willing simply to accept an answer that comes out of an analysis. They want to understand the basis for that answer.

Further, decisions are often taken not by one individual but rather by an organization that is composed of many different individuals with many different points of view. Much of the value of decision analysis is not to gain answers but rather as a process or a way of communicating. It gives a framework for bringing information together so that all the factors that bear on the decision can be integrated. This framework allows those responsible for the decision to see the relationships among the factors and to understand the importance of any disagreements that may exist about specific factors bearing on the decision addressed.

(Slide: "Elements of Good Decisions.")

Now the central idea of decision analysis is a very simple one. Our assumption is that in a world characterized by uncertainty the best way of achieving the aims of the organization or of the individuals in their decision making, which is to get good outcomes, is to make decisions that are logically consistent with the information that is available, with the decision alternatives, and with the objectives, preferences or goals of the organization.

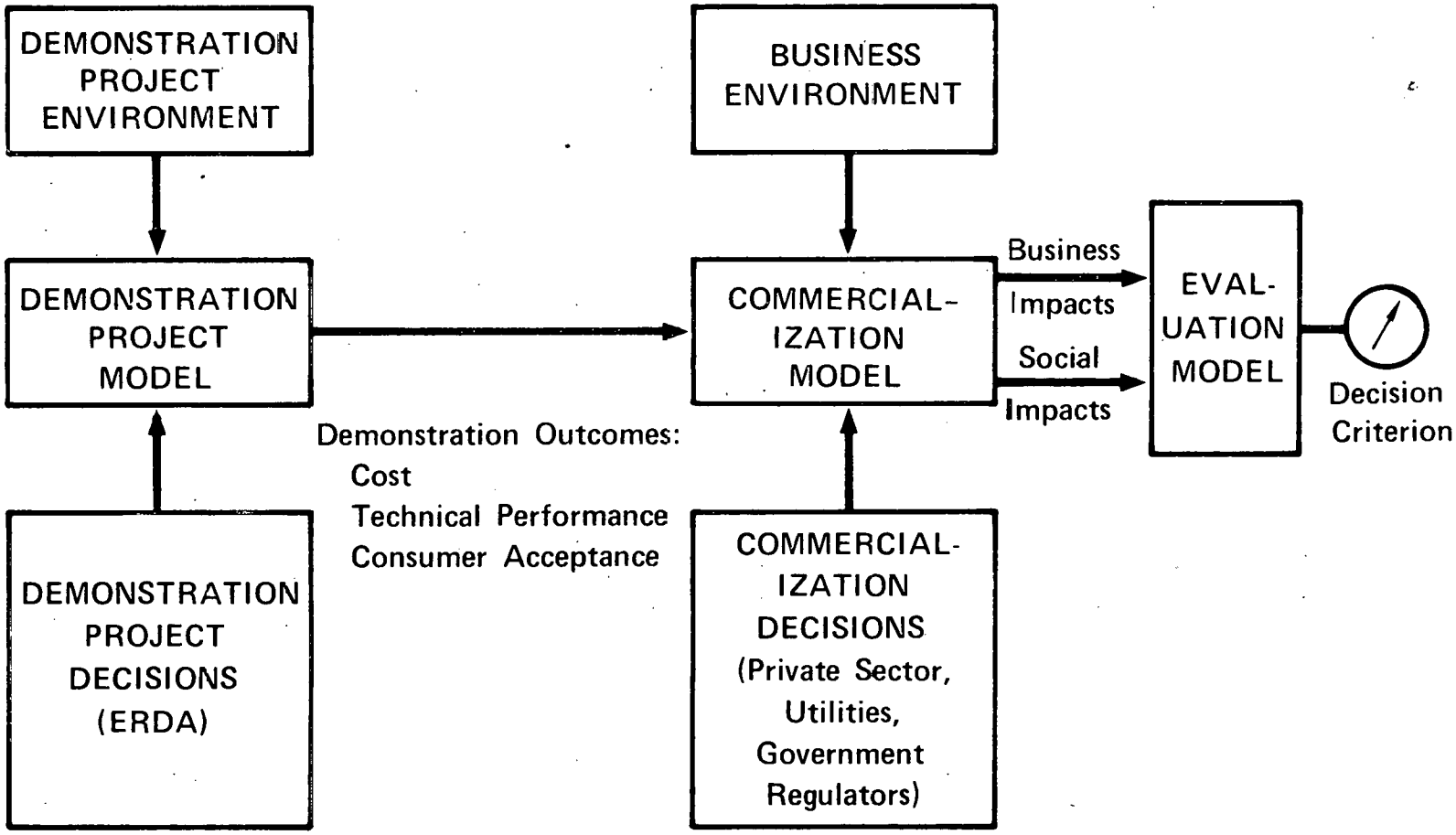
ELEMENTS OF GOOD DECISIONS



II

AN APPROACH TO ANALYSIS OF DEMONSTRATION PROJECT DECISIONS

BASIC STRUCTURE: DEMONSTRATION PROJECT DECISION ANALYSIS



which we have defined decision analysis. Rather we must consider at the outset that there are two stages of decision making.

The first stage is demonstration project selection, and in the case we are addressing here in this meeting, these are demonstration projects confronting ERDA.

The second stage is a decision as to whether the technologies being demonstrated here will be applied on a large commercial scale. We will call this the commercialization decision.

Typically the commercialization decision is not going to be made by ERDA or an other agency of the federal government. Rather the decision will be made by private firms and by regulated utilities. The decision may be heavily influenced by the action of government regulatory bodies.

So in our approach to demonstration plant decisions we must include at least two sets of decision makers. Our goal must be to assist in the decision making process involving these two stages.

We begin by examining the decisions on demonstration projects and then we build models to predict what may happen as a result of carrying out a demonstration project. These demonstration outcomes may be uncertain, and so we will examine a spectrum of possible results that might occur. The demonstration outcomes may be plant capital and operating cost; they might involve technical performance; they might relate to consumer acceptance.

Following the demonstration outcome is the decision on commercialization. Given the information obtained in the demonstration project, what will the decision makers do in terms of deploying that technology on a large commercial scale?

Again we want to model the consequences, this time of the commercialization decision. On one hand there will be business impacts to understand; on the other hand there may be environmental, political and social impacts that are also important in the mind of the decision makers who will be making the demonstration decision or the commerialization decision.

These outcomes need to be evaluated from both points of view. Both sets of decision makers will be making their decisions based upon the eventual impacts of the commercialization of the technology.

Now what makes the decisions difficult?

We have uncertainty in the demonstration outcomes. There has been a lot of discussion already today relating to these uncertainties. Quite often we talk about the "risk" of a demonstration project. Will the capital cost be far higher than estimated? This is an example of one uncertain aspect of the outcome of the demonstration project.

However, there are other important aspects of risk not related to the demonstration outcomes. In the energy area in particular we need to consider the business environment for the commercialization decisions. It may be that much of the uncertainty that generates the "risk" as perceived actually relates more to the business environment. Changes in fuel price may strongly affect the plant's earnings. These uncertainties may outweigh the uncertainty on the technical performance or the capital cost of the demonstration plant, as being crucial to the commercialization decision.

We also need to consider how the business environment at the commercialization stage may relate to the business environment at the demonstration project stage. If we're concerned, for example, with issues on consumer acceptance, is the demonstration located in such a place and carried out in such a fashion that it will give us insight as to the market for the commercialization stage of the technology?

(Slide: "Issues on Demonstration Project Decisions.")

On the following slides we identify some of the issues in commercialization decisions. Let us look at the right-hand side of that last slide ("Basic Structure"). Our focus is on the need to understand the implications of an outcome from a demonstration project. Given what happens in the demonstration, how will the commercialization decision be made?

What aspects of the business environment as contrasted to the outcome from the demonstration project are going to be important? For example, how do the economics of the technologies in the demonstration project relate to other technologies that might compete with them? What is the role of government regulation, both on the technology being demonstrated and on alternative technologies, and how will that influence the commercialization decision?

Is there a value to the demonstration project itself? Even if you knew that commercialization would not occur, are there other gains, for example, insight into future technologies beyond the current stage, that make that project worthwhile? This is another question that may need to be addressed.

ISSUES ON DEMONSTRATION PROJECT DECISIONS

- NEED TO UNDERSTAND IMPLICATIONS OF OUTCOME FROM DEMONSTRATION PROJECT:
  - Given Demonstration Outcome, How Will Subsequent Commercialization Decisions Be Made?

  BUSINESS ENVIRONMENT:
  - Position of Demonstration Technology Compared to Alternative Technologies.
  - Government Regulatory Policies That Might Promote or Inhibit Demonstration Technology in Commercial Application.

  COMMERCIALIZATION DECISIONS:
  - How Will These Decisions Be Made, and How Do They Depend on Outcome of Demonstration Project?
  - Is There a Value to the Demonstration Outcome Even If It Is Clear That Commercialization Will Not Occur?

(Second Slide: "Issues on Demonstration Project Decisions.")

Let us now look at the left-hand side of the "Basic Structure" slide. We want to understand the elements that lead to the demonstration project outcome. What we often find in the work that we have done both with government clients and with private firms is that much of the client's thinking on research, development and demonstration decisions is focused here. Emphasis is placed on the technical features influencing the demonstration outcome, and little attention is given to the business decisions subsequent to the development outcome.

We have to understand what outcomes are important for the subsequent commercial decision. What do we really want to learn out of this demonstration project in order to be able to make the decision at the next stage?

The decision on the demonstration project itself may have the character of whether or not to proceed with this specific project. If so, what are the technical and institutional characteristics? What institutional arrangements are appropriate for carrying out the project: Where should it be located? What specific technologies should be used? What monitoring facilities should be included so that the important questions are addressed in this demonstration project and this information is available for the subsequent decisions?

If the decision is not to proceed, it may be that more R&D in specific technical areas would be appropriate. Perhaps it may be appropriate to do further studies on the business environment to understand the character of the market and to understand issues relating to the environment or the public acceptance.

ISSUES ON DEMONSTRATION PROJECT DECISIONS

- NEED TO UNDERSTAND ELEMENTS THAT LEAD TO DEMONSTRATION PROJECT OUTCOMES.

  What Outcomes Are Important for Subsequent Commercialization Decisions?

  Decisions on Demonstration Project:

  - Whether to Proceed?
  - What Institutional Arrangements for Government-Contractor Relationship?
  - What Site, Specific Technologies, Monitoring Should Be Used;
  - Should More R&D Be Done Prior to a Demonstration Project?
  - Should Better Understanding of Business Environment and Public Acceptance Be Sought Prior to a Demonstration Project?

(Slide: "Motivation for a Formal Planning Process for Demonstration Projects"

Finally, we need to look at the whole "Basic Structure" slide as a planning process and to understand it as communication; that there is a need to communicate between the two sets of decision makers, the decision makers at the demonstration project level and the decision makers on the commercialization level.

As far as the federal government is concerned it is important to have coordination between the agencies responsible for the development project and the agencies that will be responsible for the regulation of this technology at commercial scale. These agencies should integrate their planning so that they understand what the other agency is going to do.

Management of risk and reward is especially important in this situation where there are two sets of decision makers. First of all, how can the risk be defined and illustrated and summarized for decision making purposes? In the example to follow we will show you a method for accomplishing this.

Second, given two decision makers, how do you allocate the rewards if the demonstration turns out to be very successful, and how do you allocate the responsibility and the losses if the outcome is bad?

It is not clear how this risk sharing will be worked out. But both sides need to understand the solution in advance. Coordination planning of the demonstration project and commercialization requires a knowledge of how the risk and reward will be allocated. Private industry is unlikely to engage in projects when it believes that profits from a good outcome will be taken away by the government, but losses from a bad outcome will be its own responsibility.

MOTIVATION FOR A FORMAL PLANNING PROCESS FOR DEMONSTRATION PROJECTS

- NEED FOR COMMUNICATION BETWEEN THOSE RESPONSIBLE FOR DEMONSTRATION PROJECT AND THOSE WHO WOULD BE RESPONSIBLE FOR COMMERCIALIZATION DECISIONS.
  - Integration of Development and Regulatory Functions of Government; Better Interagency Co-ordination.
  - Management of Risk and Reward for Demonstration and Commercialization Stages
  - Inter - Technology and Inter - Process Competition; Need to Set Priorities and Timing of Demonstration Projects Appropriate to Needs of Energy Economy
- NEED FOR COMMUNICATION ON BASIS OF FEDERAL GOVERNMENT DECISION WITH CONCERNED PARTIES:

  (State and Local Agencies, Consumers of Energy, Industries, Environmental Groups, Other Special Interests)

III

AN APPLICATION OF DECISION ANALYSIS TO A DEMONSTRATION PROJECT DECISION

DR. COOK: In the series of slides that we go through from this point on we are going to be talking about identifying the elements that are involved in planning projects of various scales, using the decision analysis methodology.

(Slide: "Application of Decision Analysis to a Demonstration Project on a New Agricultural Chemical Project.")

The particular case that I want to talk about came from a small, highly technical chemical manufacturer who had a great deal of research capability. This company had come across a couple of potential new products for the agricultural chemical business. The company had no previous experience in marketing an agricultural chemical product; their existing product lines were in entirely different industries. Nonetheless, their technically trained management was enthusiastic about the potential of these chemicals to enhance farm productivity.

We shall label the two chemicals Compound A and Compound B. Obviously there was a decision to be made, whether to pursue development or to abandon the project and have no demonstration. In order to arrive at a basis for commercialization it was evident that some form of large scale demonstration on farms needed to be made. Not only was the demonstration needed to attract attention, but also to test certain of the properties of the compound technically, environmentally, and to determine the economics of its use.

Compound A was further developed than Compound B, but B appeared more potent. A number of years of use were needed to establish credibility of either product, and the demonstration project would be very costly compared to the resources of the company. Demonstration of both A and B could be ruled out.

APPLICATION OF DECISION ANALYSIS TO A DEMONSTRATION PROJECT ON A NEW AGRICULTURAL CHEMICAL PRODUCT

- Alternatives: Commercial Scale Demonstration on U.S. Farms of Compound A, Compound B, or Abandon (No Demonstration)

- Compound A is Further Developed
  Compound B is More Potent Than Compound A

- The Demonstration Project will be Lengthy and Expensive Relative to the Company's Resources

- Potential Market for the Agricultural Chemical Product is Very Uncertain

As I mentioned before, this company had no real background in the agricultural chemical market. They could identify a product that was potentially competitive, but they did not know a great deal more than that. And they were uncertain about the size of the market for this type of agricultural chemical.

One source of uncertainty had to do with the fact that the particular chemical that we are talking about had potential in both the domestic market and in international agriculture. Actions of the federal government were important because of government programs for aiding agriculture in less developed countries as well as possible government regulation affecting the domestic market.

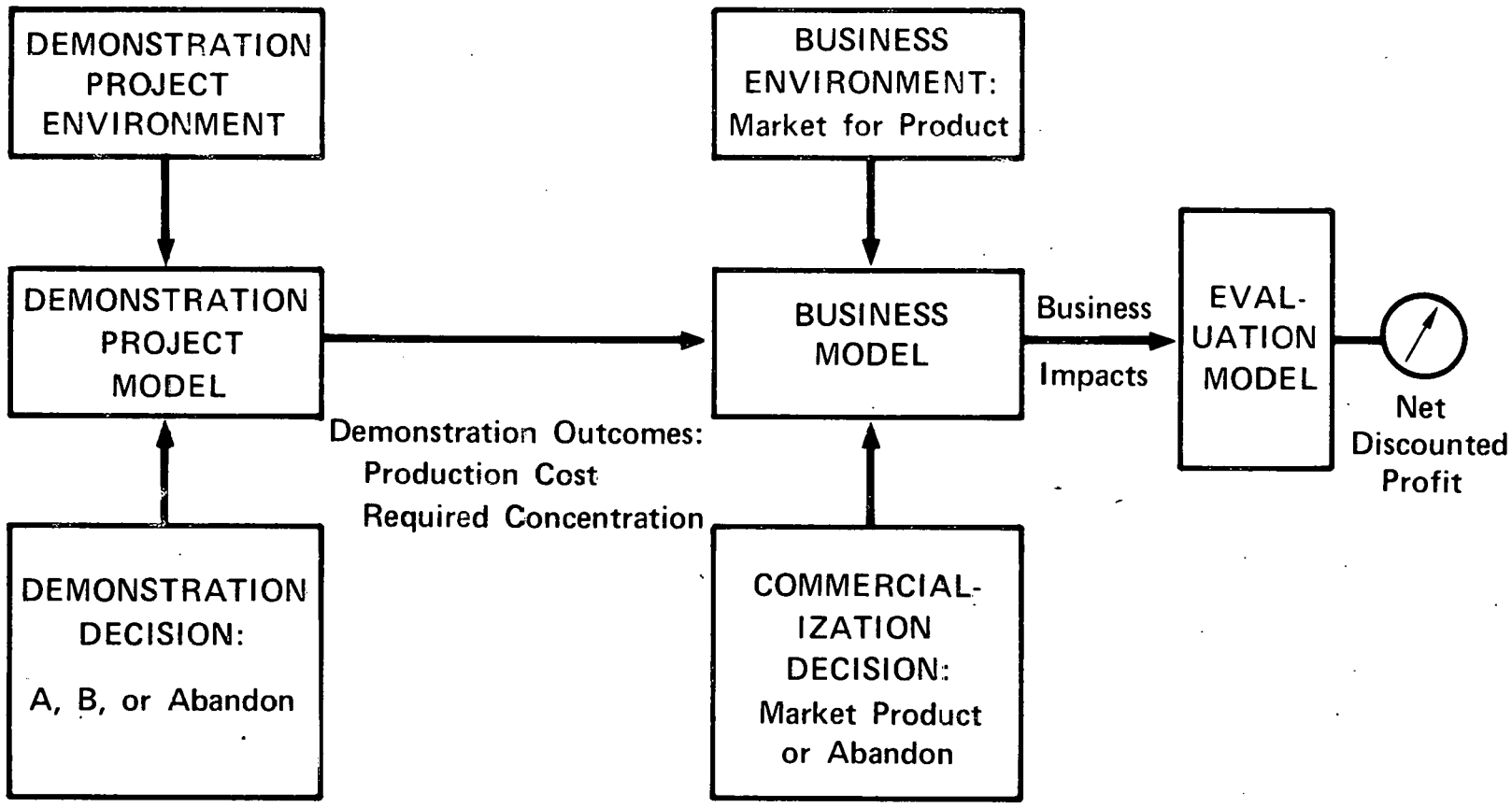
(Slide: "Agricultural Chemical Demonstration Project Decision Analysis.")

The slide that I'm showing here now is completely analogous to the one Warner showed just a few minutes ago except that this is in the context of the specific situation that this company faced.

You notice as in the other case we have a demonstration project and a business model in this diagram. (I would like to add parenthetically, at this point that the discussion that went on this morning concerning the Experimental Technology Incentives Program dealt with only a project concerning the demonstration aspect of the program. There is another companion program which SRI is conducting along with RAND covering the entire commercialization program.

Here is the commercialization area. A lot of the issues that came up as questions about that this morning will be developed in that total program.)

AGRICULTURAL CHEMICAL DEMONSTRATION PROJECT DECISION ANALYSIS



Now back to the example.

In the case of the environment for the demonstration, the environment for this situation consists of what they knew about the product cost, the environmental situation, the ecological effects, how many dollars and scientific resources it would take to carry out the demonstration, and so forth.

The main outcomes that would be observed from the demonstration program were the production cost and the required concentration of the chemical.

The point I want to make here -- and you'll see this time and time again in these projects -- is that these are observables from the demonstration program. The necessary observables for the commercialization decision had to do with the marketplace on which they had relatively little information. This is often the case in new products developed by private industry.

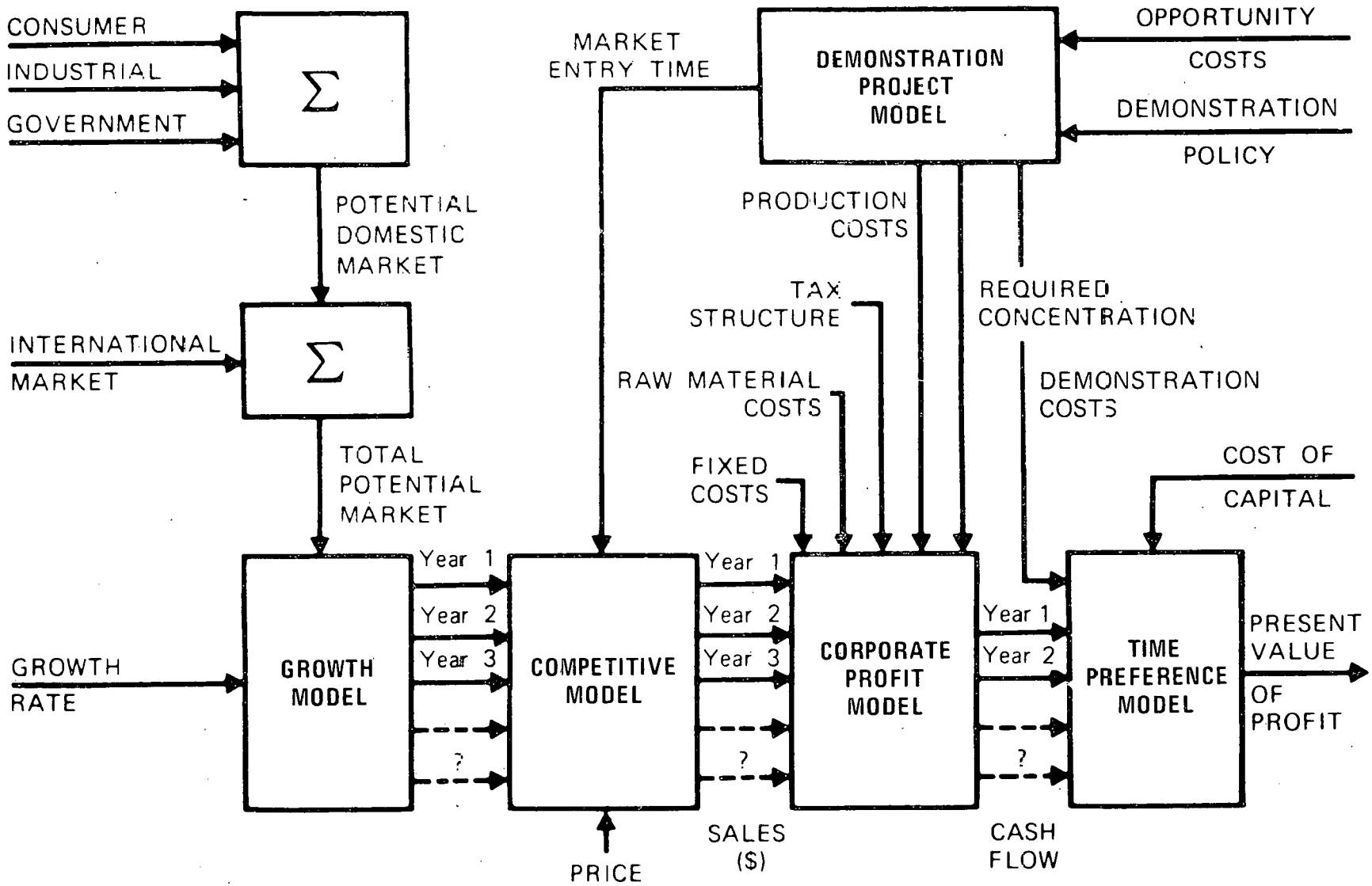
The business environment was complicated by the presence, both domestically and in the foreign market, of the federal government.

So decisions with regard to commercialization need to take account of these elements, which we have incorporated in a business model.

I want to show you now a business model. I don't want to frighten you, because despite the complexity of the diagram it is just a straightforward business analysis. It is shown in a logical form here that would be appropriate for communicating with management about the detailed structure involved.

(Slide: "Structural Model.")

STRUCTURAL MODEL



Let me identify some of the elements we saw in the earlier slide.

This is the demonstration project decision. It involved a demonstration project for Compound A or Coupound B or doing nothing, so this was the policy decision required.

Let us examine how the market was represented. Starting at the top left-hand side you see the domestic market, which is assessed by the kind of segmentation that would be made in any new product business situation. Because the international market was so uncertain as far as the experts were concerned it was represented by a multiplier of the domestic market. The total market was the sum of the two. Finally, the growth model was developed to represent how the market would change over time. This market model is completely analogous to the kind you would use in a business plan for your own particular organization.

A competitive model is identified here because there was an existing market and price structure and so on for existing products. The specifications for the existing agricultural chemicals were reasonably well known, and it was not difficult to model competitive reaction.

The corporate profit model in the lower corner deals with those elements that are involved in calculating the profit to the corporation: production cost, tax structure, raw material costs, and fixed costs associated with producing and marketing the product.

Sales were identified from the market model and then a discounted cash flow type of analysis was carried out to compute profit.

In every respect this is strictly a straightforward model of the business that this company was considering entering.

(Slide: "Use of the Structural Model.")

Using the experts in this particular organization we developed an evaluation first to see what elements were important. We could have rushed in and given them general rules for establishing a demonstration program. However, the first issue was to find out what was important to their business, given the many uncertainties involved.

You see here a list of items which would be identified as a result of the analysis based on the diagrams we saw before. A number of areas are identified that we found to be sensitive in the demonstration decision.

The most important one are ones are international market size, market growth rate, domestic market size, required concentration and production cost. These are items we have mentioned before, and it is not surprising that they turn out to be important for the decision.

For example, the international market is uncertain over a range from 3 to 8. Recall these numbers represent multiples of the domestic market. The marketing consultants were very uncertain about the international market, and they felt that reasonable estimates were between 3 and 8 times the domestic market.

The market growth rate ranges from -6% to +10%. Included in this assessment is the uncertainty about what federal regulations might do to this class of chemicals. In the domestic market size you see a similarly wide range, based on the same kind of reasoning.

The next two entries are technical variables, of the sort where the judgment normally comes from technical departments of companies.

USE OF THE STRUCTURAL MODEL

- SENSITIVITY ANALYSIS

  IDENTIFIES CRUCIAL STATE VARIABLES

STATE VARIABLE	RANGE		RANGE OF PRESENT VALUE OF PROFIT (MILLIONS)		Δ
INTERNATIONAL MARKET SIZE	3 to	8	-6.0 to	10.0	16.0
MARKET GROWTH RATE	-6%	+10%	-5.3	4.1	9.4
DOMESTIC MARKET SIZE	2.4M	6.0M	-4.4	3.5	7.9
REQUIRED CONCENTRATION	0.0005%	0.5%	1.3	-6.0	7.3
PRODUCTION COST	$.32	$1.12	2.5	-3.1	5.6
FIXED MARKETING COST	1.0M	2.0M	.6	-2.8	3.4
DEMONSTRATION TIME	2 YRS	5 YRS	1.3	-1.2	2.5
DEMONSTRATION COST	$3.5M	$5.5M	1.1	-0.9	2.0
RESEARCH OPPORTUNITY COST	0	$400K	.1	-0.3	0.4
RESEARCH COST	$450K	$750K	.2	-0.1	0.3
DISCOUNT RATE	6%	20%	0.1	-3.1	4.0

On the right side of the slide you see ranges of present value of profits calculated from the structural model we described a minute ago. These ranges indicate the relative importance of the variables.

On the basis of these results we were at a point where we needed to define the next steps to deal with the decisions which this company faced on the demonstration project.

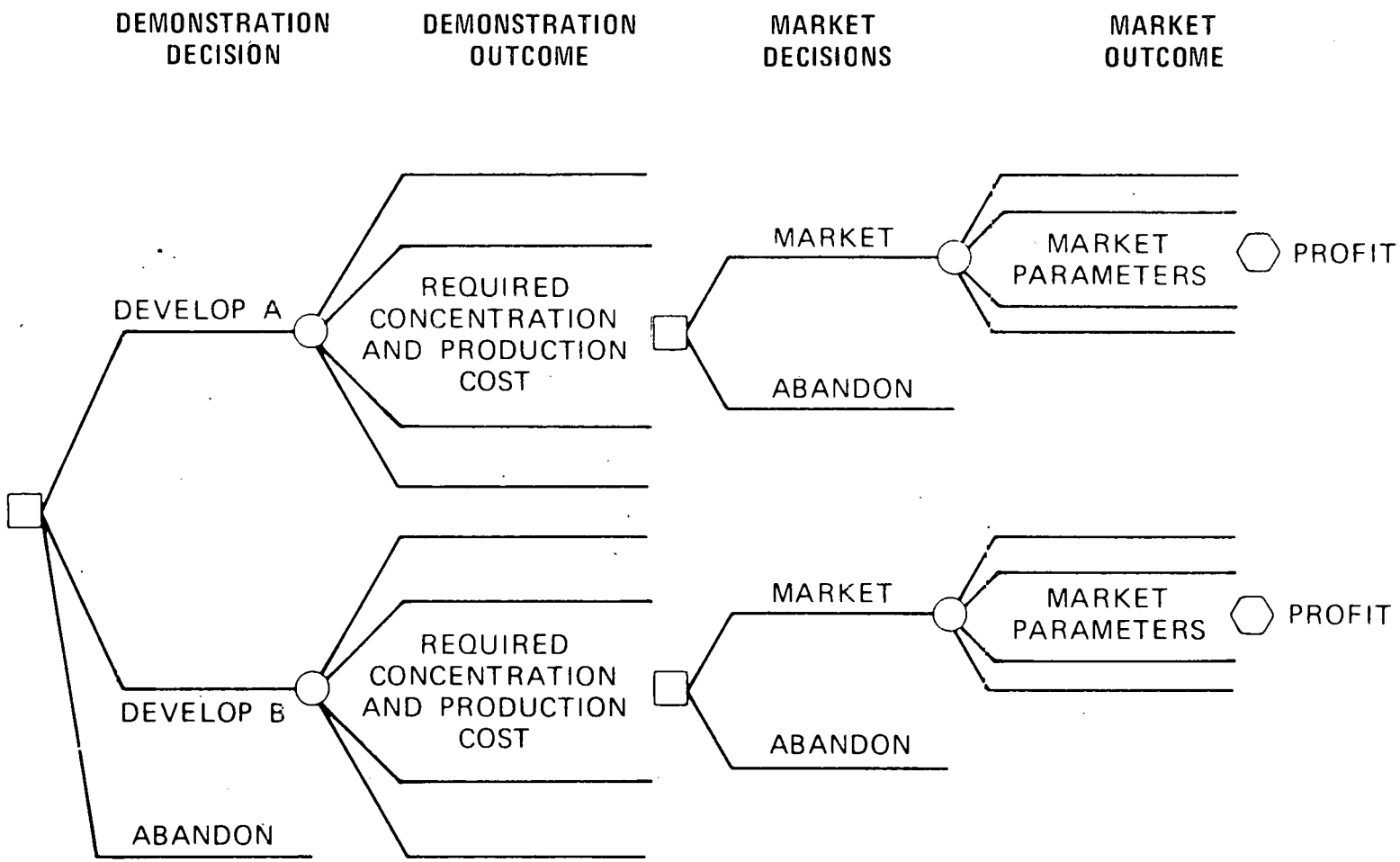
(Slide: "Probabilistic Analysis.")

Inevitably in the decision analysis methodology you come across a decision tree. Here in simple form we have reduced a more complex decision tree to show its structure. The first decision point, shown by a square, indicates three alternatives, to develop A or B, or to abandon. Next comes the uncertain demonstration outcome, shown by a circle. At this stage probabilities are assigned to levels of concentrations and costs, representing different possible outcomes from the demonstration. For example, there might be a probability of 20% of a cost of below 60 cents per pound of the material; there might also be another probability, of say, 10%, that the material would cost above $1.00 per pound in commercial quantity.

Subsequent to the demonstration outcome, a decision has to be made to market or to abandon. The time comes when people have to decide what to do. And in the nomenclature of the tree we show two branches for the alternatives, market or abandon. The next stage represents the market uncertainty; if you market, various sales levels might occur with probabilities reflecting expert judgment of the likelihood of that market outcome.

PROBABILISTIC ANALYSIS

SEQUENTIAL ALTERNATIVES AND OUTCOMES



Now each path through the tree of decisions and outcomes specifies the inputs for the profit model. We can calculate the profitability of a large collection of scenarios for how the business might evolve.

Let us look at the components that characterize each scenario. These are just the sensitive variables we dealt with before. I want to very quickly reproduce this slide ("Use of the Structural Model") to identify the components in that. In this case there is a component of production cost and a component of the required concentration. These characterize possible outcomes of the demonstration project. In the case of the market parameters there's a component dealing with the size of the domestic market, the growth rate of the domestic market, and the international market. These characterize what may happen if the product is marketed.

These components make up the structure that's involved in the decision tree which you see on the slide ("Probabilistic Analysis").

Now you might ask how we collect the information for this type of analysis. We sit down with the experts involved in making the decision, management or persons they designate. We structure the problem and then have them assess the probabilities of different outcomes occurring in the demonstration project, based on what they know now. I must stress that this is with what they know now, because this is the stage where you begin. You begin with where you are, with the understanding you now have, and you then ferret out a deeper understanding of the problem as you proceed in this kind of analysis.

(Slide) "Profit Lottery for Alternative B."

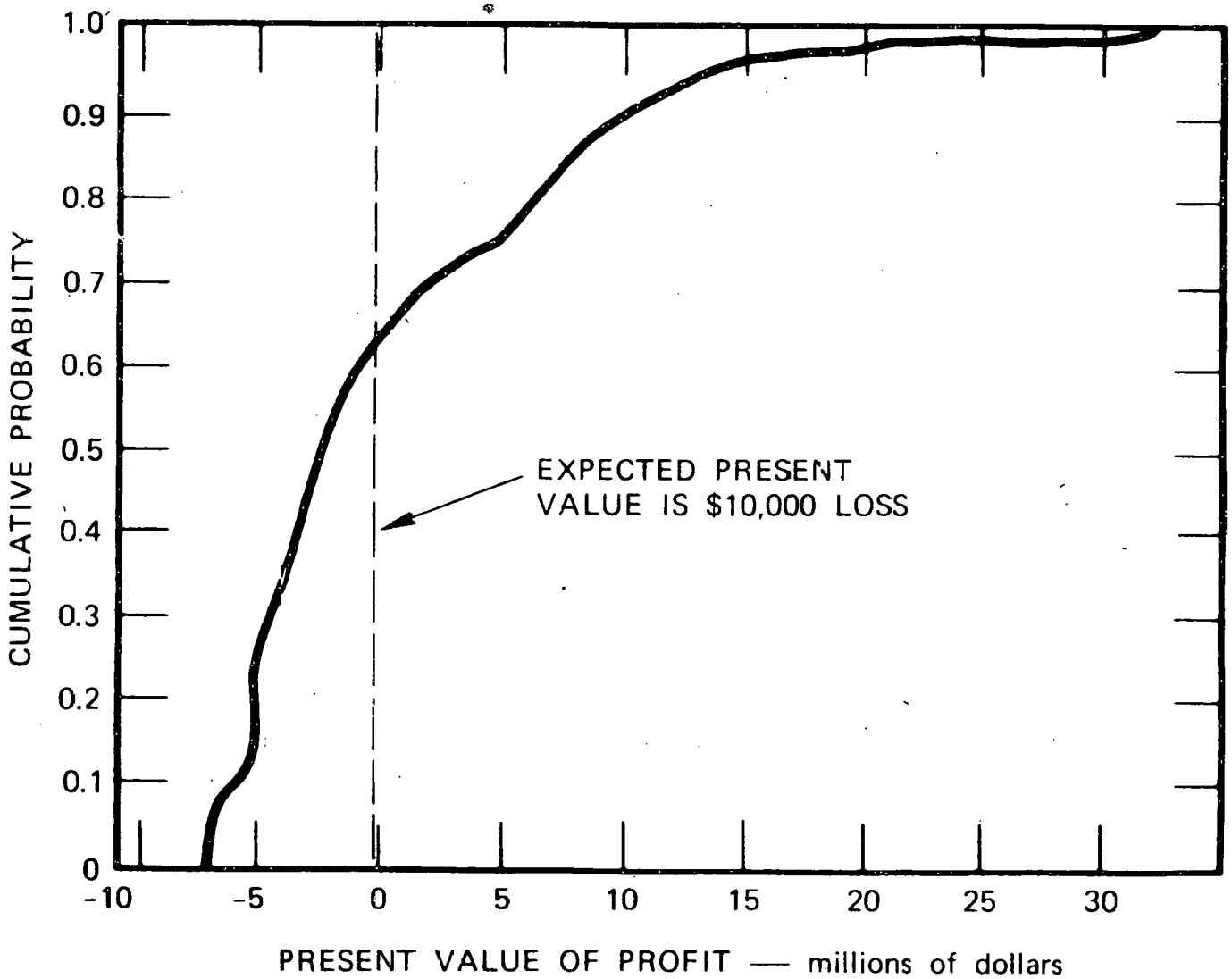
Now when you get through with such a tree you need to come out with calculations of profitability. In this case the discounted cash flow for the business venture is calculated for many scenarios, and the probability distribution is given of the results. That's what you see in this diagram, which summarizes the results for alternative B.

This diagram has a lot of information in it, so it deserves careful examination. First there is some probability here (two chances out of ten) of something like a five million dollar loss for the business. Similarly, there's a probability of about 60 percent that the company will show a loss, that is, the profit will be equal to or less than zero in this situation. There's a probability of .9 that you will not make more than ten million dollars, or equivalently, there is a probability of 10 percent of at least a ten million dollar profit.

Now the implications of this diagram are far richer than one might expect, for some interesting reasons.

How do we judge whether to proceed with the demonstration project? You say, "The expected value is a $10,000 loss. It's a tossup whether you do anything with the business or not." But the point I want to make here is that in businesses where you're uncertain, to calculate a single value

PROFIT LOTTERY FOR ALTERNATIVE B



approach to the profitability of the business may be really disastrous. If I had just calculated the expected or nominal case I would have ended up near zero. I might have concluded there is a small profit and made a decision to go ahead based on that number.

In this case there was some probability, two chances out of ten, of losing five million dollars. This company was not a large enough company to be able to lose five million dollars without some serious problems.

On the other hand, there is a small probability, one chance in ten, that it was a real money maker from their standpoint.

So what do you do in situations like this? Remember, this is a summary of the state of knowledge about their business venture at this point in time.

Well, you might say: "Suppose I had perfect information about the losses in this business --." If I could find somebody who could tell me whether I would enter into a loss situation so I could avoid it, I might make a dramatic profit with this business venture.

I could eliminate that part of the line you see to the left of zero. And if you did that the expected value of the revised probability distribution would be something like three million dollars. That's a dramatic change from where you were before.

Now the question is, how can you apply the information that you have about the business to evaluate further information that might change the decisions that you make in the business, so as to achieve a better outcome than you had before?

(Slide: "Calculation of the Value of Further Information.")

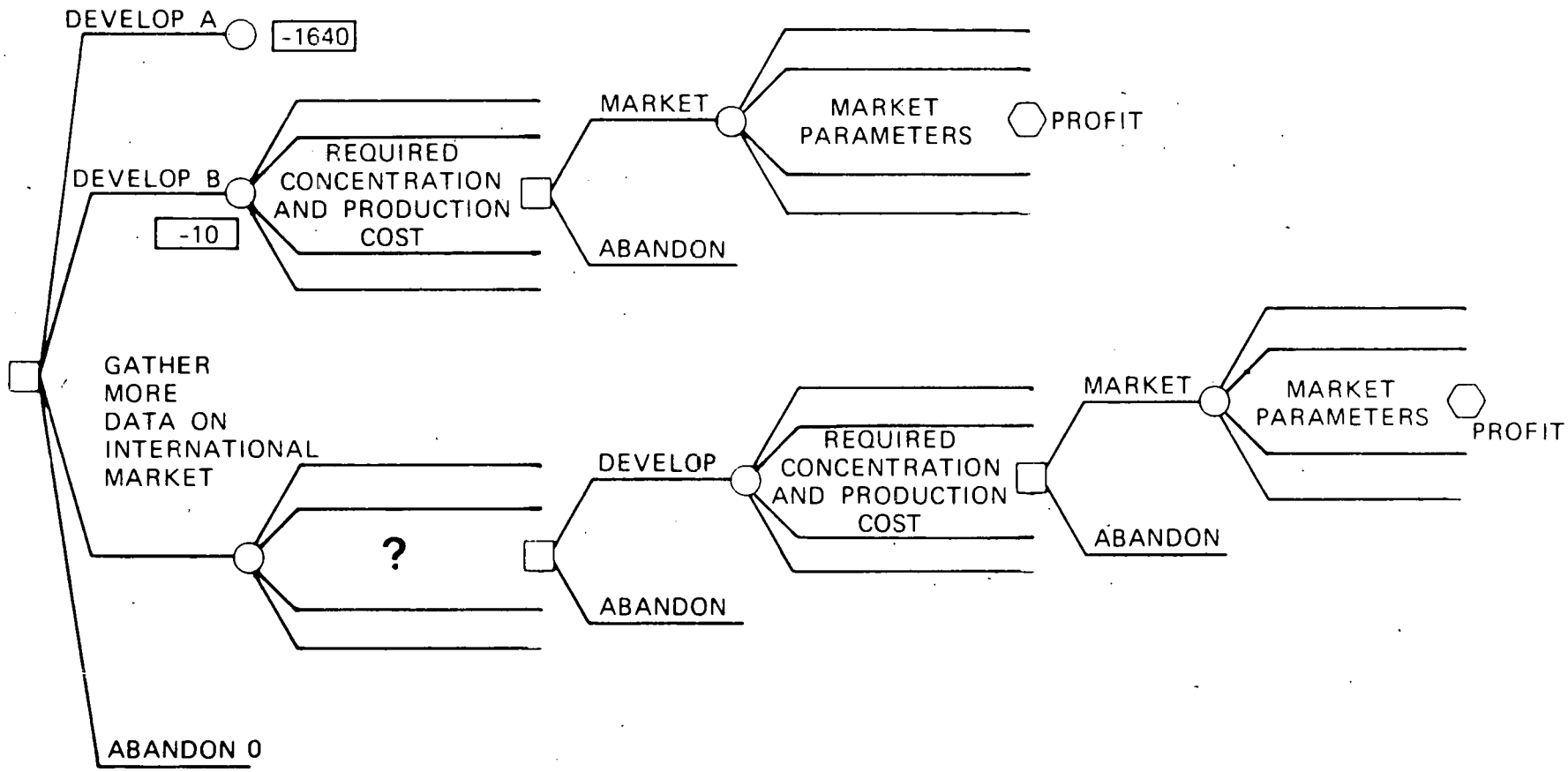
Let me go back to the decision tree to show how this evaluation is carried out. The decision alternatives at the far left are "develop A," "develop B," and "abandon," and another branch that says, let's "gather some data on the international market," which is one of the important variables.

Let's talk about the idea of perfect information. Suppose we found a man who could tell you exactly what the size of the international market was; that's perfect information. If you knew his answer, you then can determine whether you should develop A or B or abandon the venture. There is still some uncertainty about other important variables, but know the size of the international market. This allows you to improve your decision from what you would have done in the absence of this information.

So although they are often thought of as theoretical, decision trees are practical ways of organizing the elements that are involved in a business decision. You can talk about

CALCULATION OF THE VALUE OF FURTHER INFORMATION

- NEW ALTERNATIVE: GATHER INFORMATION BEFORE TAKING ACTION



them in this kind of structure and specify what you know and what you don't know. Other people's ideas can be examined to see what impact they have. You continue to the point where you can effectively deal with the decision, that is, where further information gathering or analysis is not worth its cost.

(Slide: "Results of the Calculation for the Value of Information.")

Here are the results for this business venture. We label them as the value of perfect information because they represent the ideal case of complete resolution of uncertainty. In practice this limit is generally not attainable.

What we found was that if you had perfect information about the international market, it is worth a million and a half dollars. This is about half the value of resolving all of the uncertainty, which we discussed two slides back. You can see the results for the other variables. The value of information on them is less.

Now obviously we do not have access to perfect information about the business, and our client of course knew that. But what they learned was that it might be worth a great deal to obtain more information about the international market.

So with the ideas that came out of the analysis they talked to market consultants again, in a more structured

RESULTS OF CALCULATION FOR THE VALUE OF INFORMATION

STATE VARIABLE	VALUE OF PERFECT INFORMATION
International Market	$1,415,000
Required Concentration	$504,000
Required Concentration and International Market	$1,530,000
Production Cost	$440,000

- THE VALUE OF PERFECT INFORMATION SETS THE UPPER LIMIT OF THE JUSTIFIABLE COST OF ANY INFORMATION GATHERING PROGRAM.

way this time. It turned out that information on federal government policy with regard to the international market was easily obtainable. This made the decision obvious: There was not enough of a market internationally to make the business profitable. After some further study of the domestic market, a decision was made to not proceed with the demonstration project.

This result is unfortunate perhaps, but typical of the kind of decision often involved in new business ventures. We are now going to go through in the next portion of our discussion some energy applications. We will describe a synthetic fuels analysis for the government, an application to sulfur oxide removal strategies, and a gas utility supply decision.

Warner:

DR. NORTH: I might comment before going on that the analysis just presented on the agricultural chemical decision can be thought of as evaluating a demonstration plant in order to get more information before making the commercialization decision. The decision tree framework shows how to evaluate this alternative to get more technical information, versus other alternatives of getting further information by carrying out market studies.

I think this addresses the question that Dr. David was posing earlier about the impact of information on the

commercialization decision process. The point we would like to commend for your consideration is to look at other alternatives beside getting technical information from the demonstration project. For example, there may be ways to obtain from sources outside the demonstration project more information pertaining to the business environment.

(Slide: "Difficulties in Analyzing Energy Demonstration Projects and Ways of Addressing These Difficulties.")

Now how can this type of analysis, a simple business model, and probabilities in a decision tree formulation used to structure the uncertainty, be applied to the complicated decisions that will face ERDA on demonstration plants?

(Slide: "Difficulties in Analyzing Energy Demonstration Projects")

There are three points we regard as crucial difficulties.

Point number one is the complexity of the business environment. In the application of the agricultural chemical we were able to construct a fairly simple model of the market by segmenting the market, summarizing the reasonable predictable behavior of companies with competing technology, and summarizing the changes that would occur in that market as a consequence of federal regulation.

IV

DIFFICULTIES IN ANALYZING ERDA DEMONSTRATION PROJECTS AND WAYS OF ADDRESSING THESE DIFFICULTIES

DIFFICULTIES IN ANALYZING ENERGY DEMONSTRATION PROJECTS

- THE COMPLEXITY OF ENERGY ECONOMICS
- ECONOMICS VERSUS ENVIRONMENTAL, SOCIAL, AND POLITICAL GOALS
- RELATION BETWEEN THE DEMONSTRATION PROJECT DECISION AND SUBSEQUENT DECISIONS TO IMPLEMENT THE TECHNOLOGY COMMERCIALLY

The analysis is a straightforward process, carried out by one analyst with about a month of his time, most of which was spent interacting with the market experts. I am sure in your various companies you have all seen this type of market analysis a great many times.

Point number two is the problems related to the evaluation. In the case of our client on the agricultural chemical decision, the major issue they were concerned with was profit. In the case of ERDA's decisions we have not only the business impacts to consider but a wide range of important political, environmental and social considerations. A balance must be achieved between these social objectives and the business objectives.

Point number three is that we have two sets of decision makers, and the planning process requires coordination between the two. We have a federal agency planning demonstration projects and private firms or utilities planning the commercialization. In our agricultural chemical example it was easy. Both these decisions would be taken by the same firm. For energy demonstration projects different organizations may be making those decisions with very differenct kinds of decision criteria.

We now want to turn our attention to how these difficulties might be addressed. How can we proceed to apply decision analysis?

(Slide: Difficulties #1: The Complexity of Energy Economics.")

Let's first look at the complexity of energy economics. Here is the way we've found useful in our projects to address this difficulty. It is an extension of the sort of methodology that was used in the agricultural chemical example. We develop a model of the market but to a much finer level of detail. This additional detail in the energy marketplace may be very important in the decision situation. We must consider the variety of interfuel competition in using energy resources to meet end use demand. Geography is important because of transportation cost as we assess the competitiveness of energy materials. And finally we have the changes that occur over time in the energy marketplace.

(Slide: "Complexity of the Energy Market.")

Several years ago we carried out an analysis with the Gulf Oil Corporation on their synthetic fuel policies. We have several representatives of Gulf Oil here in the audience today who participated in this work.

We started off building a business model of their planning problem as in the agricultural chemical example. Very quickly we found that we had a great deal of difficulty in dealing with the question of interfuel competition. There were so many alternatives to consider in determining

DIFFICULTIES IN ANALYZING ENERGY DEMONSTRATION PROJECTS

1

PROBLEM: The Complexity of Energy Economics

WAY OF ADDRESSING IT:

Model the Energy Marketplace, Including Effects Introduced by Market Imperfections and Government Regulations.

- Interfuel Competition
- Effect of Geography; Transportation Costs
- Dynamic Aspects

COMPLEXITY OF THE ENERGY MARKET

Resources	Resource Extraction Processes	Supply Transportation	Primary Conversion	Product Transportation	Secondary Conversion	Distribution	End-Use Conversion	End-Use Demand
Foreign Oil	Import	Tankers	Sour Crude Refining	Tankers	Combustion Power Generation	Truck	Auto Opr.	Auto
Domestic Oil	Exploration and Production	Crude Pipeline	Sweet Crude Refining	Liquids Pipelines	Combined-Cycle Power Generation	Tank Cars	Bus/Truck Opr.	Bus/Truck
Oil Shale	Mining and Extraction	Gas Pipeline	Shale Refining	Lo Btu Gas Pipelines	Large Fuel Cell	Gas Lines	Air Opr.	Air
Tar Sands	Mining and Retorting	Unit Trains	Power Generation	Hi Btu Gas Pipelines		Power Lines	Ship Opr.	Marine
Hi Sulfur Coal	Surface Mining	Slurry Pipelines	Coal H_2	Unit Trains		Service Station	Combustion	R/C Space Heat
Lo Sulfur Coal	Underground Mining		Hi Btu Gasification	Power Transmission		Local Delivery	Resistance Heating	R/C Misc. Heat
Natural Gas			Solvent Refining				Heat Pump	R/C Electromech.
Imported Gas			Liquefaction				Catalytic Burner	Ind. Process Steam
Imported Methanol			Lo Btu Gasification				Electro-Mech. Devices	Ind. Direct Heat
			Methanol Refining				Steam Generation	Ind. Electromech.
			Nuclear-Thermal-Splitting				Small Fuel Cell	Nap. Feedstock
			Nuclear Power Generation				Chemical Manufacturing	Gas Feedstock
							General Manufacturing	Coal Feedstock

what competitive forces would set the market price of a synthetic fuel product.

For example, if you're considering a synthetic gas to meet an end use need such as space heating for a residence or a commercial enterprise, you have competition between natural gas and the synthetic gas burned directly, from electricity (heat pumps or resistance heating) which might be generated from a low Btu synthetic gas, and from other fuels. Further, the price of a feedstock used to make synthetic gas like Western coal price may be set not by its value for synthetic gas but by competing uses.

All through this network we must think about the interfuel competition that will tend to set the prices over time. There is a vast multitude of combinations that might need to be considered, and we have to sort through them.

In our Gulf study we went through an excercise on the blackboard where we wrote down the economics for various fuel cycles (paths from resource to end use demand) and tried to understand what the most important issues were in determining the least cost path. We felt that we needed more detail so we started building a model of the interfuel competition.

(Slide: "U.S. Energy Model Resource Locations and Demand Regions.")

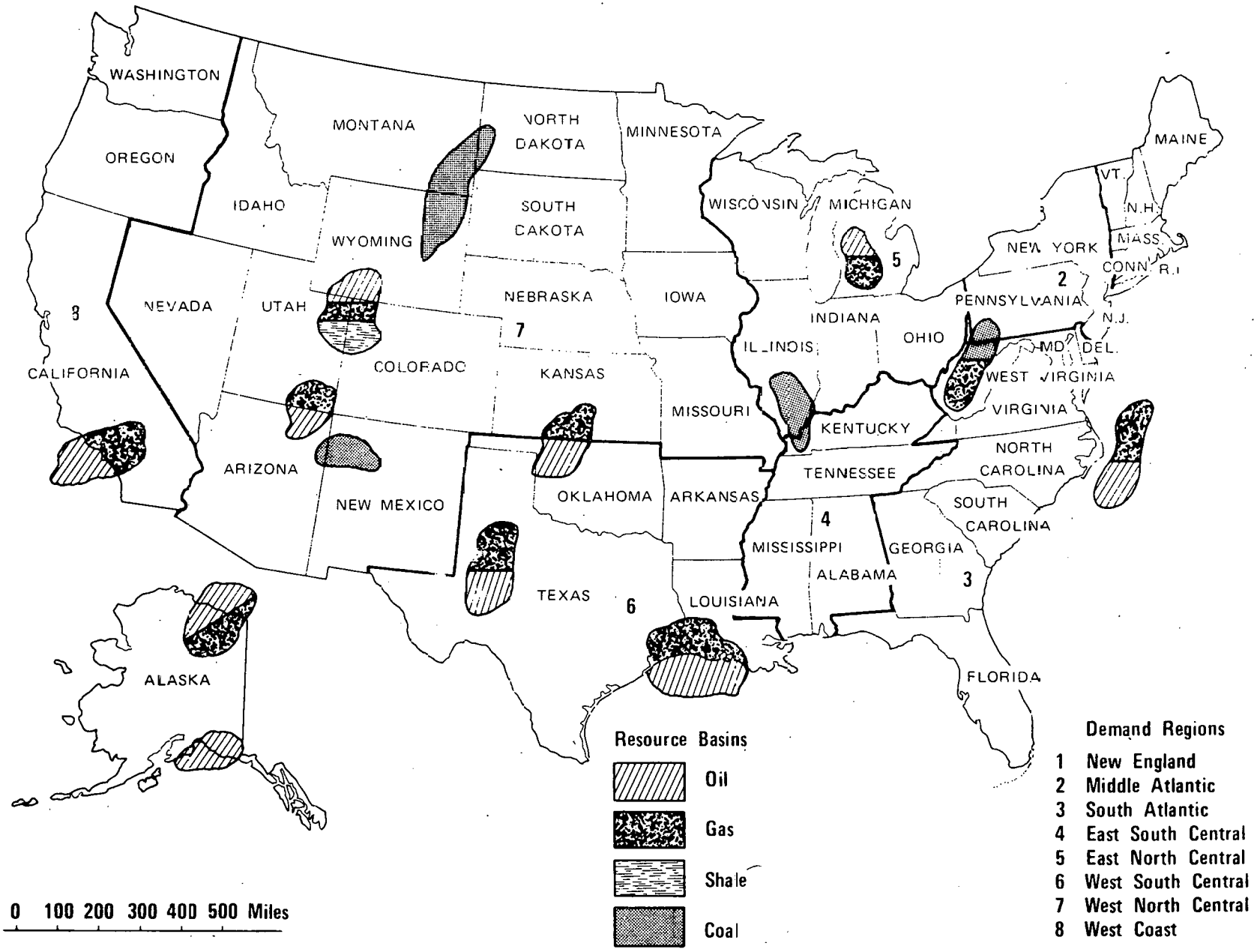
We found from the blackboard exercise that geography was important. For low sulfur Western coal, for example, it made a great difference in the price whether the coal is the Powder River Basin, in the Chicago area, or points further east. So we had to put into the model a level of regional disaggregation to take account of the fact that the transportation economics could be very important in the interfuel competition.

(Slide: "Dynamics of the Market.")

Finally, with respect to decisions in synthetic fuel policy we could be looking at a demonstration plant that would take 10 to 15 years to be established and subsequent commercial plants that might be used for 30 to 40 years beyond that. Therefore, we need a planning horizon out to the order of 50 years.

During that time the energy market is going to be undergoing many changes. There will be decreasing amounts of domestic oil and gas. There will be changes in the quantity and perhaps the character of consumer demands. New technologies will be emerging. And finally we have to consider the effect of market imperfections. People tend to have inertia in their purchasing behavior. They tend to buy the technologies they know or that are well established, and they do not necessarily switch to the ones that are least costly.

U.S. ENERGY MODEL RESOURCE LOCATIONS AND DEMAND REGIONS



DYNAMICS OF THE MARKET

THE APPROACH SHOULD ACCOUNT FOR

- LONG TIME HORIZONS (20-50 Years)
- DEPLETION OF ENERGY RESOURCES
- CHANGES IN DEMAND
- CHANGING TECHNOLOGY
- LONG-LEAD TIMES AND IMPERFECT FORCASTING

So we have to have a way of taking market imperfections into account.

(Slide: "SRI-Gulf Energy Model.")

The result of this work, which we did jointly with Gulf, was to develop a national model of interfuel competition over a 50-year planning horizon.

We disaggregated regionally with eight regions for end use demand, 30 sources of resource supply, and about 600 links involving transportation or distribution processes for moving energy materials in going from the primary resources to the satisfaction of end uses.

Therefore, this model keeps track of 2,400 located materials in 17 time periods. When you multiply these numbers together you have about 40,000 variables; for each we want to assess a price and a quantity. We are able to do this using an iterative methodology that has grown out of research done at Stanford University and SRI. With the methodology we can determine the prices and quantities over time that characterize this marketplace with supply and demand in balance.

The model allows these calculations to be made easily for many different sets of specific assumptions. Then you can do sensitivity analysis and understand which of those assumptions is important for a specific decision.

Using the model we can include differences in financial evaluation criteria. For example, a synthetic gas plant might

SRI-GULF ENERGY MODEL

A NATIONAL MODEL OF INTERFUEL COMPETITION FROM PRIMARY RESOURCE EXTRACTION TO END USE ENERGY CONSUMPTION OVER THE PERIOD 1975-2025

- Regional Disaggregation:
  - 8 Regions for End Use Demand
  - 30 Regions for Primary Resource Supply
  - 600 Transportation and Distribution Links
- Market Clearing Prices and Quantities of Materials are Computed for 2400 Located Materials in 17 Time Periods.
- Methodology: General Economic Equilibrium Theory (Iterative Balancing of Supply and Demand).
- Effects of Variations in Financial Investment Criteria, Government Regulation, and Market Imperfections can be Addressed Using the Model.

be evaluated by a regulated utility using one set of cost-of-capital factors, while a private enterprise would use a higher cost of capital. We can examine the impact of government regulations. For example, how natural gas is going to be regulated might make a big difference in the attractiveness of the synthetic gas. We can also examine the effect of market imperfections, such as a consumer's inclination to continue to use a gas furnace even if some other way of heating his home might become more economical. Consumer inertia has big implications for the demand for gas, and hence for the attractiveness of a synthetic gas investment.

This model runs. We have used it recently in looking at synthetic fuels decisions for a Task Force of the Office of Management and Budget, which Mr. Loweth alluded to. This Task Force examined various programs that the government might undertake to subsidize commercial-scale synthetic fuel plants.[1]

(Slide: "Total Primary Energy: Nominal Case; Prices of Selected Primary Resources by Location.")[2]

I'll just give you a brief look at the kind of output the model can generate, namely, a series of price and

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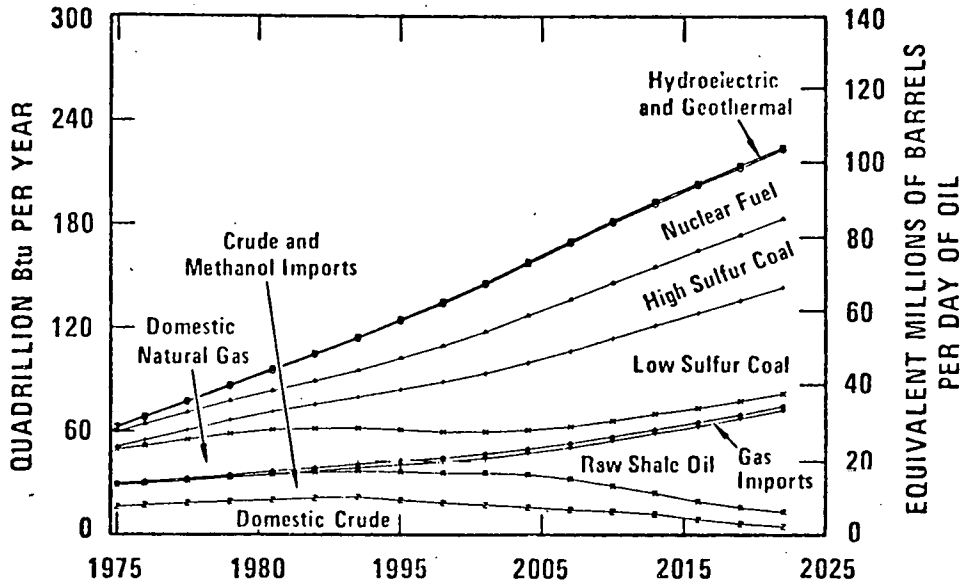
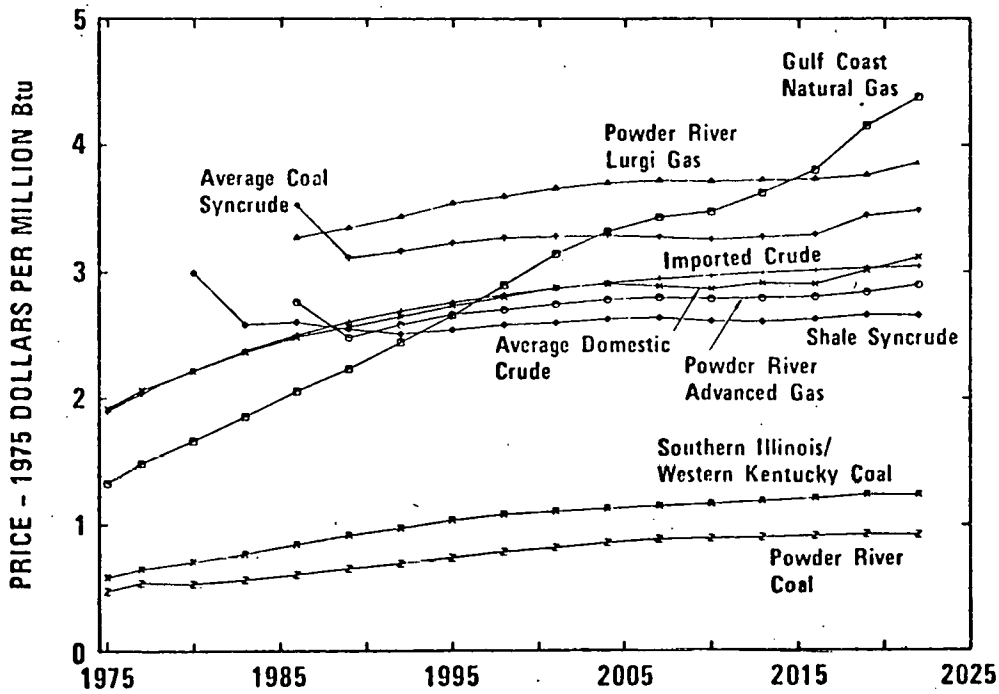
1. Recommendations for a Synthetic Fuels Commercialization Program: Volume II. Report submitted by the Interagency Task Force on Synthetic Fuels to the President's Energy Resources Council, November 1975, GPO Stock No. 041-001-00111-3.

2. Ibid, p. H20, H21.

TOTAL PRIMARY ENERGY:
NOMINAL CASE



PRICES OF SELECTED PRIMARY RESOURCES BY LOCATION



quantity projections over time showing the competition between synthetic fuels and various natural fuels.

Now I don't want to take time to explain the tremendous amount of information in these figures. In practice, we would want to examine a whole series of such graphs to see the effect of different assumptions. We do not want to fix on one set of numbers.

This energy model is a tool for understanding the business environment. We feel that such tools are needed in order to deal with the enormous complexity of the energy marketplace in the context of demonstration plant decisions.

(Slide: "Difficulties #2: Conflict between Economics and a Multiplicity of Environmental Social, and Political Goals.")

Now let's turn our attention to the second difficulty, which is a question of trade-offs. There is a conflict between the economic goal of low-cost energy and a multiplicity of social, environmental, and political goals.

Here again our method of approach is to try to incorporate the information available from various sources into a model. Then this information and its implications can be formally addressed and examined by all of those who are concerned with the particular decision situation.

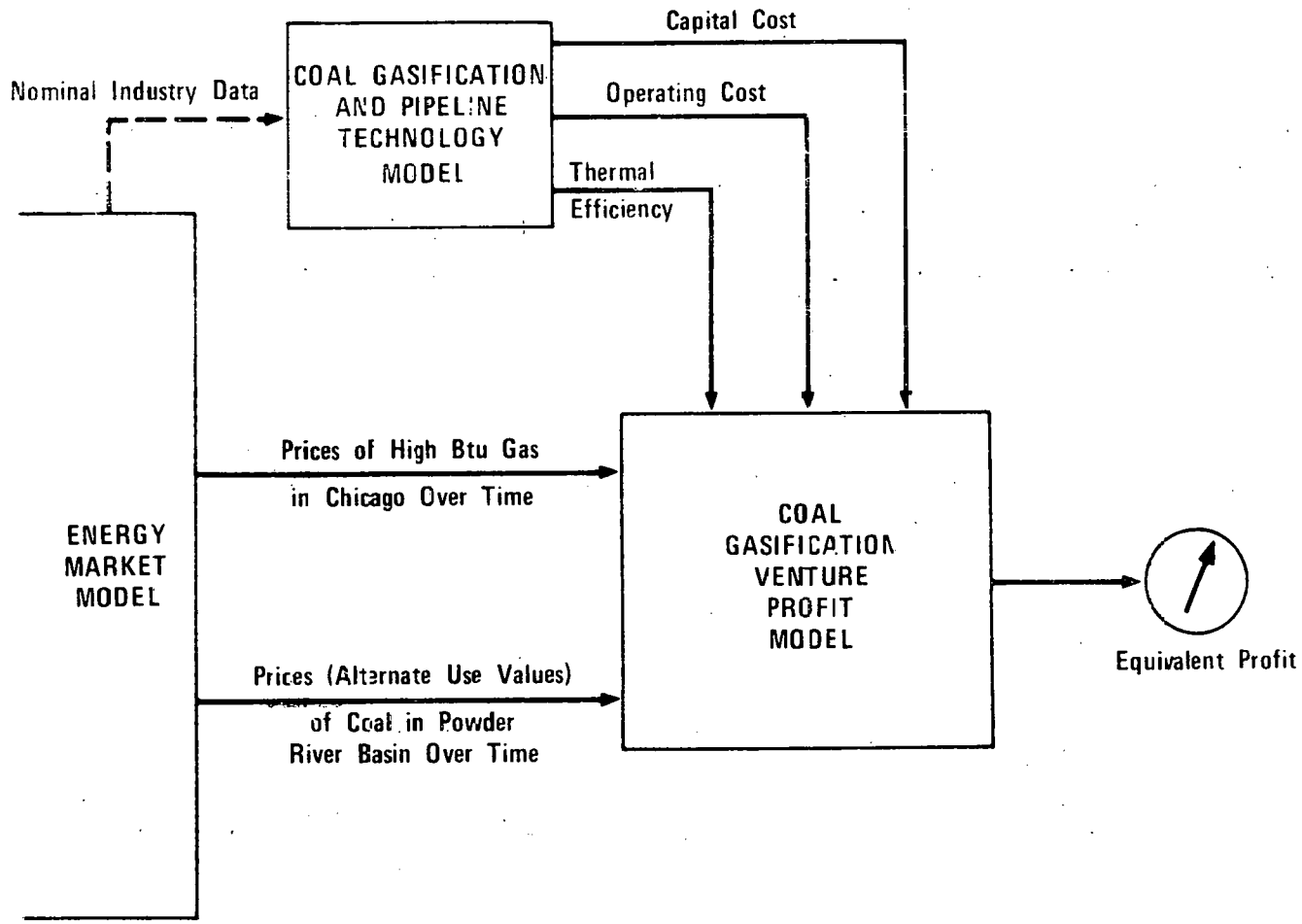
DIFFICULTIES IN ANALYZING ENERGY DEMONSTRATION PROJECTS

2

PROBLEM: Conflict Between Economics (Low-Cost Energy) and a Multiplicity of Environmental, Social, and Political Goals

WAY OF ADDRESSING IT: Develop Formal Decision Criteria Based on Explicit Value Judgments. Through Sensitivity Analysis Identify Tradeoffs Between Economic Measures and Other Goals that are Crucial to the Decision

PRIVATE SECTOR COAL GASIFICATION DECISION



(Slide: "Private Sector Coal Gasification Decision.")

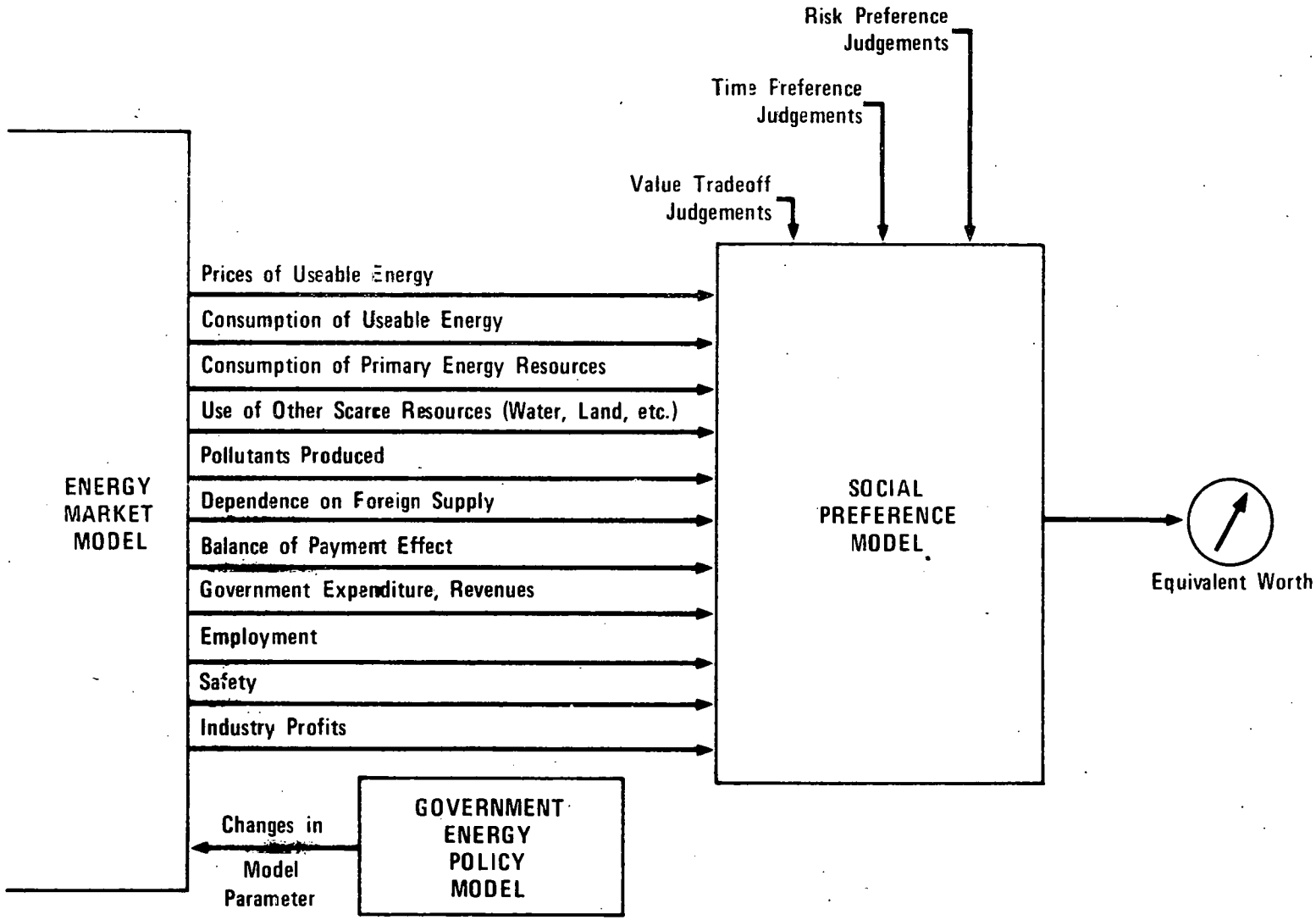
We might contrast a private sector decision, such as on a synthetic gas plant with a public sector viewpoint. The private sector evaluation might be made on the basis of the capital cost, operating cost, and efficiencies of that plant, and prices that are assumed for the product and for the feedstock. (An energy model may be helpful in assessing the prices for the product and feedstock.) From this information a discounted cash flow analysis can be used to calculate profit, just as in our agricultural chemical example.

Many private concerns will be concerned about more than just profit. They may be concerned about the quality of the service delivered to the consumers, environmental impacts, and other things of this sort. Howard Cook will address these issues in more detail when he continues his part of the presentation.

The point I want to make here is that profitability is a relatively simple criteria that one might start with in understanding how private sector decisions are made. When we look at the problem from the government's point of view that there are a great many other criteria beside profitability that also enter into consideration for the government's decisions.

(Slide: "Government Energy Policy
Decision Criteria.")

GOVERNMENT ENERGY POLICY DECISION CRITERIA



For example, there are questions having to do with dependence on foreign sources of energy supplies (the rationale for our goal of national energy independence), the balance of payments effects, the effects on the environment, and use of scarce resources whose value may not be reflected in their price. Water in the arid West might possiblty be an example of this last issue.

All of these various factors then must be taken into account: The decision maker is going to have to address these issues as well as the economics as he makes his decisions.

Given that the decision is of concern to a great many individuals and groups, how can the issues be sorted out? How can we help the decision maker to make trade-offs and judgments about the different objectives in a consistent way?

We might start by building a model to summarize information about one specific trade-off. We will illustrate by using sulfur oxide emissions from a coal-burning power plant. The material presented here is from work we carried out last year for the National Academy of Sciences.[1]

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1. North and Merkhofer, "Analysis of Alternative Control Strategies," from Air Quality and Stationary Source Emission Control, a report by the National Academy of Sciences prepared for the Committee on Public Works, U.S. Senate, March 1975.

(Slide: "Assessment of Social Costs.")

Let us consider a representative coal-burning power plant in the Appalachian area, say on the Ohio-Pennsylvania border. This plant is assumed to burn three percent sulfur coal. A thousand-megawatt plant is therefore going to produce quite a large amount of sulfur oxide emissions: about 160 million pounds per year.

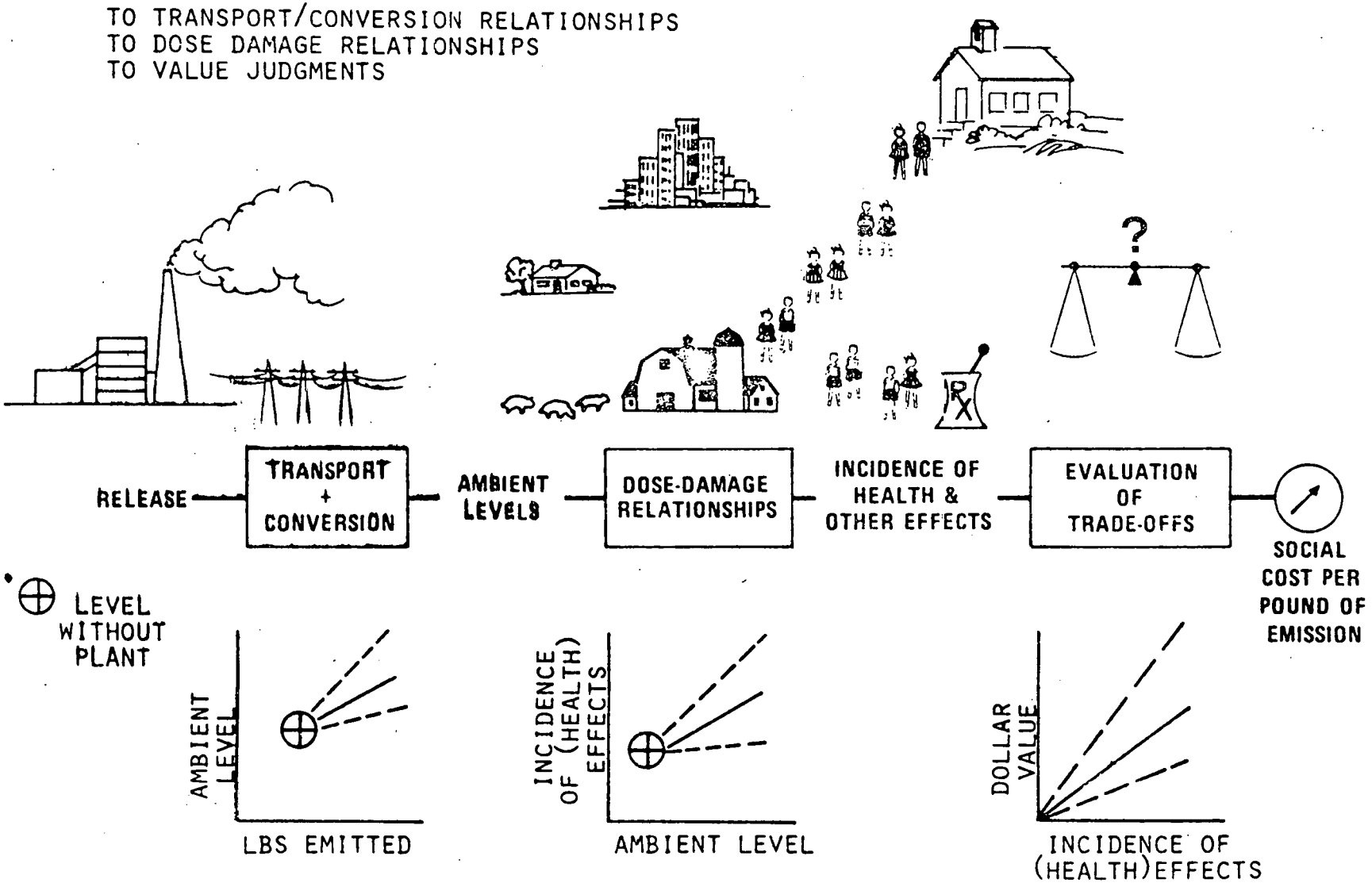
What effect are those emissions going to have on the ambient levels of sulfur dioxide and sulfate in areas downwind? For example is very much of the sulfate that is observed in the New York-Washington-Boston metropolitan complex a consequence of emissions from plants like this one and others in the same general area?

What effect do those ambient levels have on human health, on property damage, and other values of concern? We need to model those relationships. We understand first what the physical consequences of the sulfur emissions are: the number of cases of various health effects, the corrosion of galvinized steel and other materials, the damage to statues, the occurrence of acid rain with its implication for forest growth, and the reduction in visibility. We need then to bring some value judgments on these physical effects in order to relate the benefits of controlling emissions to the cost of control programs.

ASSESSMENT OF SOCIAL COSTS

SENSITIVITY ANALYSIS:

- TO TRANSPORT/CONVERSION RELATIONSHIPS
- TO DOSE DAMAGE RELATIONSHIPS
- TO VALUE JUDGMENTS



This process will allow us therefore to assess how bad the sulfur emmissions are and therefore how much it might be worth society therefore to reduce them. Reduction might be accomplished by emission control devices or, alternatively, switching to other ways of generating electric power that do not involve such large quantities of sulfur oxide emissions.

The analytical process involves working with experts in various different areas: the meteorologists and the atmospheric chemists to understand the relationship between the releases and the ambient levels; the medical specialists and epidemiologists on the relationship between the ambient levels and health effects; materials damage experts and economists who have studied property damage, etc. The evaluation questions shown on the right side of the slide will be of concern to the government agencies responsible to the citizens through the political process.

In the Academy study we assessed these quantities in numerical terms. We have mentioned the emissions of 160 million pounds of sulfur dioxide. Working with the meteorologists and the atmospheric chemists, we are able to see what these emissions might mean in terms of ambient sulfate levels 300 miles downwind: A nominal estimate is a

quarter of a microgram per cubic meter increase in sulfate levels. We then go to the doctors and epidemiologists and we ask what this change in ambient sulfate is going to mean in terms of specific health effects. As an example, let us take chronic respiratory disease as it has been defined in the epidemiological studies, namely as a period of at least three months during which the individual has on most days a persistent cough and phlegm in his throat. The nominal dose-response relationship implies that this increase in ambient levels might lead to an increase on the order of .08 of a percent in the incidence of respiratory disease. So over a population for states downwind of 50 million, that would give you of the order of 40,000 additional cases. Now how might those be evaluated? We might look at impacts of the health effect on an individual's productivity, how much he is willing to spend for medical treatment of various sorts, and how much society appears to be willing to spend to alleviate health effects of this kind. A nominal estimate used in the Academy study was $250.

We bring these elements together, and we find from a total of $10 million as the value associated with chronic respiratory disease from the sulfur emissions of the representative plant.

Including the other health effects, acid rain and so forth, we get a total for our assessment of $33 million, which

works out to about 20 cents per pound of sulfur emitted from the stack.

Now there's a big problem in writing down numbers like this because most of these quantities and relationships are very uncertain. So the use of the methodology should be not just to develop a single number but carry out a sensitivity analysis to gain an understanding of the importance of the issues.

What is the range of disagreements on those numbers and what are the impacts of various assumptions that might be made in different areas?

For example, in the transport area there is considerable uncertainty on the conversion rate of sulfur dioxide to form sulfate. We can trace the effect of this uncertainty to the 20 cents; this answer might change over a factor of two.

There is more uncertainty with regard to the dose-response relationship. Here the judgment in our Academy study was that this relationship between the ambient level and the number of cases might be ten times too high: It might only be 4,000 instead of 40,000. On the other hand it might be as much as double, 80,000 instead of 40,000.

The implications of this uncertainty can be traced through: The 20 cents might be increased to 35 cents or cut down to 9 cents.

Then we can look at the implications of different value judgments on the importance of that health effect. We found, for example, that chronic respiratory disease was a very important one. We also had included asthma attacks as a health effect, and we found out that this was relatively less important: Varying the value assigned to asthma attacks made only a few cents difference.

People from many different viewpoints on the Academy Panel examined these insights, discussed them, and criticized them. When we found that an issue was not included properly in the analysis, we would go back and revise it.

All of this then leads toward a way of making the trade-offs between the implications of the sulfur oxide emissions and the economic impact on energy production. In this case the alternatives were putting stack gas scrubbing on power stations, or switching to a more expensive, low sulfur coal. A broader question would be comparing coal-burning power plants with other kinds of energy production facilities.

(Slide: "Government Energy Policy Decision Criteria.")

In the context of this larger question we must look not at just one of these trade-offs, sulfur oxide emissions versus the cost of electricity, but a whole range of them. Going through this sort of modeling exercise I have discussed for sulfur oxide and doing sensitivity analysis can indicate the

relative importance of these many issues and help the decision makers to sort out priorities. Which are the ones that should be emphasized, where it is advisable to go into considerable detail, bringing together the best expertise and spending additional money for further analysis and information before committing to decisions? Which are the issues that are relatively less important?

The objective of decision analysis methodology is to help the decision maker to gain insights and not to obtain numbers like 20 cents per pound of sulfur oxide, which may be quoted out of context and perhaps misused in the planning process.

(Slide: "Difficulties #3: Lack of Co-ordinated Planning.")

Now let me turn to the third question, the matter of co-ordination between the public sector decisions on demonstration plants and private sector decisions on commercial deployment. And our way of addressing is again the same word, "model". We build a model of the decision process as seen by each of the concerned parties.

We want to give you two examples. One is the Interagency Task Force analysis on synthetic fuels commercialization, a government decision in which the decision further on by the private sector in large scale deployment of synthetic fuel technologies was very important. The other is a current SRI

DIFFICULTIES IN ANALYZING ENERGY DEMONSTRATION PROJECTS

3

PROBLEM: Lack of Co-ordinated Planning Between Research, Development, and Demonstration Decisions by the Government and Choice of Commercial Scale Energy Technologies by Energy Firms and Utilities

WAY OF ADDRESSING IT: Model the Decision Process for Each of the Concerned Parties: How does a Company or Utility React to Government Incentives or Regulation? How Does the Government Take into Account the Reaction of Private Firms to its Programs and Regulatory Policy?

project for the American Natural Gas Corporation, on which Howard Cook is project leader and which he will discuss in a moment.

(Slide: "Synthetic Fuels Decision Tree.")

Let me illustrate with this rather complicated looking tree the decision structure for the federal government's synthetic fuel commercialization program. This tree has the same kinds of characteristics as the simple tree that we used for the agricultrual chemical decision. There are two stages of decisions: Here on the far left there is the federal decision on support of the synthetic fuel commercialization program. This program is for commercial scale synthetic fuel plants in the decade of the '80's. Four alternatives are shown: no federal program, a federal program of one commercial scale plant of each of several kinds, leading to a capacity of a third of a million barrels per day; a medium program of a million barrels per day (this program has been recommended by the President in his 1975 State of the Union address) and finally a maximum or high program of 1.7 million per day, essentially all we could do if we were to turn all our capabilities to building synthetics plants between now and 1985.

The next stage in the tree is a series of outcomes that would be resolved subsequent to these commercial scale demonstrations. First, a change in our state of knowledge

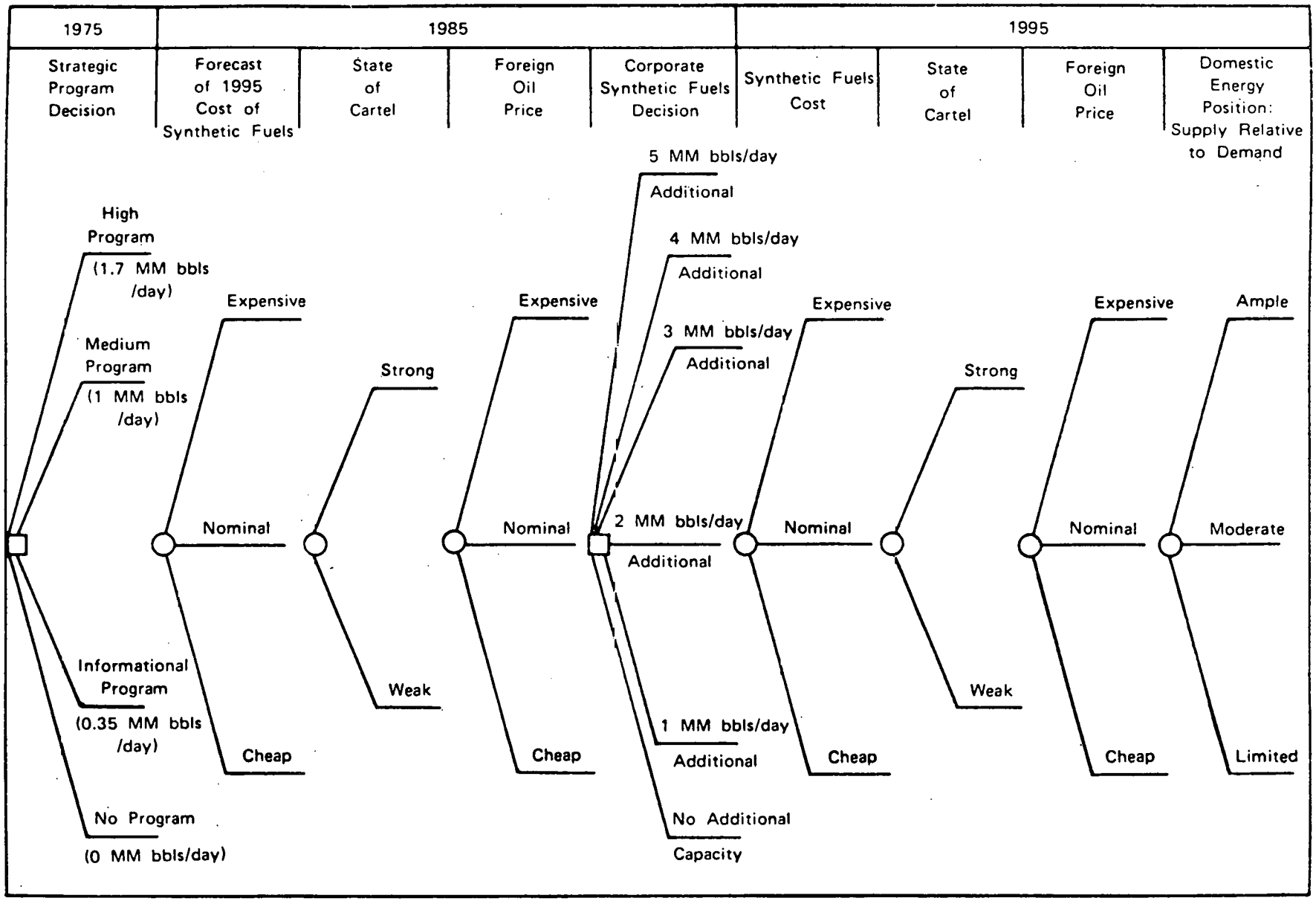


FIGURE V-2 SYNTHETIC FUELS DECISION TREE

about the cost of synthetic fuel plants, the learning that would come from building these commercial scale installations. Then there are a series of questions regarding the business environment: In particular, what happens to the price of foreign oil as a competing energy source? This depends on what happens to the OPEC cartel. Does the cartel maintain their ability to set price or do they lose that ability? For each of those situations, what happens to the foreign oil price? This may depend on other, non-political factors like how much new oil is found in various international locations.

Given all these various scenarios, defined by the government synthetic fuel program, the changes in the cost of synthetic fuel, and what happens to foreign price, there are a number of different possible states of information where the companies could be in the 1980's decade when they make decisions. Based on earlier plant experience the private sector will decide how many synthetic fuel plants they want to construct in the '80's and for use in the decade of the '90's to produce synthetic fuels on a large commercial scale.

Well, this is the commercialization decision that we might draw in analogy between a demonstration plant decision facing ERDA and this large scale federal demonstration program decision on synthetic fuels.

We show alternatives from no additional capacity

ANALYSIS OF FEDERAL PROGRAM ALTERNATIVES FOR SYNTHETIC FUELS COMMERCIALIZATION

FEDERAL GOVERNMENT PROGRAM DECISION (1975)
DECISION CRITERIA:

- Consumer Surplus
- Producer Surplus
- Embargo Protection
- Environmental and Socioeconomic Costs
- (Benefits for International Relations – Not Included Formally in the Analysis)

CORPORATE SYNTHETIC FUELS CAPACITY DECISION (1985)
DECISION CRITERIA:

- Producer Surplus

all the way up to an additional five million barrels a day in addition capacity installed during the '80's. The next stage of the tree is a series of outcomes, defining the cost that is realized on synthetic fuels, the behavior in the 90's of foreign oil price, again depending on the cartel, and finally the quantity of domestic oil and gas resources available.

Now we have many paths through this tree, and each of those paths can be regarded as a scenerio. It is characterized by forecast cost, what happens to foreign oil in the 80's, the decision taken in the private sector, what happens in the '90's to synthetic fuel costs, and finally what happens to the price of foreign oil, and to domestic oil and gas reserves.

There are a total of several thousand of these possible scenarios and what the analysis does is to sort through them. For each path we have defined a probability which is based on probabilities that are assigned individually to the various uncertain factors, just as was done in our agricultural chemical example.

With each path is associated a measure of benefit, a measure of total worth for that particular scenario.

(Slide: "Analysis of Federal Program Alternatives for Synthetic Fuels Commercialization.")

Now what goes into measure? Obviously there are

going to be different criteria for the federal government and for the commercial firm making the decision whether or not to buy mor synthetics plants in the mid-'80's. For the federal government we used decision criteria that included the benefits to the consumers of lower cost energy, the benefits to the producers (how much they would be able to realize on their investments in synthetics plants) the social beneifit of additional capacity as protection against an embargo of foreign oil, and the environmental and socioeconomic costs associated with this additional capacity.

All of these criteria were made explicit. A good deal of thought and sensitivity analysis went into defining an appropriate way to represent them for this study. The sum of these costs and benefits became the over-all criterion for the federal government on its decision on the commercialization program.

For the mid-'80's decision by the private sector on how much synthetic fuel capacity to buy, we assumed the criterion would be the return on investment ot the producers.

So then we go back to the tree.

(Slide: "Synthetic Fuels Decision Tree.")

We evaluate the best decision for 1980's commercialization on the basis of benefit to the producers. We can determine how this decision will be taken given what scenario has occurred

to this point. By working our way further backward in the tree, we can determine how the government would want to take its decision. This determination takes into account the thousands of scenarios that might follow for each of the decision alternatives.

So a great many elements are being brought together: the learning that would occur as a result of the program on the cost of synthetic fuels, the events in foreign countries that might impact on the price of oil, the behavior of the private sector, and so forth. The analysis provides a way of assembling all of this information so that the individuals in the Synthetic Fuels Task Force could study it, critique it, and examine the effects of alternative assumptions in coming to their decision recommendations.

Slide: "Components of Expected Discounted Net Benefit.")

This slide presents the components of benefit for the various program alternatives. There is a misprint in the handout which I have corrected on the slide.

Examining the four progam alternatives by the categories of benefit to the consumers, benefit to the producers, and embargo protection, and socioeconomic protection, we found that the benefit for embargo protection and the cost associated with environmental and socioeconomic problems more or less

TABLE 5 COMPONENTS OF EXPECTED DISCOUNTED NET BENEFIT

	Expected Discounted Net Benefit (billions of 1975 dollars)				
Program Alternative	Consumer Surplus	Producer Surplus	Embargo Protection	Environmental and Socioeconomic	Total
No Program	0	0	0	0	0
Information Program (1/3 MM bbls/day)	1.07	-2.71	0.43	-0.44	-1.65
~~Maximum~~ Medium Program (1MM bbls/day)	3.29	-8.74	1.18	-1.14	-5.41
~~Large~~ Maximum Program (1.7 MM bbls/day)	4.55	-15.77	2.23	-1.99	-10.98

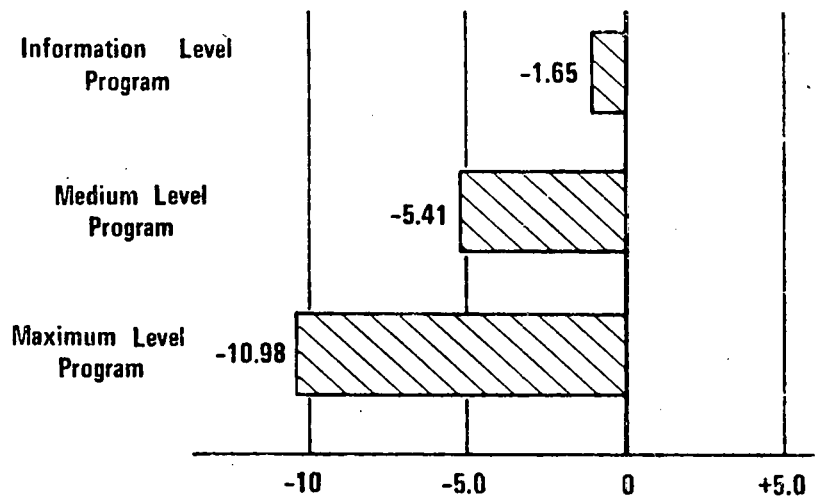


FIGURE 30 BENEFITS OF SYNTHETIC FUELS PROGRAM ALTERNATIVES RELATIVE TO NO PROGRAM

balance each other out. The benefit for lower cost energy for the consumers was more than offset by the expected net loss to the producers; hence the need for a government subsidy exceeding the benefits expected for the consumers.

The effect of this analysis was to motivate a change from a commitment to the million barrel a day program to a smaller commitment, to an informational level program, with an option to expand in a second phase up to a million barrel a day program if subsequent information motivates such an expansion. This was the statement that Mr. Loweth alluded to this morning.

The results of the analysis are very sensitive to the probability that is assigned to the continued strength of the cartel. There are other critical assumptions, and I can easily spend more than our total of 90 minutes discussing this analysis. We do not have to time to go into the details.

So the point I want to leave you with is the need to model the decision criteria as seen by both sets of decision makers: the federal government for their program decision, and the private sector for the decision they will make on subsequent commercialization of synthetic fuels technologies.

Howard?

(Slide: "Gas Utility Application of Energy Alternatives.")

DR. COOK: What you say in the last few slides is

contrasted graphically with what I will talk about in the next few minutes. I will be discussing commercial applications with the American Natural Gas Company, which is going through the process of replanning a business in the environment of changes in available energy sources. Commercialization decisions in this case involve a great number of alternatives for gas companies like the American Natural Gas Company.

There is a drastic change in the circumstances for the gas utilities. Historically they have had a business where the supply came from a single source, where they interested pipeline companies in transporting the gas, and where the business was continued based on exploration and development by the various kinds of producers involved.

Dramatically or traumatically, whichever way you want to talk about it, they now face some completely new alternatives in their business. The officers of the American Natural Gas Company find themselves in a position of completely relearning the components of their business, where problems like capitalization are of a great deal of importance. Over the next ten year period the capitalization of the company may be between three and four times what it is today. This is a dramatic change in the characteristics of the company.

Technical characteristics are also changing. They may be involved in high technology synthetics where up to this

GAS UTILITY APPLICATION OF ENERGY ALTERNATIVES

ISSUES:

- Timing of Alternatives Relative to Service Heeds of Utilities
- Capital Resource Requirements Are Huge Compared to Capitalization of Existing Utilities

FACTORS:

- Natural Gas Supply Is Uncertain and Dwindling
- Regulatory Basis for Business Is Uncertain
- Decisions That Must Be Made Along With High Btu Gas Demonstration Plant Decisions
  - Strategies for Additional Natural Gas Supply
  - Low Btu Gas Plants
  - LNG Supply
  - Coal Mining and Distribution
  - Level of Customer Service

time they have been involved only in the technologies of exploration, development and pipeline and distribution.

Almost unquestionalbly the company will be involved in some excrutiating decisions about supply alternatives. As characteristics of the gas industry today you see declining supplies and in the early and mid and late '80's you'll see significant shortfalls.

I think the characterization of this gas company is like many others. If you looked at the FPC allocation scheme for numbers from 1 to 9, where 1 is the residential heating classification and the others are various classes of commercial use, in general I think what you see is that based on supplies that are available, it is going to be hard to maintain, even with little growth or no growth in demand, a supply of gas adequate to serve the residential heating classification.

Limiting gas supply has great economic effects for the industrial community. A very significant point in that case is the fact that whatever happens in the choice of demonstration programs and alternate supplies for these companies, it is going to be necessary for them to face shortfalls in supply in the not too distant future.

The timing of alternatives is extremely important to them, so there is a constraint on demonstration programs that needs to be identified. In most cases the companies will

be forced into curtailments of service if gas supply alternatives don't come to pass.

By the way, I want to mention at this point there was a comment made this morning in the discussion about the total energy picture. As the gas and electric industry is now constituted in most cases -- this isn't true in all cases -- gas utilities and electric utilities are separate today. The problem of integrating the supply decisions in the combined market is therefore much more difficult than it was some time ago. New supply involves huge investments for either gas or electric utilities. Some basis for resolving how to raise this capital would be an interesting question to look at over the whole spectrum of energy demonstration projects.

If you decide that you are going to go all electric you would obviously not expand gas supply. If you decide that new gas supplies are the way to go, this is another class alternatives. Most likely we will have a mix of both kinds of alternatives.

I mentioned that capital resource requirements for new supply are huge compared to capitalization of existing gas utilities. It now appears as a fact that we are entering into the decision making process in this particular utility where certainly the gas supply is uncertain and dwindling, and the

regulatory basis itself for the company enters into the business development.

One of the questions involved is if a gas company proceeds to obtain a significant new supply for themselves, will its old supply be reallocated by an allocation procedure, given that there are some traumatic supply problems in nearby areas, where utilities don't have the supplies required to meet residential demand? And in effect we are seeing these situations developing now.

Now with regard to what happens to demonstration projects there are a bunch of competing kinds of alternatives that occupy the minds of these utilities. I want to point out some problems that need to be resolved in the commercialization decision with regard to high Btu demonstration plant decisions.

One of the situations involved -- and this has shown up very pointedly in our model in this particular instance -- the fact that a very far-ahead look at the business alternatives involved in gas supplies -- that is, exploration, development and production companies -- has not been the practice for this particular company although they have a very adequate supply compared to a lot of utilities. The business ventures such as entering new areas or developing a new supply prospect have generally been planned perhaps three years ahead up to this point.

The question of future supply investments is really a problem which because of the characteristics of supply alternatives should now be planned at least ten years ahead.

Low Btu gas plants. Suppose high Btu demonstration programs don't come along and the dwindling supply situation persists. Metropolitan and other highly industrial areas, for example the Ford River Rouge plant and surrounding complex, might well go to low Btu gas plants as an alternative, not as an interim but for some significant time.

LNG supply. There is a possibility that foreign supply of LNG will only last for a short period of time. There is great uncertainty about the length of time of supply, about the price, and about the problems of introducing that kind of supply technology..

Coal. There is the possibility of coal mining and coal distribution for direct burning to meet certain of the energy needs of the current customers and prospective customers.

Then finally the item which I mentioned earlier: the utility must plan ahead for the level of consumer service, they will provide. The service could be limited to existing residential gas customers, growth in residential customers, or various levels of commercial gas use.

So this picture is graphically different from the standpoint of the business environment and from the standpoint

of commercialization decisions than the illustration that Warner went through. A basic character of gas utility is the need to determine the basis for their future business: what customers they will serve and what level of supply alternatives they will pursue. This background is essential for understanding their viewpoint on demonstration plants as an alternative for future supplies.

(Slide: "Summary.")

I want to move ahead now, and very rapidly go through a summary of the over-all approach that we talked about.

(Slide: "Iterative Philosophy.")

The basic approach we're talking about is an iterative approach. In the case of the American Natural Gas Company we began our initial effort with the officers of the company participating in the modeling, looking at the results and the relationships, and finding out some surprising things about their business, both in terms of the business relationships and some of the technical relationships, in order to understand what is happening in the model results. An effort to bring the financial and technical pictures together for a business has a great deal of importance.

Then sensitivity analysis is used to gain insight into which things are important, and eventually to the point of deciding what information needs to be collected.

V

SUMMARY: A DECISION ANALYSIS APPROACH FOR EVALUATING DEMONSTRATION PROJECTS

I mentioned the idea in the American Natural Gas case of going back and spending a period of time developing the fuel exploration and development picture better than and over a longer period of time than they had done before in order to try to understand with further insight what the supply situation might be.

Subsequent analysis at finer levels. We want to continue the refinement and learning process to the level needed for a practical basis for making decisions in the business. So we first build an over-all model relating the variables in the business. Then for those factors that are important for the decision we expand the model to finer levels of detail and include more specific information. This process should provide a balanced basis that is realistic and practical as far as the business is concerned.

(Slide: "Steps for Decision Analysis Application: A").

Specification of the decisions. We talked about the need to specify the decision. I want to point out that in identifying decision alternatives we are talking about R&D level alternatives as well as demonstration project alternatives and commercialization decisions. You can't talk about the demonstration project without understanding the R and D level context.

Identity of outcomes. In the case of the American Natural Gas Company, the appropriate set of outcomes was an

ITERATIVE PHILOSOPHY

AN ITERATIVE APPROACH IS OFTEN NEEDED IN CARRYING OUT APPLICATIONS OF DECISION ANALYSIS

- Initial Effort: Simple but Comprehensive Analysis of Demonstration Project Decision
- Use Sensitivity Analysis and Value of Information Calculations to Gain Insight on Where Analysis and Information should be Refined
- Subsequent Analysis at Finer Levels of Detail to Achieve Basis for Decision

STEPS FOR DECISION ANALYSIS APPLICATION

A. SPECIFICATION OF THE DECISIONS

- Identify Decision Alternatives
  - at R&D Level
  - at Demonstration Project Level
  - at Commercialization Level
- Identify Outcomes
- Identify Organizations with Decision-Making Authority and Other Parties Concerned with the Decisions
- Identify Interactions with Other Demonstration Projects and Programs

important point for discussion with management. Very often commercial organizations are labeled as being crass, but this company was very conscious of its role as a public service company. In addition to profits, the level of service was a great deal of concern to them because of the economic impact on industry in the areas they serve. And finally, the price of gas to the customers they serve is very important to them. If they go to coal gasification plants the price of gas might be of the order of three or four times what it is currently.

In their service area of northern Michigan about 40 percent of their customers live on incomes of about $5,000 a year. An increase in heating costs would be a traumatic experience for those people. The decisions on service level and price for these people need to be resolved by American Natural Gas and the regulatory agencies involved.

Identify the organizations with decision making authority and other parties concerned with the decisions. This is the regulation problem: Who decides how gas supplies will be allocated and priced for people who are now on their gas lines, new customers, and industrial users? Many organizations and groups will be involved in this decision.

Identify interactions with other demonstration projects or programs. This is a more general point. If there are a number of programs competing at some level, decisions will

STEPS FOR DECISION ANALYSIS APPLICATION

B. DEVELOPMENT OF STRUCTURAL MODELS

- Model for Outcomes of Demonstration Project
- Model for Market Including Interfuel or Interprocess Competition, Technological Change, and Other Dynamic Aspects
- Evaluation Models for Commercial Organizations (What Will Demonstration Project Outcome Mean for Commercial Firm, Including Effect of Government Regulation?)
- Evaluation Model for Government, Including Tradeoffs on Environmental, Social, and Political Goals (What Will Commercialization Mean to Various Concerned Parties? How Should Commercialization Be Regulated, Given Commercial Response to Regulation?)
- Sensitivity Analysis to Gain Insight on Effect of Uncertainty

be required to determine which of the competing programs should be continued. A basis is needed to evaluate programs and communicate between programs for planning purposes.

(Slide: "Steps for Decision Analysis Application: B.")

The next stage is the development of structural models. We have illustrated the elements now several times: modeling the demonstration outcomes, modeling the market for the technology being demonstrated, evaluation models for commercial organizations and evaluation models for government organizations, and sensitivity analysis to gain insight on uncertainty with regard to over-all program decisions.

(Slide: "Steps for Decision Analysis Application: C, D.")

The kind of probabilistic analysis which briefly in the agricultural chemical example I discussed involved identifying and assessing probabilities for the important uncertain state variables.

We did not talk much about whether probability assessment is a practical art. We have discovered it is a practical art, that you can structure problems and use probabilities effectively.[1]

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1. For a discussion of probability assessment see C.S. Spetzler and C.S. Stael von Holstein, "Probability Encoding in Decision Analysis," Management Science, Vol. 22, P. 340, November 1975.

STEPS FOR DECISION ANALYSIS APPLICATION

C. PROBABILISTIC ANALYSIS

- Identification, Assessment of Probabilities for Uncertain State Variables that are Crucial to the Decisions
- Identification of Strategies on Commercialization for Scenarios Involving Various
  - Outcomes of Demonstration Projects
  - Exogenous Technical, Economic, and Environmental Factors
  - Changes in Social, Political, or Government Regulatory Environment
- Identification of Preferred Demonstration Plant Decision
- Sensitivity Analysis

D. CALCULATION OF THE VALUE OF RESOLVING UNCERTAINTY BEFORE PROCEEDING WITH DEMONSTRATION PROJECT

Identification of strategies for commercialization. I alluded to this when we talked about identifying the path through the decision tree. How would firms decide whether to buy a demonstrated technology, taking acount of the demonstration outcomes and the external variables characterizing their business environment?

The final steps are identification of a preferred demonstration plant decision, and sensitivity analysis to examine the factors that motivate the decision in further detail.

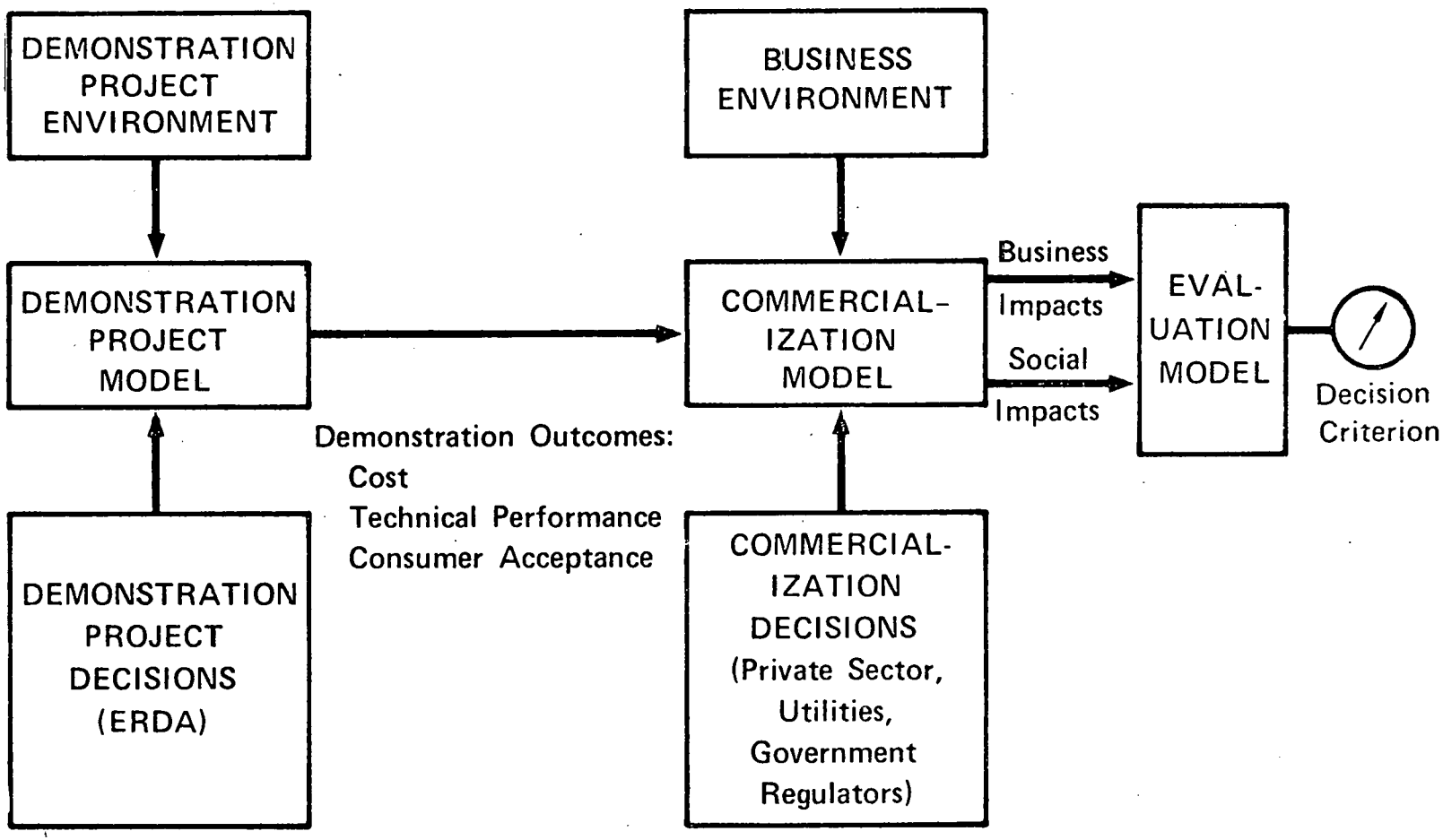
DR. NORTH: I want to make a couple of final comments on this slide in conclusion.

(Slide: "Basic Structure: Demonstration Project Decision Analysis.")

The methodology that we have presented for the decision like the agricultural chemicals example is simple, and straightforward. Use of a business planning model for discounted case flow analysis, and sensitivity analysis to understand which are the important elements in the business planning model, is taught at virtually every business school. Many companies use these ideas extensively.

The use of decision trees, with probabilities on uncertain inputs, and calculation of the probability distribution for an over-all measure of profitability, is taught extensively

BASIC STRUCTURE: DEMONSTRATION PROJECT DECISION ANALYSIS



in business schools and is used by a number of companies. Many firms do not now use these methods, but the practice seems to be spreading.

We at SRI have worked with many companies in putting these methods into practice in the private sector. The application of these ideas to planning in the public sector is not widespread. The practice is in its infancy with only a few examples that have been carried out. Problems such as demonstration plants for ERDA are more difficult, for it will take a great deal of work for these methods to be implemented in a fashion that is useful and credible for the decision makers.

We have tried to enumerate what we see as the three most important difficulties. The first is the need to achieve an understanding of the business environment. This might be accomplished using a large-scale computer implemented model like the SRI-Gulf Energy model, or similar models that have been developed by various other organizations. The second is the problem of integrating the economic objectives with the environmental, political and social objectives. This integration will be a difficult process: Much time and effort, and participation from many disciplines will be needed. Finally, the problem of coordination between private sector planning on commercialization and government planning on projects. One of the problems in planning demonstration plants,

which we have seen often in our private sector experience, and heard alluded to in the public sector, is too much focus on the left-hand side of the diagram ("Basic Structure"). You can characterize this viewpoint as "have technology, will travel:" For this viewpoint success is technical success in the demonstration outcome; that is the end of the planning horizon. This can be a dangerously shortsighted viewpoint.

In our opinion it is extremely important to understand the right-hand side of the diagram: the market for the new technologies. What is the need for the technology being demonstrated? How will the technology fill that need? How might that need change because of changes in the business environment, changes in the regulatory environment, and perhaps changing public attitudes regarding environmental and social goals? Understanding these issues seems to us of paramount importance in the evaluation of ERDA's demonstration programs.

Thank you.

DR. CHARPIE: Are there any questions?

MR. BEHNKE: I would like to make one comment.

I think it was a very interesting discussion. In decision tree planning, one of the things I didn't hear was the matter of confidence levels in the calculations that you're making.

I think if you look back over history of, say,

the last 20 years in the energy business I think there are a number of new developments that have occurred that nobody ever thought about very seriously.

You recognize the great danger of overdependence on the operation of this kind of modeling for decision making.

DR. NORTH: May I respond to that? let me respond in two ways, first by going back to my original slide.

(Slide: "Elements of Good Decisions.")

First of all what we are talking about is a decision process for making a good decision, that is, one that is consistent with the goals and the information available. We do not guarantee good outcomes. There is nothing in the methodology that is going to prevent surprises, and we cannot resolve the uncertainties. We do not have access to a clairvoyant with a crystal ball.

It is true that what appeared to be good decisions on the part of energy companies have in fact led to bad outcomes. I don't see that we are going to be able to avoid similar situations in the future. I think that anybody who looks at this methodology as offering a solution to that problem is mistaken. I don't think decision analysis methodology can promise that.

It may be that decision analysis will be helpful in helping people to think through the implications of the information

that is already available, and to prevent surprises in the sense of thinking through the uncertainties in a little bit better, more complete and more comprehensive fashion.

(Slide: "A Language and Philosophy.")

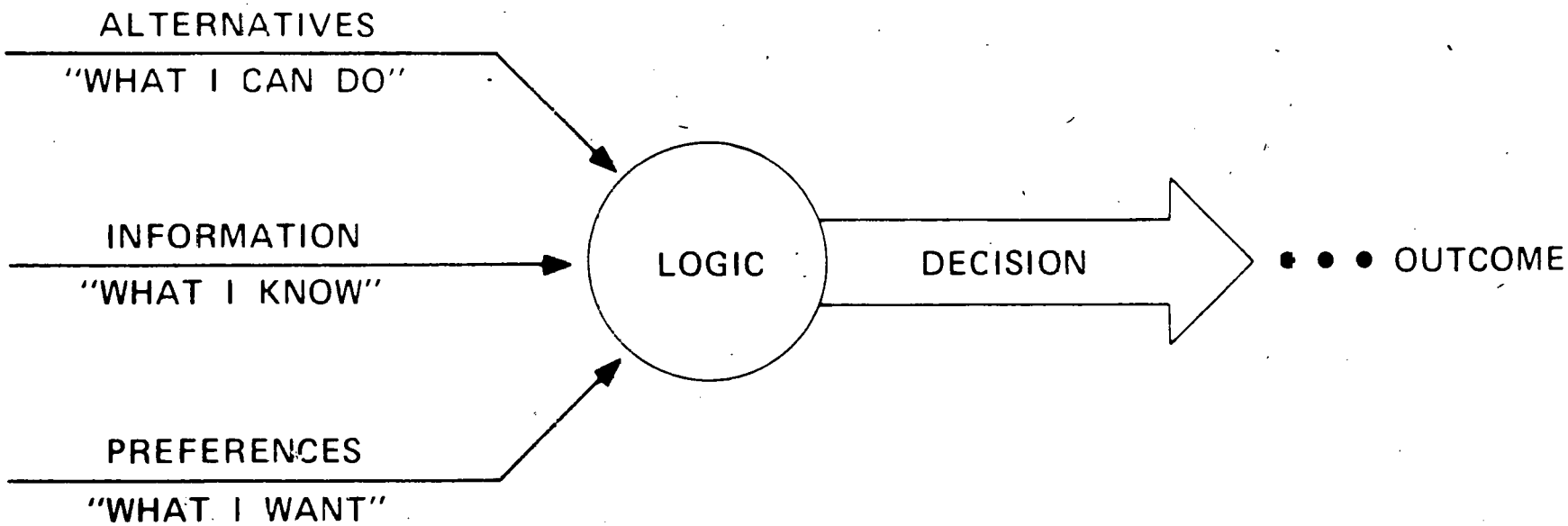
The second response I would like to make to your comment relates to the other introductory slide. We need to distinguish between the methodology as providing answers, and the methodology as a process and a framework for discussion.

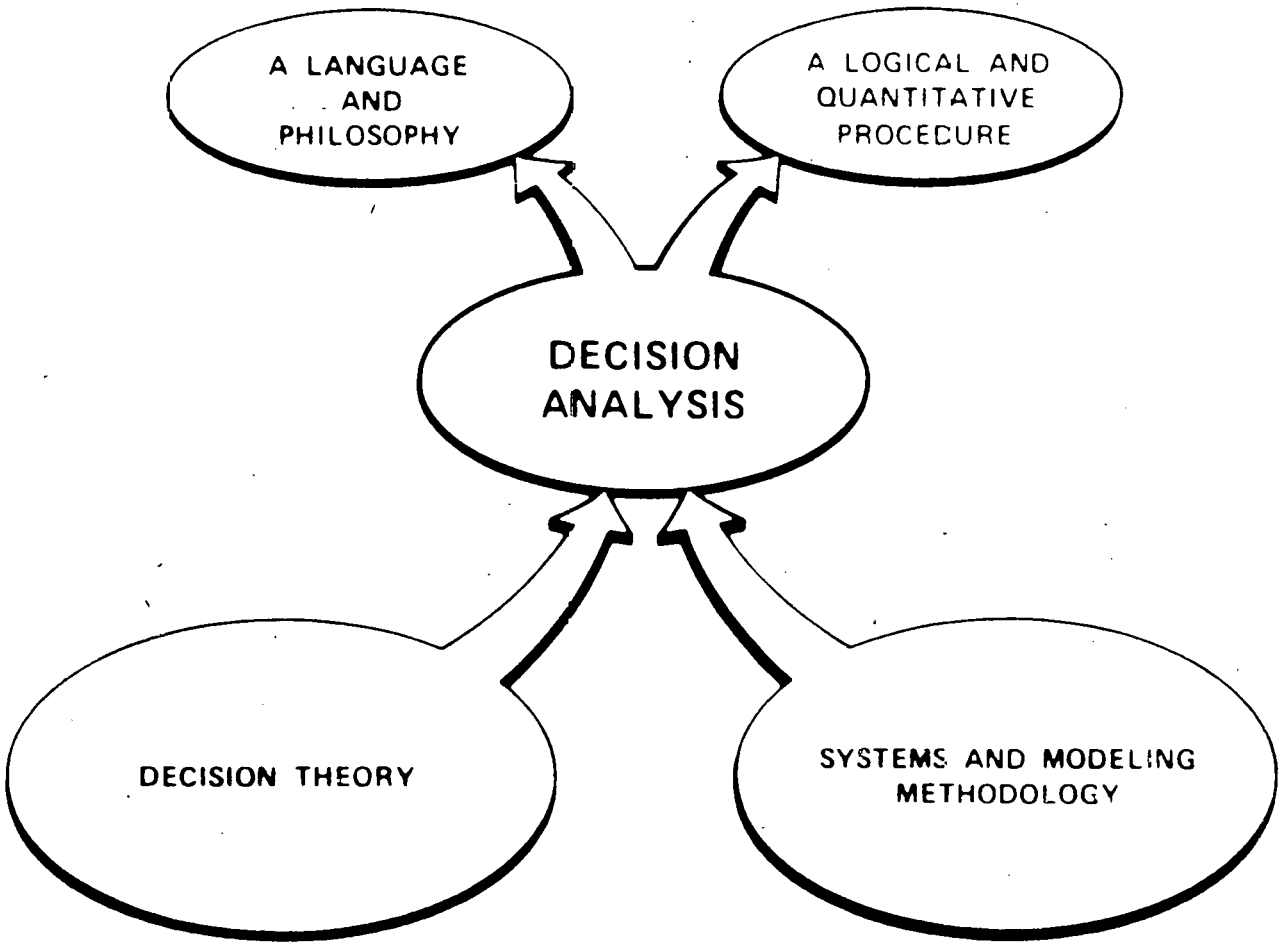
Management is going to be making the decisions. Typically the decision process involves integrating many different points of view and areas of expertise. Where we see the methodology as being useful is primarily as a framework for this integration, and not as a way of getting an answer that will stand there and be judged badly in retrospect when much more information is available than was available to the management that made that decision.

"How can these methods be validated?" is the question we are often asked. And I think we have to answer it in a way that I am borrowing from a Marine Corps Colonel, whom I heard asked the same question at a Department of Defense presentation.

When asked how his simulation model for a Marine landing exercise was validated, he said, "It gives my commander a warm feeling in his gut." As the commander makes the decisions

ELEMENTS OF GOOD DECISIONS




A LANGUAGE AND PHILOSOPHY
A LOGICAL AND QUANTITATIVE PROCEDURE
DECISION ANALYSIS
DECISION THEORY
SYSTEMS AND MODELING METHODOLOGY

the model makes him more comfortable with his decision making responsibility.

I think this is all that methodology can provide. We cannot guarantee correct answers and good outcomes. All we can do is help assimilate the information and help the decision maker to feel more comfortable that the information available to him has been taken into proper account.

DR. COOK: Warner has given an answer that is certainly a philosophical answer, and it is the right answer. I would like to answer from the standpoint of the old salt, because we were using these kinds of techniques in the nuclear business a dozen years ago.

In the safety area much of the probabilistic analysis that appeared in the Rasmussen Report, Appendix 1 is essentially the same as work that had been done earlier, in 1964 and 1965. The analysis was not carried through because the position of the government agency did not permit these methods to be used.

Systematic identification of decision alternatives and careful thinking about structure makes you look at the problem much more broadly. And many of the suprises -- While you can't guarantee that you're going to avoid them, many of the things which turn out to be pitfalls can be identified in advance and related to the other aspects of the problem. And that is a great deal of help in planning.

This is my answer from practical experience done. While I agree perfectly with Warner's answer with respect to the fact that you can't guarantee no surprises, you certainly can help develop the structure to help avoid them.

DR. CHARPIE: Any other questions?

MR. DAVIS: It seems to me one of the aspects we are trying to deal with when you're trying to develop a long-range program is to come up with what I guess I would call a prudent program which protects you against unfavorable things happening in the future, sort of the reverse of what Wally Behnke says, in trying to allow for favorable problems.

But to some extent, and it seems to me to a considerable extent, in the over-all energy business we are trying to make sure that we have got some of the alternatives available in case we need to use them. It is not necessarily a matter of projecting what the probability is of having to use them, but to make some allowance for the fact that we may simply be in very bad trouble and need to have them, and develop some sort of a course of action which would lead to these being available technically and in other ways at a time when they may be needed, even though the probability of that may not be assessed today as being very high.

I'm sure this comes into the decision analysis thing in some manner, but it seems to me it leads to something

other than the sort of straightforward probability assessment that you describe.

DR. COOK: If you recall this morning, when I went through the structure of this agricultural chemical problem I identified that as an area that you go through. And one of the things you would like to do with this kind of analysis is to identify alternative scenarios, identify branch points at which, if you're in difficulty with one alternative, you can switch to another one.

So the idea of a hedging strategy or a contingent plan is all a part of the structure. And more than that, there is a pre-planning element to it that allows you to, in an organized fashion, consider how you will take corrective action.

MR. DAVIS: This came to my mind when you were talking about synthetic fuels, to demonstrate that it is cheaper to do it one way than another, and you may get the same amount of information. I agree, but on the other hand, this is something we might just need and might be willing to pay more for as insurance. I happen to be personally convinced we need it.

DR. COOK: That's a value judgment that must be applied in the program. And if the value of having those alternatives is high enough you in fact will want to have them. The value judgment has to be worked out. Warner talked about trade-offs between alternatives; and that's what I think

you're talking about: is it worth it to you to have those trade-offs in a form that allows you to have flexibility?

DR. NORTH: Let me respond directly to your question about synthetic fuels by showing a little more complicated tree than we had in the presentation.

(Slide: Partial Decision Tree Display of Results)[1]

This tree shows the industry's decision based on what happens in the eighties. It shows how many plants did industry decided they need to buy, based on the price of foreign oil and the cost projections that are made after the original plants in the 1970's government program are operating. And we see decisions taken all the way from four million barrels a day capacity being purchased to no additional capacity being purchased.

This decision can be regarded as contingency planning. A great many possibilities should be considered in this analysis. And the degree to which uncertainties such as changes in foreign oil price have been taken into account is part of the feedback that has to come from the decision makers and their advisors, with whom the methodology specialists, such as Howard and myself, are working. After all, they are the experts on the business and they know what the right questions are. And our job is to provide a framework to pull all these issues together.

MR. DAVIS: In this particular connection is this your judgment of what industry will do, or does industry--

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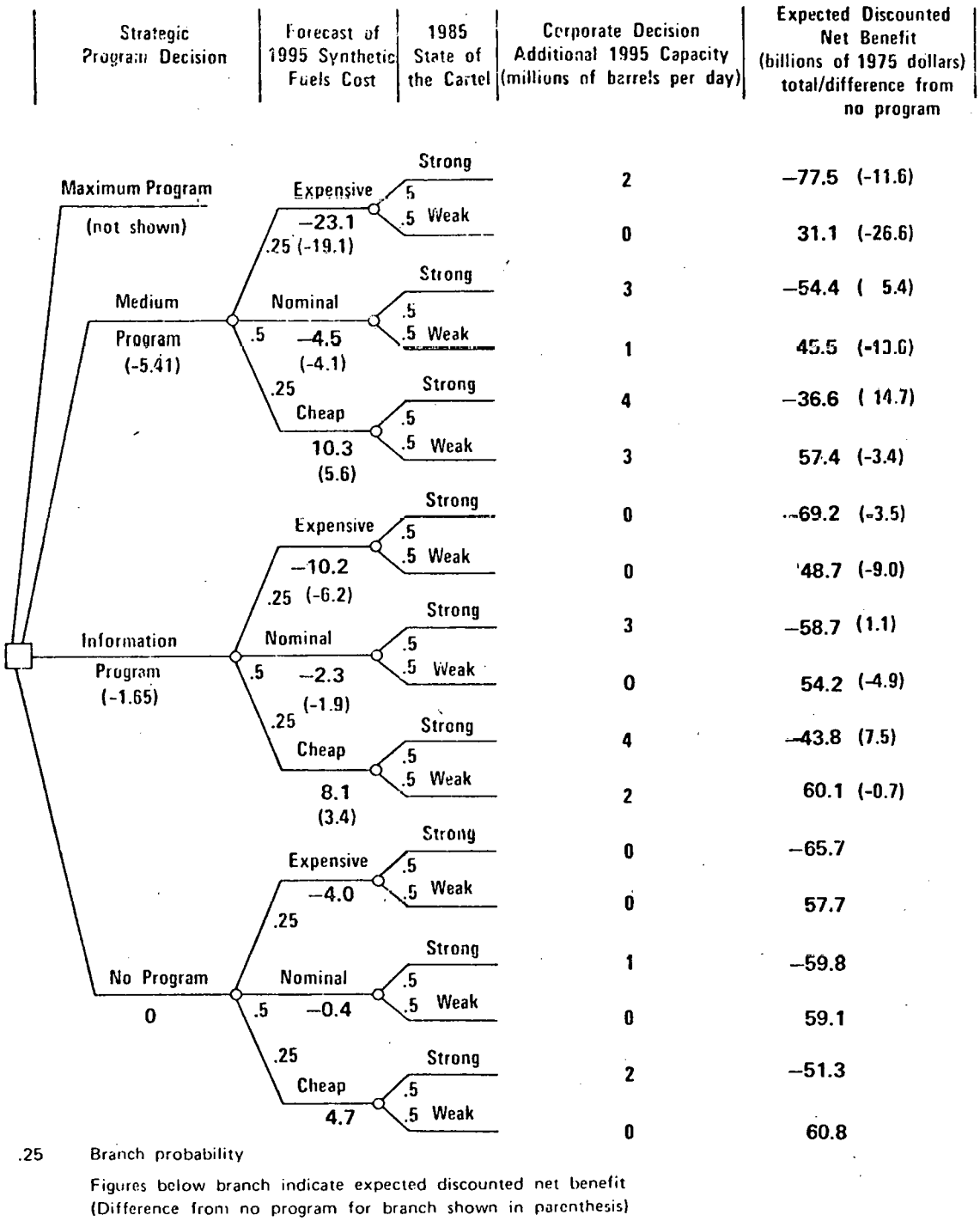
1. From the Synfuels Interagency Task Force Report, Vol. II, p. 67



.25 Branch probability

Figures below branch indicate expected discounted net benefit (Difference from no program for branch shown in parenthesis)

FIGURE 32 PARTIAL DECISION TREE DISPLAY OF RESULTS

DR. NORTH: This is a judgment made by the Federal Interagency Task Force in their assessment of the situation. I might add that this analysis was done from start to finish, including the writing of the report, in a total of six weeks. So there really was not time for a lot of industry-government interaction. As far as we were concerned, we were providing support to the government Interagency Task Force in this area.

MR. DAVIS: Could I make one other comment?

In the discussion here it seems to me we're treating demonstration plants as something sort of separate from the overall commercialization process. And this was highlighted, I think in some ways, by the charts.

Just as a matter of philosophy it seems to me that you tend to look at the whole process, transferring the technology from wherever it's developed to commercial use, and the goal of demonstration plants is doing that.

It's going to be too bad if somebody sets them aside as something magical and separate, and not have it as part of the overall process.

It seems to me it's the basic philosophy of looking at demonstration projects.

DR. COOK: That's exactly what we try to bring out when we point out that the demonstration project really

comes in right alongside the other alternatives, as far as the business alternatives and the supply alternatives.

MR. DAVIS: You were assuming they had to have a demonstration plant.

DR. COOK: No, it's one of the decisions they might have to make.

DR. CHARPIE: I'd like to ask a different kind of question.

In thinking about the application of these techniques, these processes, which you describe properly as fairly conventional to ERDA's major project, demonstration projects, I find a problem I don't know how to do; that is, that most the demonstrations you talked about here can be broken down into pieces which are described in terms of probabilities running from zero to one.

My perception is that in the area of energy projects, however, where there are two or three levels of time-sequential decisions, one of which -- one series of which is related to government action, and part of which is related to social and political and environmental evaluations that the variables are not continuous, that they often have just the zero and the one there.

For example, you will be allowed to import LNG or you won't; it will be possible to put some sulphur into the atmosphere or it won't.

And often these kinds of -- the technique which is designed to treat the continuous variables, I think in the case of these massive energy projects is going to have to deal with these discontinuities.

Now, how can you look at the first generation, or the first two generations of the decision process when the discontinuous variable is in the last step?

DR. NORTH: Let me describe from our commercial experience how we have often dealt with this issue.

DR. CHARPIE: Companies never get themselves in this trap by their own choice.

DR. NORTH: The problem companies often face is that as they contemplate the decision on a new technology, their crucial uncertainty is what the government will do in regulating that business.

One of our client's largest investment decisions in the energy area was made in the face of possible government regulation of the company's main product. And the question was whether this company should jump into a new technology in advance of the government regulation and get a jump on their competitors, or wait to see whether the government would force the industry to change technologies.

Now in this case there was some probability assigned to government regulation, and there was a great deal of uncertainty

as to what that probability ought to be. Some people in the company felt, "It's almost certain the government is going to do this because of the way the environmentalists feel about this issue," and other people were saying, "Well, you know if you look at the number of people this is going to put out of jobs and the dislocation of the industry, we don't think the government is going to impose the change except very slowly over a number of years."

Now you can define what this difference of opinion means. A lot of thought may have to go into just exactly what probabilities we use in that analysis. And you wind up with a conclusion that maybe the swing this uncertainty makes in the company's profits is so big that we'd better investigate a hedging strategy; how we can best protect ourselves against the impact of government regulation, or what the lack of government regulation might mean to our business -- the question Ken Davis was raising.

DR. CHARPIE: I'm trying to address this from the ERDA point of view.

DR. QUARLES: From the ERDA point of view, doesn't the answer fit right in, because of the variety of technologies they will need to have to meet the total energy supply? So that some parts of technology might be foreclosed by government action or some other negative roadblock; and yet, as you look at all the possibilities researchers are trying to develop,

you can reasonably assign some probabilities and still come out, on balance, in a strong position.

DR. COOK: I think there's another important factor. You can assign probabilities, but what happens when the event happens? How do you change things when the probability becomes zero or one?

I think this is a further step in the planning process, to have a structure ready when people say, "Now I've got to regroup." We aren't regrouping from zero and contemplating our navel and saying "Where are we going?" We are really dealing on a constructive communication basis.

I think the answer is right, but I think there is also another advantage of being able to be resilient when you get to the point of events actually happening.

DR. CHARPIE: Any other questions?

(No response)

DR. CHARPIE: Well, let's take a 15-minute break now and get on with our agenda.

(Recess)

APPENDIX F

Carl M. York
Consultant

A Study of the Role of Environmental and Safety Factors in ERDA Sponsored Demonstration Projects

Prepared for: The Demonstration Project Task Force
of the
Office of Industry, State and Local
Government Relations,
ERDA
Washington, D.C. 20545

Prepared by: Carl M. York, Consultant
July 30, 1976

679 Carlston Avenue
Oakland, California 94610
(415) 832-0850

A Study of the Role of Environmental and Safety Factors in ERDA Sponsored Demonstration Projects

I. Introduction

In 1975 a Task Force on Demonstration Projects as a Commercialization Incentive was formed by the Office of Industry, State and Local Governments of the U.S. ERDA. The objective of this task force is "to advise ERDA on methods of structuring technical demonstrations of new or improved energy systems so that these demonstrations may be responsive to non-technical, as well as technical, issues which are vital in the ultimate decision to proceed with commercial exploitation." The membership of the task force was carefully selected to provide a balanced representation from the principal interest groups involved in commercialization decisions in the field of energy: the developer, the investor and the regulator.

When the task force met, their programs included a number of presentations by ERDA staff members on various demonstration projects that were under way or being considered. As these staff briefings continued through the course of several meetings, some members of the task force became concerned that the role of environmental and safety factors in the planning, implementation and evaluation of the demonstration projects was not clear. It is the purpose of this study to examine that role and to determine, if possible, whether or not the concern of the task force members was justified.

To address this task, the present study has focused on two cases of demonstration projects which had come to the attention of the Task Force during the staff briefings. Both of these will be described below and attention will be focused on how each one has dealt with environmental and safety problems. Although these problems are specific to each demonstration project, the methodology used to solve those problems is sufficiently general in application, that the conclusions of this study will not be limited to two individual demonstration projects. After presenting the two case studies, they will be summarized and an interesting policy issue which surfaced during interviews with the staff will be posed for the ERDA management.

II. The Clean Boiler Fuel Demonstration Plant

This demonstration project is commonly referred to as the Coalcon Project, because the Coalcon Company, an affiliate of Union Carbide and Chemical Construction Company, is to design, construct and operate a plant for producing clean boiler fuels from high-sulphur coal under joint sponsorship with ERDA. (cf Reference 1 and Appendix A) The plant is to be fully integrated from receipt of coal to delivery of a finished product, including cleanup of all waste streams and recovery of all potential by-products. Coalcon is organizing a consortium among private companies and public agencies to provide fifty percent of the financial support for the program, while ERDA will supply the other fifty percent.

The overall objective of the project is to verify the commercial economics, the technical scale-up potential, and the physical and chemical

feasibility of a process for producing clean boiler fuel in a commercial-size, wholly integrated plant. This plant is to convert 2,600 tons of high sulfur coal a day into 3,900 barrels of clean liquid fuel and 22 million cubic feet of high-BTU pipeline-quality gas per day. These products will be evaluated for compatibility with current power plant and boiler designs.

The project is being conducted in four phases:

Phase I, Preliminary Engineering;

Phase II, Detailed Plant Engineering;

Phase III, Plant Construction; and

Phase IV, Plant Operation, Testing and Evaluation.

The chart presented in Figure 1 shows these four phases as a function of time for the Coalcon Project. In addition, the role of environmental and safety efforts are indicated at the bottom of the chart.

In Phase I, the emphasis might tend to be on the preliminary engineering of just the plant design. However, the site selection process involved the establishment of criteria by which a choice could be made. These criteria included environmental factors which were broken out into three categories, physical, human and biological.

Under physical factors in the environment, site proposals were to evaluate water quality, availability and limitations on use. These limitations had to spell out the water quality ratings compared to E.P.A. acceptable limits, limitations on effluent contaminants and temperature, as well as a list of the use and discharge permits which would be required at any proposed site. Air quality had to be assessed for existing wind

patterns, proximity to population centers, and similar factors, before estimating the impact of projected levels of change caused by the introduction of the new plant operation. State permits and regulations on air quality had to be spelled out. Both solid and liquid waste disposal had to be examined in detail. The impacts on humans, flora and fauna are similarly specified in the site selection criteria.

Seven states were asked to suggest sites and document them according to the detailed criteria outlined above. Sixteen sites in six states were proposed and an internal evaluation began. If the data were complete, other federal agencies were contacted (e.g. E.P.A., U.S.G.S., Army Corps of Engineers, etc.) to review the proposals. Eight of the proposed sites were rejected by evaluating the data submitted. The other eight were visited by an ERDA team and also an independent third party under contract to ERDA. The information submitted by Coalcon, the independent third party contractor and the ERDA team for site visits was forwarded to the Site Review Panel chaired by the Assistant Administrator for Fossil Energy. This panel prepared the data for submission to the ERDA Administrator for final selection. Of the fourteen criteria used to compare the various sites, four dealt with the environment as shown in the rating sheet in Figure 2. In addition to the symbolic ratings used by Coalcon, numerical values were assigned by the ERDA third party contractor to each of the criteria for each site in order to determine an overall rating for each one. The New Athens, Illinois site was finally chosen by the ERDA Administrator.

As seen in Figure 1, the site selection came in the fourth

quarter of 1975 and was made after only a few months of field studies. Once the site was selected, the ERDA staff could focus its attention on the details of the environmental assessment which would have to be done in Phase II of the project, "Detailed Plant Engineering."

Under Phase II, the site specific environmental assessment will be made by carrying out more field studies and examining the process effluents from the plant to be built. These studies will be compiled into a draft of an environmental impact statement. In the meantime, an Environmental Task Force for the project will monitor and guide these efforts. The Task Force includes representation from the Assistant Administrator for Environment and Safety of ERDA, the Assistant Director for Environment and Safety in Fossil Energy, the ERDA Division of Fossil Demonstration Plants, and the ERDA Pittsburg Energy Research Center. Representatives of the U.S. Environmental Protection Agency - Region V, the State of Illinois, and the U.S. Water Resources Council are also on the Task Force.

These Task Force members and their staff are to oversee the ERDA Environmental Assessment Activities with respect to this demonstration plant. The objectives of these activities are to direct and review environmental analysis and data gathering in order to:

- prepare the environmental impact assessment;
- develop the Environmental Impact Statement;
- insure early consideration of community concerns; and
- begin to provide data for development of the ongoing environmental monitoring program.

The result of these efforts will be the Environmental Impact Statement for

this plant, which will include analysis of any possible adverse effects and evaluate alternatives and an environmental protection strategy. Public hearings on the draft document are to be held and additional means to mitigate any adverse effects will be solicited. Public comments will be considered in preparing the final Environmental Impact Statement.

An essential feature of the environmental protection strategy for this demonstration project is the Environmental Monitoring Program to be started during Phase II. This program has as its objectives the continuing identification of all environmental health and safety impacts which might develop during the lifetime of the project. The program will:

— establish an environmental baseline;

— monitor any changes in that data during plant construction and operation;

— monitor the transportation and fate of pollutants; and

— control equipment effectiveness in handling pollutants.

This monitoring program is to continue through Phases III and IV of the project to provide a continuity of sensing and control over environmental health and safety problems which might arise.

In summary the Coalcon project can be said to have considered environmental and safety factors from the outset. The initial Request for Proposals for sites required detailed consideration of these criteria. After a site selection was made, then even more detailed field work was begun. As Phase II of the project gets under way, the environmental protection strategy with its monitoring program design and implementation becomes vitally important. Two questions can now be asked.

What will the relationship be between the results of the environmental protection strategy adopted for this demonstration plant and that more generalized strategy which will be required for future full scale implementation of the technology?

Where will the responsibility lie within the ERDA organization to analyze the lessons learned from this demonstration project and to extract general guide lines for the preparation of environmental impact statements for full scale applications of the technology?

The next case to be considered suggests a resolution, if not a definitive answer, to these questions.

III. The Imperial Valley Geothermal Demonstration Project

The U.S.G.S. has designated six areas within the Imperial Valley of California as known geothermal resource areas. ERDA's Division of Geothermal Energy and the San Diego Gas and Electric Company have negotiated an agreement to construct and operate a 10 MWe geothermal thermal loop experimental facility in the valley near Niland, California. This facility will utilize two production wells with a combined flow rate of 800,000 lbs/hr. This geothermal fluid is expected to contain 17 percent by weight of solids and 3 percent by weight of noncondensable gases (CO_2, H_2S, etc.). Steam will be produced by flashing, then will be scrubbed to reduce

impurities and finally passed through a heat exchanger to vaporize isobutane. The isobutane will circulate in a closed loop which will include an expansion valve to simulate a turbine. The isobutane will be condensed by cooling water with a heat sink provided by a spray pond. The residual brine and steam condensate will be taken from the heat exchanger and reinjected into the earth. The noncondensable gases will be removed and vented into the atmosphere.

It is anticipated that if this 10 MWe facility is successful, then it will be followed by a 50 MWe demonstration plant at the same site. This larger demonstration plant might be operational by the end of 1981, while the smaller, 10 MWe facility is expected to begin operation in the spring of 1976.

Figure 3 indicates the original schedule proposed by the San Diego Gas and Electric Company. As seen in Appendix B there have been some changes in the project, but the steps in development have remained the same as shown. It is to be noted that the first studies of environmental impact were to begin in 1975 and in fact they did.

In the spring of 1975 ERDA/AES appointed the Lawrence Livermore Laboratory to be the "lead laboratory" for carrying out a long term project to acquire as complete an understanding of the environmental quality in the Imperial Valley as possible, <u>before</u> any major geothermal developments were made. Once this environmental "baseline" has been established the purpose of the project will be to insure that the development of geothermal resources proceeds on an environmentally sound basis. This baseline project is described in detail in Appendix B. (c.f.

Reference 2)

The great concern for the environment of the Imperial Valley stems from the fact that it is one of the nation's most productive agricultural resources. In 1974 the gross value of agricultural production in the valley was in excess of $550 million. Because the valley receives less than 3 inches of natural rain fall a year, all of the crops depend upon irrigation water from the Colorado River. There is a constant battle against salt buildup in the soil and much of the cultivated land contains drain tile at a depth of several feet to permit over-irrigation so that the salt can be washed through the soil to prevent build-up.

The geothermal test wells in the Niland area are surrounded by this prime agricultural land in full production. Hence it is essential that the brines and gases given off by these wells not interfere with the agricultural productivity, or contaminate the natural aquifers or irrigation drainage systems. Cooling systems must be carefully designed so that significant amounts of salt and other chemicals, such as boron, are not carried over and released in cooling tower drift. Unless a volume of fluid equal to the amount withdrawn is reinjected into the ground, large area land subsidence might occur. Such subsidence could wreck the gravity flow irrigation and drainage systems.

The project led by the Lawrence Livermore Laboratory has a primary goal to insure that large scale geothermal development proceeds in an environmentally sound manner, that major problem areas are anticipated, and that necessary feedback of information to those concerned with technology development takes place so that appropriate control measures may be

instituted if justified. The program has been designed with a high degree of flexibility so that emphasis can be shifted to focus on the most important, unresolved issues as they arise during the course of the development of the geothermal resource. A major effort will be made to coordinate and to transfer information to the many individuals and organizations concerned with the development. The extensive list of these organizations is found at the end of Appendix B. A secondary goal of the program will be to accumulate sufficient data so that any problems associated with the development of geothermal resources may be readily distinguished from those due to other causes.

The Imperial Valley "Baseline" Project illustrates one way in which the Assistant Administrator for Environment and Safety can be involved in demonstration projects of new energy technologies. In addition to including environment as a part of the overall demonstration project plan, as in the case of the Coalcon Project described above and as indicated in the proposal from San Diego Gas and Electric for geothermal development laid out in Figure 3, a major parallel effort on the R & D aspects of Environmental Health and Safety has now been launched. One of the most experienced interdisciplinary teams from an ERDA National Laboratory has been given lead responsibility to design and implement a long term study. At ERDA headquarters, a staff coordinator from Environment and Safety has been assigned to work directly with the Division of Geothermal Energy as a member of the management team. (c.f. Appendix B, Organization Chart).

The principal concern of Environment and Safety is that low-level, long-range, environmental and health problems not be overlooked.

In view of the Atomic Energy Commission's problems with contaminated ground water seepage from their plants and the Department of Defense's troubles with leaking nerve gas, this concern is certainly justified. The overall mission of ERDA is to develop safe, clean, environmentally acceptable new energy technologies as soon as possible. Such a broad mission cannot be carried out by the technology development manager alone, but will require active collaboration with Environment and Safety from the start. This is not meant to imply that every development project should or might have as extensive a program as that of the Imperial Valley Environmental Project described here. It does suggest that perhaps the Assistant Administrator for Environment and Safety might have an explicitly assigned responsibility for the determination of the environmental consequences of technology development and for the specification of the means of minimizing unacceptable consequences.

IV. Conclusion

In the two cases of demonstration projects described above several common points emerge. First, the role of environmental and safety impacts has been a major consideration of the ERDA staff from the earliest planning phases, right on into the operations monitoring phase. Second, when sites have been chosen with the aid of general criteria, then on-site environmental baseline studies have been begun and long range plans laid out for that specific location. Third, there is a high level of awareness on the part of the ERDA staff of the important role environmental health and safety play in the project they manage from inception to implementation.

Thus the initial concern expressed by members of the task force is not justified on the basis of this investigation.

However, the course of the investigation has uncovered a clear policy issue for the management of ERDA to consider. Each demonstration project represents an operating example of a future technology and each project presents a unique opportunity to learn from experience about the environmental consequences of that technology. At present there is no clear cut assignment of the responsibility and authority within ERDA to determine when a technology development is environmentally acceptable. This responsibility together with that of drafting generalized guide lines for environmental impact statements relevant to newly developed, full-scale technologies should be assigned to Environment and Safety. Such an assignment is completely consistent with the role of Environment and Safety in carrying out the overall ERDA mission.

VI. Acknowlegements

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L. Anspaugh and P. Phelps

- Lawrence Livermore Laboratory

Special thanks are due to Dr. Robert Charpie and Dr. Alan Pasternak, members of the Task Force, for their guidance in formulating the study.

References

1. "Coal: Demonstration Plants", ERDA 76-32-2, p. 5.

2. "An Overview of the Imperial Valley Environmental Project," by L. R. Anspaugh and P. L. Phelps, UCID-17067, Lawrence Livermore Laboratory, April 8, 1976.

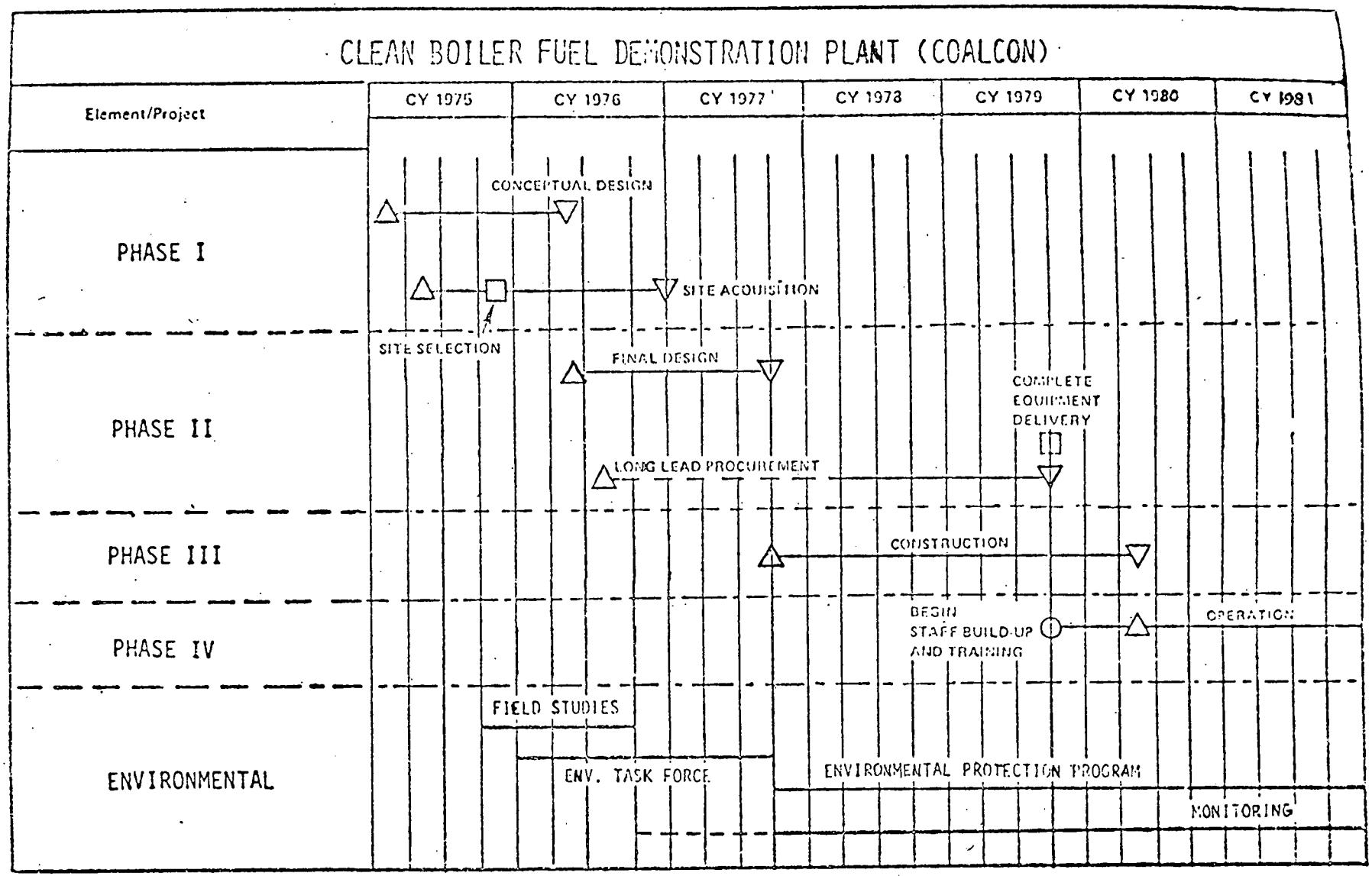

CLEAN BOILER FUEL DEMONSTRATION PLANT (COALCON)
Element/Project
CY 1975
CY 1976
CY 1977
CY 1978
CY 1979
CY 1980
CY 1981
PHASE I
CONCEPTUAL DESIGN
SITE ACQUISITION
SITE SELECTION
PHASE II
FINAL DESIGN
COMPLETE EQUIPMENT DELIVERY
LONG LEAD PROCUREMENT
PHASE III
CONSTRUCTION
PHASE IV
BEGIN STAFF BUILD-UP AND TRAINING
OPERATION
ENVIRONMENTAL
FIELD STUDIES
ENV. TASK FORCE
ENVIRONMENTAL PROTECTION PROGRAM
MONITORING

Figure 1

COALCON SITE EVALUATION

EVALUATION CRITERIA	NEW ATHENS	ALT #1	ALT #2	ALT #3
COAL AVAILABILITY	◉	◒	○	○
LAND	◉	◒	●	◒
WATER AVAILABILITY	○	◒	◒	◒
FREEDOM FROM ENVIRONMENTAL PROBLEMS	◉	◒	◒	◒
MATERIAL & MARKET ACCESSIBILITY	◒	◒	◒	◒
LABOR	◒	◒	◒	◒
SOCIO-ECONOMIC	○	◒	○	◒
ENVIRONMENT				
METEOROLOGY/AIR QUALITY	◒	◒	○	○
BIOLOGY	◉	○	◒	◒
WATER QUALITY	○	○	○	○
ASH DISPOSAL	●	○	○	○
POWER	◒	◒	○	○
TRANSPORTATION	◒	◒	◒	◒
EXPANSION POTENTIAL	◉	◒	◒	◒
COMMUNITY ATTITUDES	◒	◒	◒	◒
CONTRACT SERVICES	○	◒	○	◒
TAXES	○	◉	◒	◒

◉ - EXCELLENT - QUALITY & COST BEST OVERALL FOR DEMO & COMMERCIAL
◒ - GOOD - QUALITY & COST ADEQUATE FOR DEMO & COMMERCIAL
○ - FAIR - DEFICIENCIES RELATIVE TO HIGHER RATED SITES
◌ - POOR - SEVERE PROBLEMS OR DEFICIENCIES

Figure 2

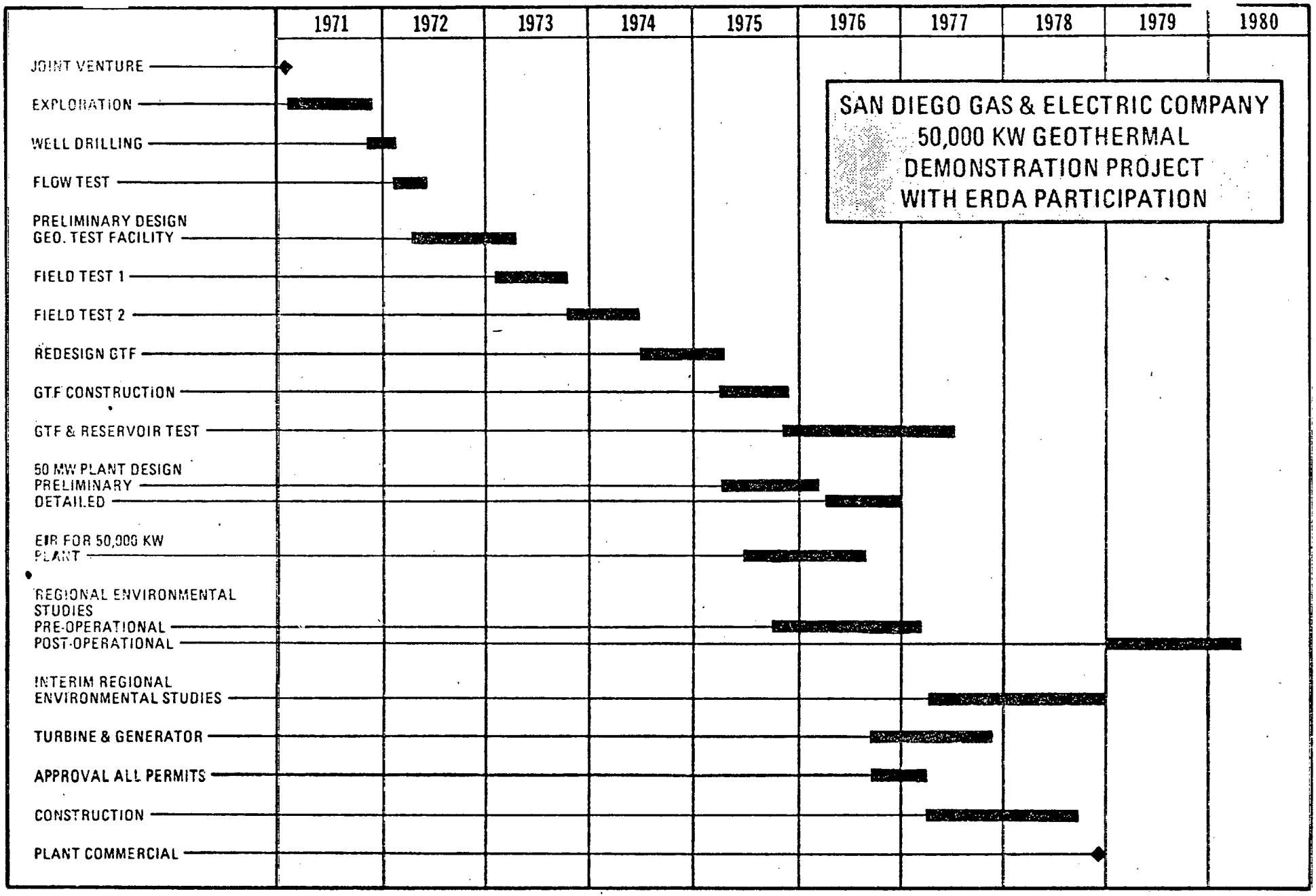

SAN DIEGO GAS & ELECTRIC COMPANY
50,000 KW GEOTHERMAL
DEMONSTRATION PROJECT
WITH ERDA PARTICIPATION
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
JOINT VENTURE
EXPLORATION
WELL DRILLING
FLOW TEST
PRELIMINARY DESIGN
GEO. TEST FACILITY
FIELD TEST 1
FIELD TEST 2
REDESIGN GTF
GTF CONSTRUCTION
GTF & RESERVOIR TEST
50 MW PLANT DESIGN
PRELIMINARY
DETAILED
EIR FOR 50,000 KW
PLANT
REGIONAL ENVIRONMENTAL
STUDIES
PRE-OPERATIONAL
POST-OPERATIONAL
INTERIM REGIONAL
ENVIRONMENTAL STUDIES
TURBINE & GENERATOR
APPROVAL ALL PERMITS
CONSTRUCTION
PLANT COMMERCIAL

Figure 3

Appendix: A

ERDA 76-32-2
UC-89

COAL DEMONSTRATION PLANTS

QUARTERLY REPORT

APRIL–JUNE 1975

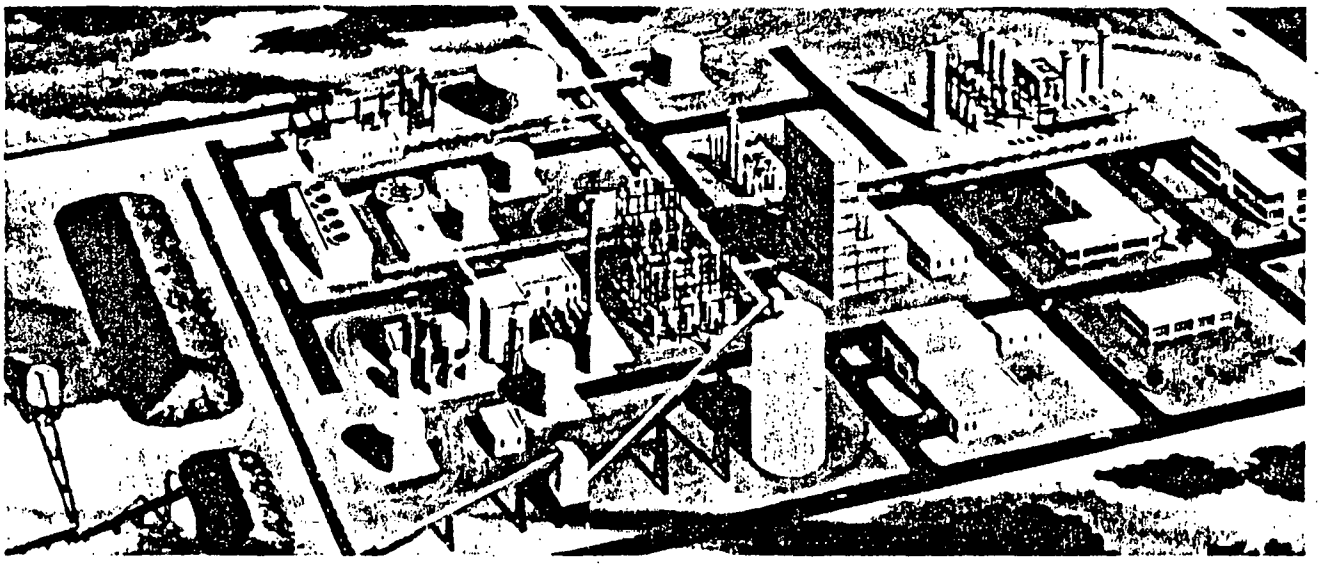
Philip C. White
Assistant Administrator
Office of Fossil Energy

Raymond L. Zahradnik
Acting Director
Division of Coal Conversion and Utilization

Neal P. Cochran
Acting Assistant Director
Demonstration Plants

Office of Fossil Energy
Energy Research and Development Administration
20 Massachusetts Avenue, N.W.
Washington, D.C. 20545

I. CLEAN BOILER FUEL DEMONSTRATION PLANT



COALCON COMPANY
NEW YORK, NEW YORK

Contract No. E(49-18)-1736
Total Funding: $237,222,300

INTRODUCTION

Under the sponsorship of ERDA, a demonstration plant for producing clean boiler fuels from high-sulfur coal is to be designed, constructed, and operated by Coalcon Company, an affiliate of Union Carbide and Chemical Construction Company. The plant must be fully integrated from receipt of coal to delivery of a finished product, including cleanup of all waste streams and recovery of all potential by-products. Coalcon is organizing financial support for the program, in the form of a consortium providing 50 percent cost sharing, among private companies and public agencies.

The overall objective of this contract is to design, construct, and operate this demonstration plant in order to verify the commercial economics, technical scale-up potential, and physical and chemical feasibility of a process for producing clean boiler fuel in a commercial-size, wholly integrated plant. This demonstration plant is to convert 2,600 tons of high-sulfur coal a day to 3,900 barrels of clean liquid fuel and 22 million cubic feet of high-Btu pipeline-quality gas per day. These products are to be evaluated for compatibility with current power plant and boiler designs.

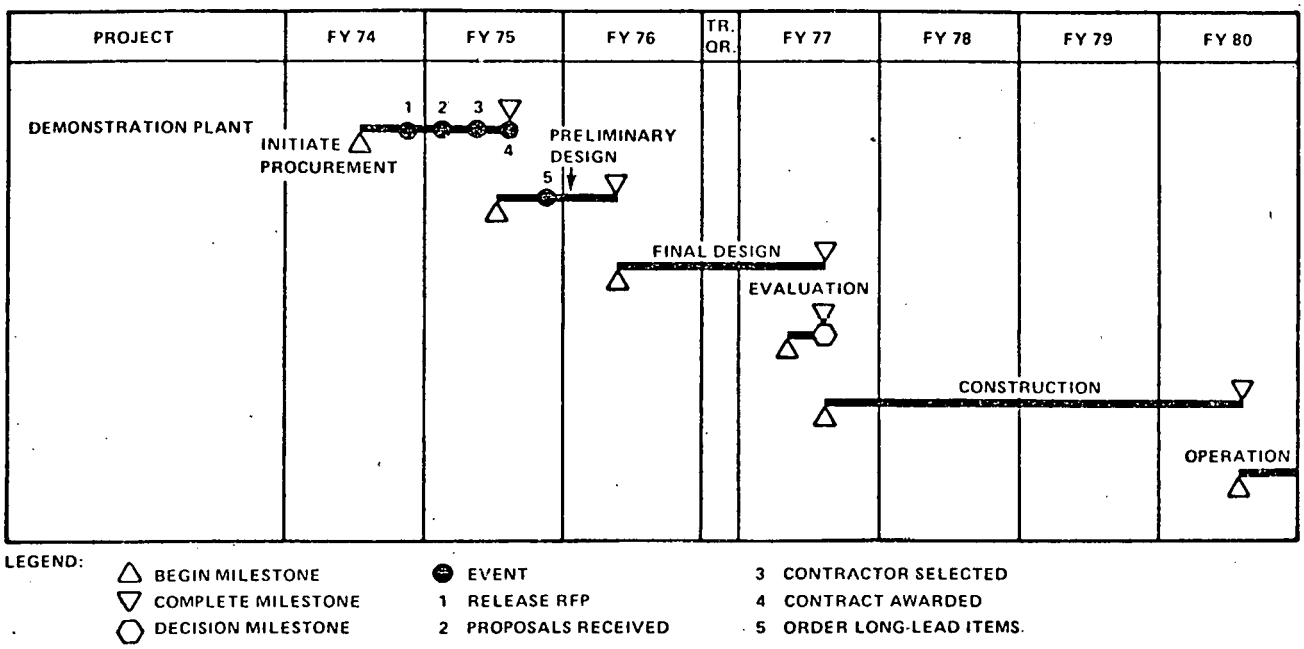


Figure I-1. CLEAN BOILER FUEL PROGRAM SCHEDULE

The effort is being conducted in four phases. Phase I, preliminary commercial plant process design and engineering, involves (1) identification of characteristics and requirements for a plant for demonstrating, with minimum risk, the economic feasibility of future commercial plants (minimizing plant end-product costs is the major criterion) and (2) preparation of detailed process designs and a preliminary plant design for the demonstration plant. Phase II includes detailed demonstration plant design, engineering, and planning activities and preparation of detailed specifications, drawings, and a construction bid package. Phase III, demonstration plant construction, includes site preparation, equipment purchase, construction, field erection, and plant acceptance and check-out. In Phase IV, the plant will be operated to produce synthetic products and to obtain data for evaluating the potential of this process for full-scale commercial development and production. The schedule for this project is shown in Figure I-1.

PROCESS DESCRIPTION

The process selected by Coalcon for producing clean boiler fuel in the demonstration plant is Union Carbide's hydrocarbonization process, which produces both liquid fuel and high-Btu pipeline-quality substitute natural gas. In this process, shown schematically in Figure I-2, coal is crushed, dried, and preheated to 650° F in a stream of hot flue gas. The hot coal is separated from the flue gas by a cyclone separator and is admitted to the high-pressure processing system by means of lock hoppers. A hydrogen stream carries the coal into the hydrocarbonization reactor where it mixes with additional hydrogen at an elevated temperature and pressure. The hydrogen is supplied by a char gasification system. Hydrocarbonization consists of a combination of coal devolatilization and hydrogenation of the various constituents of the volatile matter. The partially converted coal remains as char.

The remainder of the system includes purification and separation of the components into various useful or waste fractions. Immediately after hydrocarbonization, the product gases are separated from the entrained char in a cyclone separator. The fractionator removes the heavy oil and a lighter oil fraction (mostly decane, toluene, and trimethyl benzene); ammonia is recovered from the gas stream by a wash system and is sold for fertilizer; hydrogen sulfide, carbon dioxide, and trace hydrocarbons are removed by an acid-gas removal system. As a final step, the gas is passed through a cryogenic system; a liquefied petroleum gas type fuel is removed from the gas

stream as is a hydrogen-rich fraction for recycling to the hydrocarbonization reactor. The remaining product is synthesis gas, primarily carbon monoxide and hydrogen, which is sent to a methanation reactor for enrichment to high-Btu pipeline-quality gas.

HISTORY OF THE PROJECT

Work under this contract was initiated in January 1975. Union Carbide's hydrocarbonization process was selected as the process to be demonstrated. Two alternate designs are being considered: a high-pressure system and low-pressure system. The process design for the high-pressure system has been prepared and requires only minor modifications before final evaluation. Current efforts are concentrated on developing the preliminary design of the low-pressure system. In addition, Coalcon is evaluating various alternative process subsystems for the commercial plant. Coalcon is working with the U.S. Army Corps of Engineers to develop a list of equipment with long lead times for procurement for the demonstration plant.

Tests in support of this program are being conducted at facilities in Tonawanda, New York; South Charleston, West Virginia; Buffalo Testing Laboratories in Buffalo, New York; and in-house laboratories. The Tonawanda minitest facility is directing its work toward confirming kinetics and yield data for agglomerating high-sulfur bituminous coals (Pittsburgh seam No. 8, Illinois No. 6, and Kentucky No. 11). The South Charleston facility is being used to evaluate alternative methods for deagglomerating high-sulfur bituminous coals in the hydrocarbonization process. At the Buffalo Testing Laboratories, the physical properties (viscosity, density, pour point, heat capacity, etc.) of the liquid product are being analyzed; ultimate analysis is being performed on coal, char, and liquid products; and the major groups (phenols, bases, acids, etc.) in the liquid product are being determined. The in-house laboratories are performing proximate analysis of coal; determining the bulk and particle densities and size distributions of coal and char; calculating the simulated boiling point distribution of products using gas chromatography data; determining the heating value of coal, char, and liquid products; analyzing gas products for major and minor components; and analyzing liquid products for major components. Union Carbide's computer

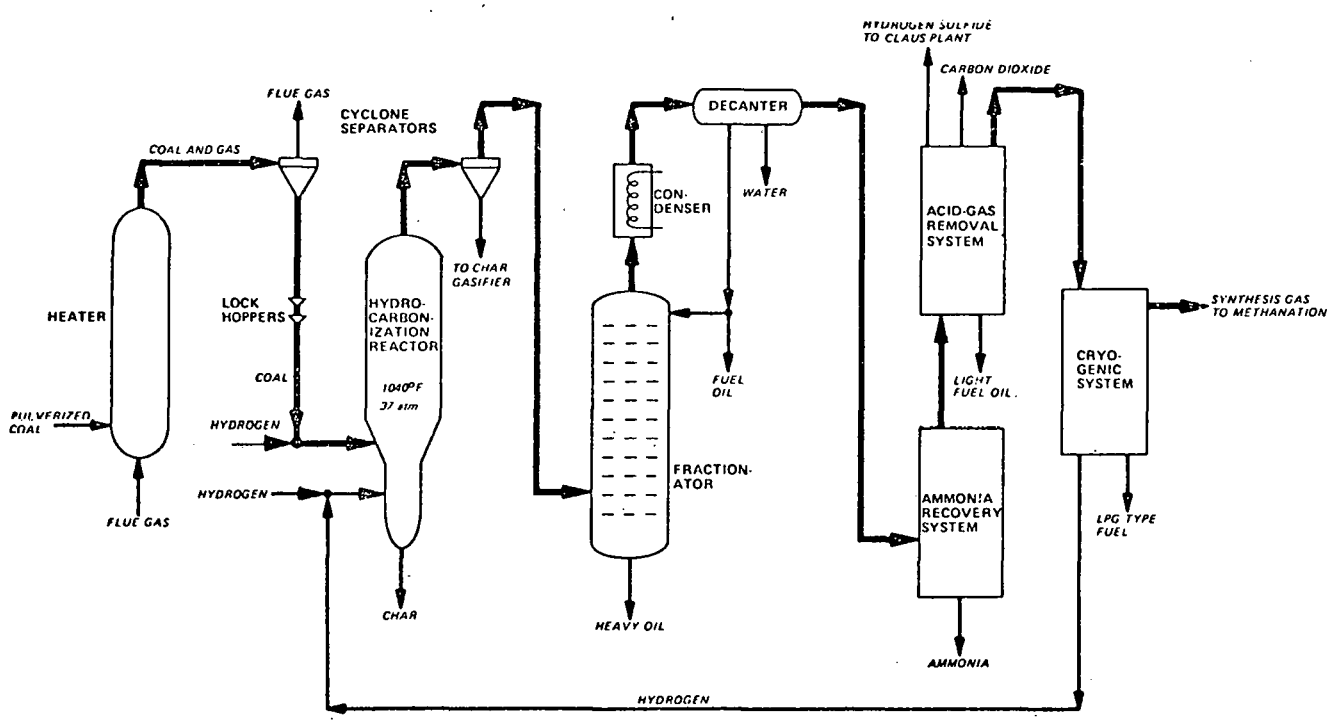


Figure I-2. HYDROCARBONIZATION PROCESS SCHEMATIC

process simulation system, PROBE, is also being used to support this project.

PROGRESS DURING APRIL-JUNE 1975

Summary

During the quarter, Coalcon continued the development of the preliminary design and engineering of a commercial plant. By the end of the quarter, preliminary process flow sheets for 14 of 21 process sections were completed. Work on the process subsystems included definition of most of the coal sections except the coal heating system; review of preliminary sketches of the hydrocarbonization reactor; study of gas cooling and heavy hydrocarbon separation, with the determination that the product oil will be separated into two fractions; completion of schematics for all of the gas processing sections, including the selection of the Sulfinol system for acid-gas removal; and selection of the Texaco partial-oxidation process for hydrogen production.

Work at the minitest facility involved development of a prototype coal feeder and dryer. Preliminary tests at the deagglomeration test facility were delayed. At the Buffalo and in-house laboratories, instruments were checked out and development of procedures was initiated.

Other technical support included computer processing, with emphasis placed on simulating the fractionator/decanter system, the cryogenic hydrogen purifier, and the acid-gas removal system. In work relating to site selection, Pennsylvania, Ohio, Indiana, West Virginia, Kentucky, and Illinois submitted information on possible sites for the demonstration plant. Evaluation of these potential sites was initiated. Work on determining long-lead-time items also continued throughout the quarter.

Preliminary Commercial Plant Design and Engineering

Development of the preliminary design of a commercial plant using a hydrocarbonization process continued throughout the quarter. By the end of the quarter, preliminary process flow sheets for 14 of the 21 process sections were completed; the other two sections were in the engineering and drafting stages. Nine of 12 data packages for economic evaluation of process equipment alternatives were submitted for estimating; engineering for two of the remaining three was about 90 percent completed, and one was to be submitted from an outside source. Information is being collected and submitted for drafting of individual section layouts based on the process flow sheets and on the data established for the various pieces of equipment within each section. Piping and instrumentation diagrams will be developed concurrently from the preliminary process flow sheets. Work completed on the various subsystems is discussed below.

Coal Preparation

By the end of the quarter, most of the coal processing sections had been completely defined, and review of the preliminary designs and drafts had been initiated. The only section not completed was the coal heating system, which was in the final stages of engineering for the entrained-bed operation. Sketches of the postcombustor system for producing oxygen-free flue gas were submitted to the engineering group for review. The process flow schemes have been completed for all of these systems.

Coal Hydrocarbonization

The hydrocarbonization reactor operation and the unit operation called fluid coking, now commonly used in refineries, were compared. Similar characteristics included the transfer of the solid bed from one portion of the reactor to another and the injection of raw material into the reactor. Preliminary sketches of the reactor, including the coal distribution system around the reactor, are being reviewed.

Gas Cooling and Heavy Hydrocarbon Separation

A model for flash separation in tower trays has been substituted in the computer program. In the meantime, manual calculations, using the given overhead vapor compositions, have been made to obtain probable product composition. Because the product oil would have a flash point too low to be considered commercially acceptable, it will be separated into two fractions, one having a flash point of around 100° F and the other being a gasoline fraction having a vapor pressure of less than 1 atm.

The results of a study indicated that there were considerable amounts of ammonia and hydrogen sulfide in the water stream from the decanter; thus, the water stream will have to be

stripped of these two compounds. In addition, the gasoline fraction will have to be treated for hydrogen sulfide content before it is stored for sale; an investigation is underway to find a suitable process for removing the hydrogen sulfide.

Gas Processing

Schematics were completed for all of the gas processing sections (ammonia recovery, acid-gas removal, hydrogen purification, and methanation), and data packages for all of these were nearly completed. Sulfinol was selected as the acid-gas removal system for the commercial plant and work is proceeding on this basis. Estimates are being prepared to conduct an economic comparison of three alternative acid-gas removal systems, although process considerations now indicate that Sulfinol will have lower operating costs.

Char Burning and Steam Generation

A flue gas balance is being made throughout the entire system to determine flue gas flow and temperature, availability of heat, etc., for use in different sections of the plant. The required size for the furnace must be determined to prepare a request for proposals. The arrangement and protection of the heating coils that are required to preheat the hydrogen to the desired temperature have been under investigation.

The overall steam balance based on the proposed process sections as they now exist was revised. This balance indicated that there may be a slight shortage of steam. To eliminate the shortage, extra raw coal will have to be burned.

Sulfur Removal and Recovery

The designer of the Aqua Claus process studied the effect that the presence of hydrocarbons in the stream of carbon dioxide and hydrogen sulfide will have on the operation of the plant. These hydrocarbons enter the stream from the acid-gas removal section. As of the end of the quarter, Coalcon had not received this information.

Char Cooling

The basic design of the clean boiler fuel plant requires that the char be cooled to between 200° F and 300° F, ground, and distributed according to demand to the hydrogen plant and to the steam generation section. The economic feasibility of an alternative design for char grinding in a wet process for direct feeding to the Texaco gasifier in the hydrogen section will be determined.

Hydrogen Production

The Koppers-Totzek and Winkler installations in Europe were visited to study alternative high-pressure gasification processes. Preliminary process flow diagrams were prepared for the gasification processes and the subsequent gas purification, including the shift reactor vessels and the carbon dioxide and hydrogen sulfide removal units.

Based on an economic evaluation of methods of hydrogen production, the Texaco partial oxidation process was selected for the commercial plant design. The utility usage and steam balances for the remainder of the plant are being corrected based on this decision.

Other Subsystems

The steam balance is being updated for the final process configuration, taking into account all of the final changes. In addition, water and waste products are being defined and the preliminary effluent list has been produced for consideration in proposing waste treatment facilities.

Facility Support

Minitest Facility

A metering valve and the fluidized-bed coal feed system were designed, and a full-scale prototype was built for the purpose of evaluation and calibration. The coal feeder can accommodate both lean-phase and dense-phase transport of coal into the reactor by means of a new valve (a commercial, 2-inch ball valve modified as a rotary feed valve). The coal is metered by varying the frequency of valve actuation. The prototype will be used to develop the technique for continuously feeding coal to the plant at a constant and known rate, calibrate the coal delivery rate of the metering valve as a function of the valve rotational speed, and calibrate the fluidized-feed coal-output conditions against the fluidized-feed bed variables.

The coal dryer was redesigned to allow both coal drying and preoxidation in one unit consisting of a fluidized bed using nitrogen as a heating medium. The coal will be preoxidized by injection of oxygen into the nitrogen stream. Final selection of the oxygen-injection system will be made during the test program.

The pneumatic instrumentation, a datalogger to facilitate analysis of the data generated by the minitest facility, and other related equipment were specified and ordered.

Deagglomeration Test Facility

Preliminary tests in this facility were delayed because of problems with the instrumentation and delays in the calibration of the system. Additional delays were encountered during shakedown tests. The first carbonization runs are scheduled for July.

Buffalo Testing and In-House Laboratories

All analytical equipment necessary for the tests being conducted at these facilities was received. Checkout of the instruments and development of procedures and standards were initiated.

Other Technical Support

Computer Processing

The fractionator/decanter system for processing the liquid-vapor reactor product was simulated with a computer model using five equilibrium stages in the fractionator. The five theoretical trays were not sufficient to provide the sharp separation desired between the overhead and bottom products. It was decided to modify the fractionator design so that the phenolic materials are rejected in the bottom product. Elimination of phenol from the column overhead prevents the problem of treating decanter wastewater and eliminates a fuel loss associated with dissolved phenolics in the water. Furthermore, an investigation into fuel oil specifications showed that the combined liquid fuel from the fractionator/decanter does not meet the American Society for Testing Materials flash-point specification for No. 6 fuel oil. Consequently, it was decided to produce two liquid fuels: a fraction equivalent to No. 6 fuel oil (fractionator bottom) and a lighter gasoline fraction (overhead product removed from the decanter). To accomplish these objectives, a fractionator containing 20 stages will be required. A computer model for this new system was developed.

The cryogenic hydrogen purifier was simulated, but because of problems with the downstream equipment, the purifier design had to be modified. It was determined that commercially available methanation catalysts could not tolerate the level of C_2 and heavier hydrocarbons without adding large quantities of steam to the methane/synthesis gas feed. Therefore, it was decided to redesign the purifier to reject the C_2 to C_5 hydrocarbons separately from the methane/synthesis gas stream. The process configuration for this new design has been established, a computer process model was developed, and simulation of the process was started.

A single-reflux, cold-methanol wash system was assembled and simulated on a computer. Several economically attractive alternatives were also modeled, including (1) split reflux system, (2) split reflux with nitrogen stripping of the carbon-dioxide-rich methanol, and (3) light-oil prewash to reject C_2 and higher hydrocarbons upstream of the methanol wash. This latter arrangement substantially reduces the methanol prewash requirements and eliminates C_2 and C_3 from the acid gas.

Site Selection

Site presentations were made to Coalcon by Pennsylvania, Ohio, Indiana, West Virginia, Kentucky, and Illinois. Since some states presented information on more than one site, the first step in evaluating and ranking the candidate sites will be to determine the best candidate in each state. Criteria such as coal, water, transportation, and environment will be used to make the decision. Only the best site in each state will be included in the in-depth evaluation by Coalcon. In addition, since all states chose to respond to requirements for a commercial facility, all sites will be judged on their capacity to support a commercial liquefaction plant.

Procurement

The attempt to identify long-lead-time items continued. However, since the process design is just beginning, and alternative process studies have not yet been completed, identification of some long-lead-time items is being delayed.

Furthermore, results from the minitest facility could change equipment specifications. In other work relating to procurement, Coalcon initiated the review of the bid package prepared by the Corps of Engineers and prepared an abstract. In addition, a detailed list, by type of equipment, of projected equipment delivery dates was issued and will be updated every 2 months.

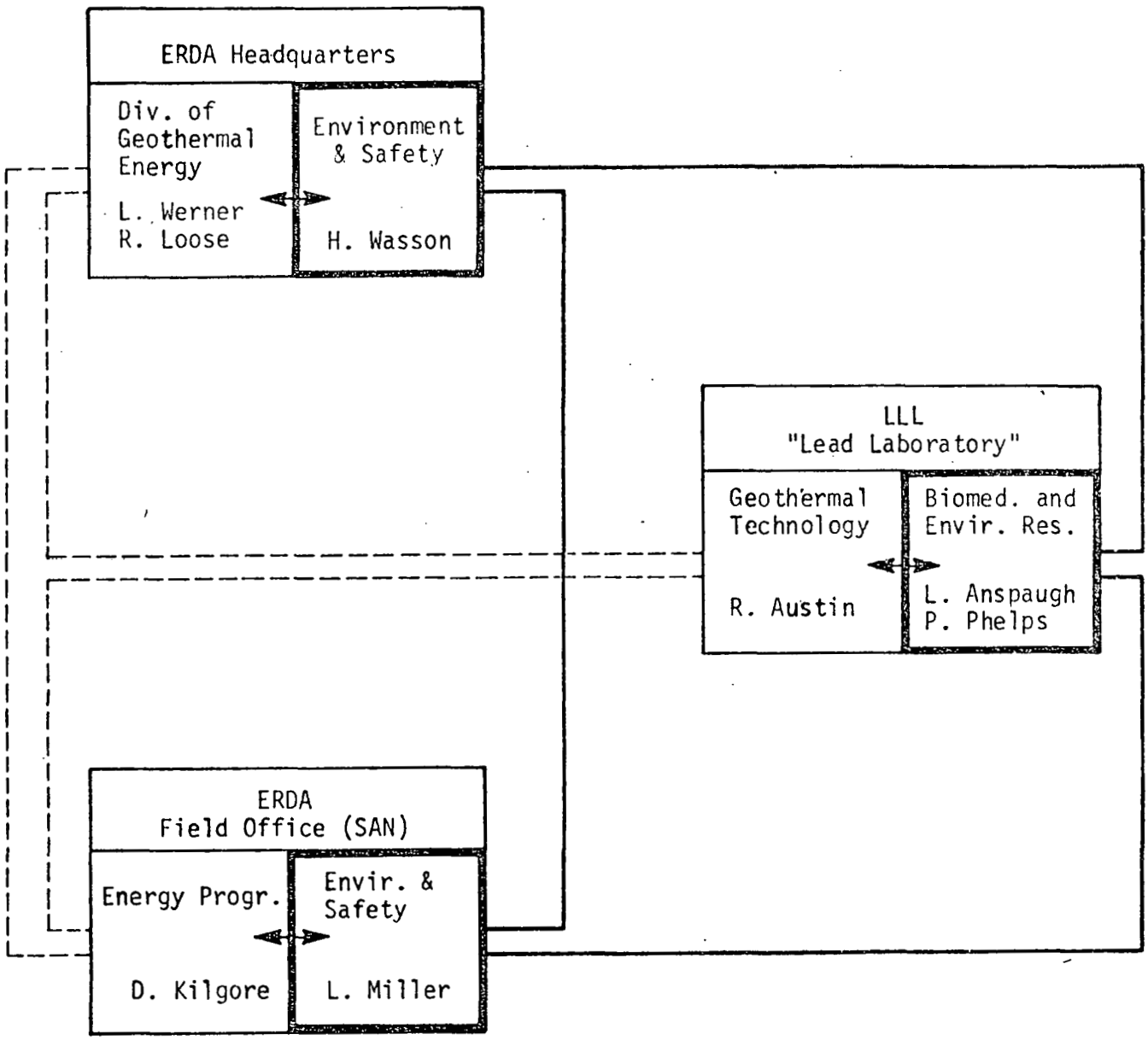
AN OVERVIEW OF THE IMPERIAL VALLEY ENVIRONMENTAL PROJECT

Editors: L. R. Anspaugh
P. L. Phelps

Contributors: N. B. Crow
P. H. Gudiksen
K. F. Haven
K. D. Pimentel
R. L. Ritschard
J. H. Shinn

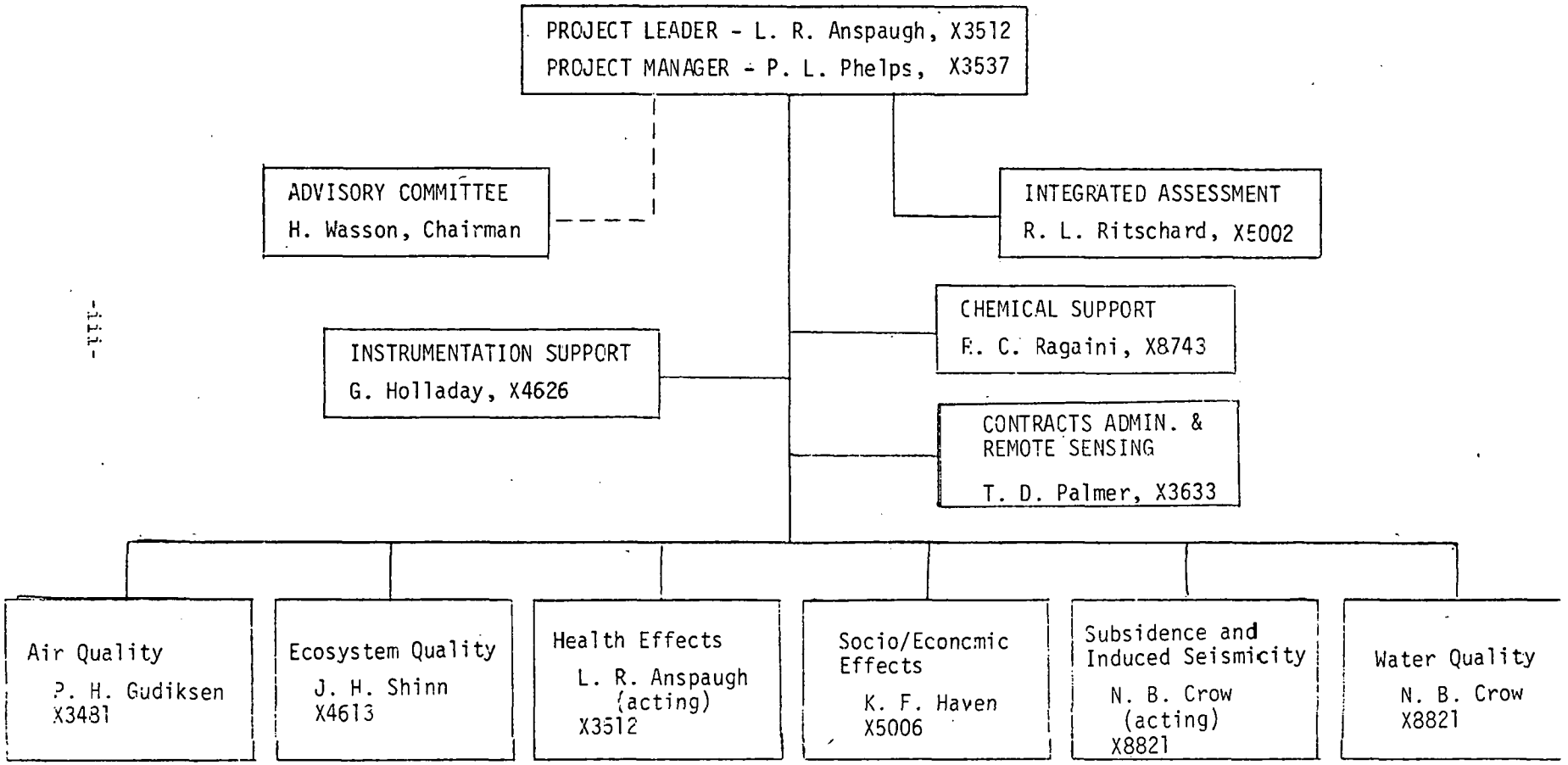
Biomedical and Environmental Research Division
Lawrence Livermore Laboratory, University of California
Livermore, California 94550

This project is being conducted for the U. S. Energy Research and Development Administration, Office of Environment and Safety, Washington, D. C.



Relationship of the Imperial Valley Environmental Project (IVP) to the U. S. Energy Research and Development Administration. The IVP is under the auspices of the Assistant Administrator for Environment and Safety of ERDA. Close coordination exists between the Geothermal Technology and Environmental groups. Names indicated are principal contacts.

PROJECT ORGANIZATION
IMPERIAL VALLEY GEOTHERMAL SURVEY PROJECT



IMPERIAL VALLEY ENVIRONMENTAL PROJECT

Biomedical and Environmental Research Division
Lawrence Livermore Laboratory, University of California
Livermore, California 94550

1.0 Introduction

The Lawrence Livermore Laboratory has been appointed by the U.S. Energy Research and Development Administration to be the "lead laboratory" for carrying out a long-term project to acquire complete understanding of the environmental quality in the Imperial Valley of California prior to any major developments. The purpose of this project is to ensure that the development of geothermal resources proceeds on an environmentally sound basis. Consequently, the Imperial Valley Environmental Project (IVP) is committed to an intensive and comprehensive study designed to establish an environmental baseline for the Imperial Valley as well as to develop an understanding of the environmental and other effects associated with development of geothermal resources.

The IVP is organized into seven main study sections, which when taken together cover all the significant issues and concerns. The sections are:

1. Air Quality
2. Water Quality
3. Ecosystem Quality (Soil, Plants, Animals, etc.)
4. Subsidence and Induced Seismicity
5. Health Effects
6. Socio-Economics
7. Integrated Assessment

A strong thrust of the project is to integrate the output of the various studies into a single overall assessment. This includes not only the data obtained from the Lawrence Livermore Laboratory studies but input from all other identifiable programs as well. To this end, the Imperial Valley Environmental Project is developing a data base from information available through a number of previous and current studies relating to the long-term environmental assessment of the Imperial Valley. The Lawrence Livermore Laboratory is working closely with a number of universities and various federal, state and county agencies and other groups to obtain the needed information. These efforts are in part funded by the Imperial Valley Environmental Project. Also, a great deal of cooperation with various other public groups has been achieved, and their programs in some cases have been reoriented to assist on problems specific to the development of geothermal resources in Imperial Valley.

2.0 Air Quality

One of the potentially important impacts of large-scale development of geothermal resources within the Imperial Valley is degradation of air quality. Nearly all geothermal development schemes will release noncondensable gases to the atmosphere. The principal constituent of the noncondensable fraction is CO_2, but lesser amounts of H_2S, H_2, CH_4, NH_3 and N_2 are generally present as well. Some of these gases may undergo reactions in the atmosphere; the most notable is the conversion of H_2S to SO_2 with subsequent possible transformation to H_2SO_4. The objective of the LLL air quality program is (1) to measure the current levels of selected air pollutants at various locations within the Imperial Valley, (2) to characterize the atmospheric transport properties on a valley-wide basis by measuring specific meteorological parameters at several locations, and (3) to evaluate the rate of emission of selected pollutants from geothermal operations as well as from other sources (feed lots, fertilizer plants, etc.). Use of these data in our three-dimensional atmospheric transport models will permit us to predict the annual average change in air quality throughout the entire valley due to the operation of several proposed geothermal power plants situated anywhere within the valley.

To accomplish these objectives we plan to install six fixed-location stations to monitor ambient air quality. They will measure the concentrations of O_3, H_2S, SO_2, S, and particulates. We are currently negotiating with investigators at the University of California, Davis, to undertake the sampling and analyses of the particulates. The particulates will be size-fractionated and elemental analyses will be performed on each size fraction. Selected particulate samples will be analyzed also for chemical composition of the sulfur-containing compounds, either by LLL or by a laboratory not yet selected. The gas-sampling will be performed by LLL with cooperation from the State Air Resources Board, the Air Industrial Hygiene Laboratory (Berkeley) and the Imperial County Air Pollution Control District.

The approximate locations of these six stations are shown in Fig. 1. All are situated within a few kilometers of the most likely source points and are also fairly evenly spaced throughout the entire valley. Two stations are within the Salton Sea KGRA (Known Geothermal Resource Areas) to define the flow entering or exiting the north end of the valley. Another two stations are similarly located at the south end of the valley within the Heber and East Mesa KGRAs. The remaining two stations are in the central portion of the valley. Meteorological measurements will be made using 10-m towers at five of the stations. At the sixth, the Heber site, the San Diego Gas and Electric Company (SDG&E) will erect a 60-m meteorological tower under EPRI funding, and an acoustic radar will be installed for the determination of mixing heights. Upper-level wind and temperature measurements made on an irregular basis at the U. S. Naval Parachute Test Range will also be used as input to our atmospheric transport models.

In addition to the fixed stations, a mobile field laboratory will be equipped with a comprehensive capability for measurements relating to air quality. Its main purpose will be to provide measurements at specific release sites (source terms) and to measure ambient air quality in the immediate vicinity of and downwind of specific sources. It will also have the capability for making meteorological measurements.

Because of the startup of the SDG&E Company's Geothermal Test Facility near Niland in the near future, the source-term measurements program is taking a leading role in the early phases of the program. Measurements of H_2S, NH_3, CO_2, hydrocarbons, and volatile metals such as Hg and As will be made on a cooperative basis by the Battelle Northwest Laboratories, LLL and other groups.

In order to develop a predictive capability for estimating the impact on air quality of the development of a particular geothermal resource region, it is necessary to resort to modeling techniques. This will be accomplished with the use of LLL's advanced three-dimensional flow models. These models utilize regional topography and measured wind information to produce interpolated and extrapolated wind fields on an Eulerian grid superimposed over the topography. The wind fields are then adjusted for mass consistency to eliminate artificial convergences and divergences. These flow fields are then used as input to either the three-dimensional advection-diffusion particle in cell code (ADPIC) or the two-dimensional coupled transport-kinetics code (LIRAQ).

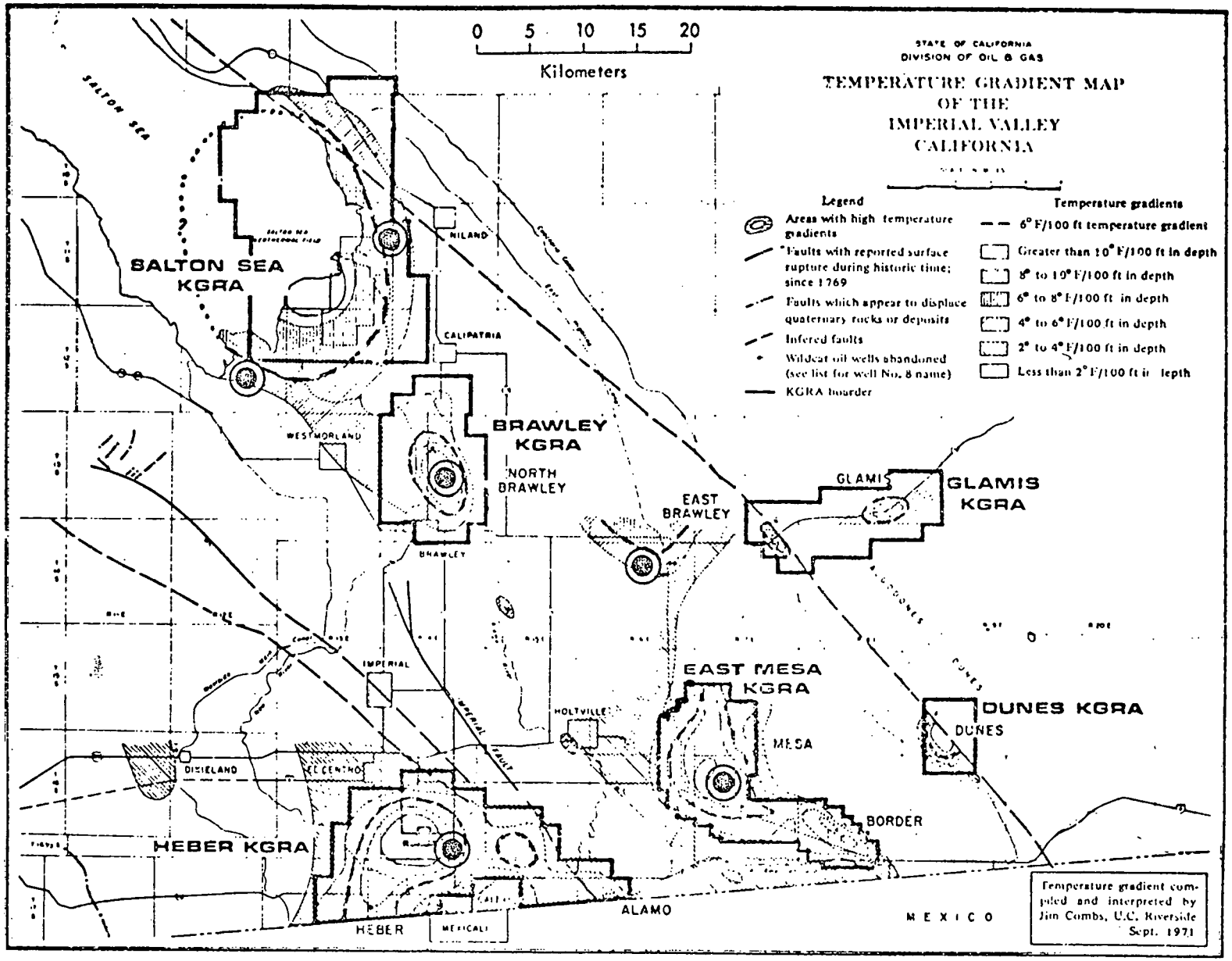


Fig. 1. ◉ — Locations of Monitoring Stations for Characterizing Pollutants and Meteorology. (Map adapted from Palmer, et al., 1975).

3.0 Water Quality

The water-quality effort of the IVP is intended to determine the baseline levels of water quality existing in the Imperial Valley at the present time, especially in the vicinity of geothermal fields, and to detect and evaluate any impacts of geothermal development on the water in the Valley and the adjacent Salton Sea. We are aware that extensive programs concerned with water quality are being carried out by local, state, and federal agencies, and our program emphasizes full cooperation with all such programs.

One of our major purposes is to develop information to allow detection of inadvertent leaks from geothermal wells and facilities into the surface-water and groundwater systems of the vicinity of geothermal fields. To do this, we must know the characteristics of both the geothermal fluids and the existing water systems, especially transient changes due to other causes such as leaching of agricultural lands. We intend to develop a geothermal "fingerprint" -- characteristics of geothermal water that would disclose its presence in the surface water and groundwater. Our program will include sampling for this "fingerprint" in addition to continuous monitoring for sudden increases in salt content. Sampling and analysis will not be confined to determination of the special characteristics to identify geothermal fluid contamination; we will do rather extensive analysis for mineral constituents in the surface water system. We have begun our program with sampling in the Salton Sea geothermal field area, and will expand it as rapidly as possible to other areas of the Valley.

A study of the hydrology of the Salton Sea is a part of our program. There is considerable anxiety about the potential for increase in salinity in the Sea, but very little data are available about the conditions in the Sea. We intend to make salinity measurements in the Sea to enable us to understand the distribution of salinity both horizontally and vertically in the water body. The results should be useful in evaluation of the existing situation in the Sea, as well as any impacts which might occur as a result of geothermal development of the adjacent Imperial Valley.

Also included in our program is a systems analysis of the water system of the Salton Basin, including the possible impacts of geothermal development. For example, availability of cooling water may be a pacing factor for development, and we envisage construction of a computer model to evaluate various sources of water and systems of cooling.

4.0 Ecosystem Quality (Soil, Plants, Animals, etc.)

This subprogram has the objective of developing sufficient information so that the potential long-term effects of geothermal development on the present ecosystems of Imperial Valley can be predicted, and avoided or remedied where necessary. The primary ecosystems of concern are the agricultural lands, the Salton Sea, and the wildlife refuges in the area.

The ecological baseline studies and a few preliminary ecological effects studies in Imperial Valley were initiated in October '75 and by January '76 had committed six people in the field and one person in chemical analytical support.

Seven tasks are underway as of this date. In waterfowl ecology, 100 ducks (4 species), 20 geese (2 species), and ten other birds have been collected from Salton Sea refuges in cooperation with U. S. Fish and Wildlife Service and California Department of Fish and Game. Tissue from these birds is being analyzed for trace elements, heavy metals, and pesticides, and the remainder preserved for future reference. Habitats of endangered bird species are being mapped, and buffer zones will be defined to minimize noise effects, power-line collision mortality and power-plant obstructions to flight paths. Samples of soil, plants, sediment, irrigation water, river water, and Salton Sea water have been collected intensively near active sites of geothermal development (SDGE) and are being collected in addition to milk and lettuce to a lesser degree regionally. Analyses for trace elements and heavy metals are being conducted but the majority of samples will be preserved for future reference. Preliminary ecological effects of geothermal gases on crops have been studied by controlled fumigations of lettuce at the USDA-ARS Field Station at Brawley, where stomatal response and photosynthesis were examined for a few hours following initial exposure at different concentrations. Factors controlling soil and plant uptake (and emission) of geothermal gases (H_2S, CO_2, NH_4) are being investigated in micrometeorological experiments. Studies of aquatic food chains have begun with collection and culture of the top and bottom trophic-level species. The detritus-converting "pile worm" Neanthes, has been collected and cultured in the laboratory to establish potential toxicity. A 2000-gallon culture facility is being readied to culture the predator fish corvina in water from the Salton Sea, to study sensitivity to salinity and geothermal pollutants.

In the next six months, additional programs will be initiated. Several small contracts will be awarded for specific baseline and effects study tasks. These include studies of brine movement and salinity in soil, water requirements of crops, agricultural tile-drain practices, fish populations, aquatic food-chain dynamics, noise/power line effects on birds, desert ecosystems at East Mesa, apiary pathology, chronic gas fumigation of crops, and ecology of nonmigratory predatory birds.

5.0 Subsidence and Induced Seismicity

The objective of this program effort is to document the baseline levels of naturally occurring subsidence and seismic activity, and to identify any similar effects which might be caused by geothermal production. We are emphasizing full cooperation with other agencies having similar goals.

Subsidence: The IVP is cooperating in the tentatively scheduled resurveying of the 1st- and 2nd-order networks existing in the Valley as the result of the activities of the interagency Imperial Valley Subsidence Detection Committee. Twice since 1971, this group has sponsored surveys covering the entire Imperial Valley, which have provided invaluable data about naturally occurring ground surface elevation changes.

We are also sponsoring detailed local leveling in the Salton Sea area in advance of the startup of the Geothermal Test Facility to be operated by San Diego Gas & Electric and others, and the test facility at the Sinclair #4 well, operated by Southern California Edison and partners. It is planned to extend similar coverage to other active geothermal areas in the near future.

It is also planned to assist with additional horizontal control surveys in the Imperial Valley, both locally near geothermal activities and on a large scale, to help in gaining understanding of regional changes.

Other projects soon to be started up include installation of additional subsidence-measurement equipment where useful, and a computer modeling project designed to predict the effects of withdrawals and reinjection of geothermal fluid.

Induced Seismicity: One subsidence-control technique which will be employed is low-pressure reinjection of geothermal fluid. While many hundreds of millions of gallons of water have been reinjected in oil fields without untoward effects, high-pressure injection in Colorado has caused induced seismic activity. While low-pressure injection has not been implicated in such activity, the possibility cannot be dismissed. The Imperial Valley has a high level of naturally-occurring seismic activity. It is therefore imperative to have as much data as possible about such activity, so that when geothermal production begins we will be able to distinguish between the naturally occurring events and any which might be induced by geothermal activity. Recently published studies of the 1975 Brawley earthquake swarm have located epicenters of the earthquake and suggest that it may very well be possible to distinguish seismic activity induced by injection from naturally occurring earthquakes. We therefore wish to increase seismograph coverage in the areas near geothermal production, potential and actual, to help in this documentation.

We are presently contracting with the U. S. Geological Survey to install six new seismographs in the Salton Sea field area, as a part of their study network. Our plans are to extend such detailed coverage to other prospective geothermal areas.

It is also important to define when any such manmade effects become significant. As a part of the program, we plan to make a study of the effects of subsidence and possible induced seismicity on the environment.

6.0 Health Effects

This program is still in the planning stages. The effort will be closely coordinated with the program on Integrated Assessment.

7.0 Socio-Economics

The long-term socio/economic study plan can be divided into four sequential task categories: System Characterization, Model Development, Scenario Development, and System Impact Analysis. Each of these categories is composed of a number of individual interactive tasks. The following is only a summary sketch of the major components of each category.

System Characterization: A major portion of this study element is a baseline study of Imperial County. Primary source data will be collected from refined county business-pattern tapes, combined covered and uncovered employment statistics, county personal income and earning tapes, 1970 census data with updates, county fiscal data, and OBERS projections. This portion of the study will also include comparative analyses of a number of basic economic and social indicators between Imperial County and other counties and agricultural regions within California. Finally, the character of the State energy system will be analyzed with primary emphasis on electrical energy and the potential role of geothermal energy within that system.

Model Development: No formal social or fiscal model will be developed. The economic model used will be based on the Input-Output model being developed by E. Lofting for the NSF study. Our efforts on the model will be directed toward refinement of the agricultural sectors and of the geothermal-agriculture interrelationships and interactions both internal and external to normal economic activity.

Scenario Development: The scenario is a rehearsal of possible consequences based on analyses of the available relevant information. The first major portion of the scenario development will involve analysis of a number of other county-level areas which have been impacted by a major energy-related development, and the compilation from that analysis of a list of probable and improbable impacts within Imperial County as a function of the rate and level of geothermal development. This list will primarily involve fiscal and social impacts and economic impacts which an Input-Output analysis cannot detect (i.e. price changes, major-product/product-substitutions, etc.). The remainder of the scenario development effort will involve identification of alternative rates and levels of geothermal production and associated employment, land conversion, population shifts, and direct economic activity; identification of a range of water-management schemes for the county as a whole; identification of agricultural crop, irrigation substitution trends which might be expected without any geothermal influence; and projected county growth patterns.

Impact Analysis: The impact-analysis portion of the study will apply the developed scenarios into the county economic model to detect both direct and indirect impacts of geothermal development on the economy and upon employment patterns, fiscal demand-and-supply balances in the public sector, and social patterns. The goals of this study element are fourfold:

1. To identify sectors which will always be negatively impacted by geothermal development, sectors which will always be positively impacted, and the relative magnitude, importance and redistribution effects of each as a function of each scenario.

2. To identify other affected sectors as a function of each scenario and to identify tools available to the County to ensure optimization of these impacts within the constraints of the scenario.

3. To identify economic and desirable multiple-use potentials for geothermal resources and energy (water desalination, drying operations, mineral recovery, etc.) and the trade-offs between electrical energy and each alternative use.

4. To identify the potential differences between how the State and County view both the optimum geothermal development rates and levels and the resultant product to the County.

8.0 Integrated Assessment

The goal of the Integrated Assessment Program is to evaluate in a quantitative manner the impact upon man and the environment resulting from geothermal energy development in the Imperial Valley and to make this information available to other agencies, legislative bodies, and planning groups.

Initially, the Integrated Assessment Group will accumulate data from existing sources on the state of the Imperial Valley system, including available land and water resources, air and water quality, ecosystem structure and stability, and data pertaining to the social, economic, demographic, and political structure of the Imperial Valley communities. A comparable effort is presently under way that will identify the potential geothermal energy requirements so that several alternative schemes for geothermal energy can be developed. The baseline information on Imperial Valley will be used when assessing the impacts from the various geothermal development scenarios.

Another important function of the Integrated Assessment Program is to determine which of several options for either resource development or effluent-control strategies is preferable from a cumulative ecological, socioeconomic, and human health standpoint.

The Integrated Assessment Program will serve as the focal point and coordinating group for data collection and research efforts among the primary survey programs (e.g. Air Quality, Water Quality, etc.). Initial assessments will be made during the current fiscal year to help characterize potential problems and to identify areas where further research efforts and data collection are required for improved evaluation and assessment.

An important aspect of the Integrated Assessment effort is to supply critical information to decision-makers in order to assure development of energy alternatives that will have minimal unfavorable impact upon man and his environment.

The IVP is coordinating with environmental and related programs within a number of organizations. This list represents the organizations involved to date.

Organization	Air Quality	Water Quality	Ecosystem Quality	Subsidence & Induced Seismicity	Health Effects	Socio-Economics	Integrated Assessment
Governor's Office of Planning and Research, State of California						●	●
Energy Resources Conservation and Development Commission, State of Calif.							●
Resources Agency, State of Calif.	●	●	●	●	●		●
Dept. of Water Resources, State of Calif.		●					●
Air Resources Board, State of Calif.	●				●		●
Dept. of Fish and Game, State of Calif.			●				
Dept. of Conservation Div. of Oil and Gas				●			
Department of Health, State of California	●						●
University of California Field Agricultural Station			●				●
Department of Public Works, Imperial County				●		●	●
Air Pollution Control District, Imperial County	●						●
Imperial Irrigation District, Imperial County		●		●			●
U. S. Environmental Protection Agency	●	●	●				●
U. S. Fish and Wildlife Service			●				●
U. S. Geological Survey		●		●			
U. S. Department of Agriculture, Imperial Valley			●				●
U. S. Navy, El Centro Meteorological Group	●						
National Science Foundation	●	●	●	●		●	●
University of Southern Calif.		●					
Systems Control				●			
Calif. Institute of Technology						●	●
Univ. of Calif., Riverside			●				
St. Marys' College	●		●				
Battelle Pacific Northwest Lab	●					●	
Systems, Science and Software				●			
Electric Power Research Institute	●						●
University of Calif., Radiation Laboratory, Los Angeles, Calif.			●				
Brookhaven National Laboratory	●				●	●	
Jet Propulsion Laboratory						●	●
San Diego Gas and Electric Co.	●			●			●
Southern Calif. Edison Company			●	●			●
Union Oil Corporation				●			●
Imperial Magma Corporation				●			
EGG, (Las Vegas, Nev./Santa Barbara, Ca.)	●		●				
Pomona College, Pomona, Calif.			●				
Bureau of Reclamation				●			●
Colorado River Regional Water Quality Control Board		●					
University of Calif., Davis	●					●	●

APPENDIX G

APPENDIX G

LIST OF FEDERAL, STATE AND LOCAL APPROVALS, PERMITS AND LICENSES

REQUIRED PRIOR TO CONSTRUCTION OF A POWER STATION IN CALIFORNIA

Agency/Authorizations and/or Agreements	Needed For:
FEDERAL AGENCIES	
1. Nuclear Regulatory Commission	
A. Limited Work Authorization (Optional)	All nuclear facilities and/or other facilities to be constructed near a nuclear facility.
B. Construction Permit	
C. Operating License	
D. Appropriate Nuclear Materials Licenses	
2. Federal Aviation Administration	
Notice of Intent to Construct and Approval of an Obstacle and its Marking pursuant to an Airport Airway Analysis Study.	Must file on all obstructions (stacks, units, transmission lines, meteorological towers etc.) in excess of 200 feet above ground level or within specified distances from an existing airfield.
3. U.S. Forest Service	
Special Use Permit or Easement	All facilities and activities on or crossing U.S. Forest Service Land.
4. Federal Communication Comm.	
License to Construct and Operate Electronic Transmitting Equipment	Any facility with VHF paging equipment, microwave radio to provide transmission line protection circuits, load frequency control with power system, other operating and administrative telephone services.

Agency/Authorizations and/or Agreements	Needed For:
5. Bureau of Land Management	
A. Land Acquisition	A. All facilities and activities on or crossing BLM land.
B. Special Land Use Permits	B. Required to perform geotechnical feasibility and foundation studies, drilling programs, and aggregate source studies.
C. Special Land Use Permits	C. Required for weather monitoring stations, temporary roads, aggregate pits and batch plants.
D. Special Material Sale	D. Required for obtaining aggregate and clay lining material sources.
E. Easements	E. Required for transmission lines, permanent roads, cooling water lines, and pumping station and construction water lines.
6. Bureau of Indian Affairs	
Agreements and Easements	All facilities and activities on or crossing Bureau of Indian Affairs land.
7. National Park Service	
Land Use Permit	All facilities and activities on or crossing National Park Service lands (pumping stations, transmission lines, service roads and soils and geological investigations).
8. Bureau of Reclamation	
Land Use Permit	All facilities and activities on or crossing Bureau of Reclamation land.
9. Bureau Outdoor Recreation	
Land Use Permit	All facilities and activities on or crossing Bureau of Outdoor Recreation land.

Agency/Authorizations and/or Agreements	Needed For:
10. Bureau of Mines	
Land Use Permit	All facilities and activities on or crossing Bureau of Mines land.
11. Department of Labor Occupational Safety and Health Admin.	
OSHA Requirements-Adherence, interpretation of and variances (Regulations differ within individual states. For California see State Item #8D.)	Adherence required for all facilities. Subject to spot checks at any time and inspection and/or review in case of fatality or complaint.
12. Army Corps of Engineers	
Permit to Construct in Navigable Waters	Facilities with construction activities within navigable waters.
13. Advisory Council on Historic Preservation	
Protection and Preservation of Historic and Cultural Properties	Any project that requires a Federal permit, license or grant on properties that are listed in or eligible for nomination to the National Register of Historic Places (National Register).
A. Detailed Archaeological and Historical Literature and Field Studies	
B. Determination of No Historical Site Impact	
C. Impacted Site Memorandum of Agreement (Federal and State)	
D. Compliance with Memorandum of Agreement Mitigation Program	
14. EPA	
EPA Authority to Construct	Construction of new stationary sources
15. Review of RWQCB	Review and concurrence on NPDES proceedings
16. Secretary of the Interior and Colorado River Water Contractors	Final approval of Water Supply Contracts

Agency/Authorizations and/or Agreements	Needed For:
STATE AGENCIES	
1. State Department of Public Health	
A. Contaminated Equipment License	All nuclear facilities
B. Radioactive Material License (radium 226 sources)	All nuclear facilities loading
C. Approval to Construct	Facility with air contaminant discharge to the atmosphere in those states where no local agency exists.
D. Radiological Monitoring Program Approval	All nuclear facilities
2. California Water Resources Control Board	
Certification of Compliance	Facilities that affect state water quality including ground water resources. Also review of NPDES and NRC Application proceedings
3. State Department of Transportation	
A. Encroachment Permit	A. Facilities that require construction, maintenance or repairs on or across State highway (i.e., highway relocation, addition of signals, change in drainage, etc.)
B. Crossing Permit	B. New transmission and communication line crossing.
4. State Department of Parks and Recreation	
Encroachment Permit	Facilities that require construction, maintenance or repairs on or across Department of Parks and Recreation lands.
5. California Public Utilities Commission	
Certificate of Convenience and necessity	All new generating and transmission facilities.

Agency/Authorizations and/or Agreements	Needed For:
6. State Department of Fish and Game	
Administrative review of requirements and procedures having potential impact	All facilities requiring filing with the Environmental Protection Agency.
7. Colorado River Commission	
A. Land Use Rights	All facilities that are on or across Colorado River Commission lands or extract water from the Colorado River which is under the Commission's jurisdiction.
B. Water Contract	
8. State Department of Industrial Relations - Division of Industrial Safety	
A. Permit to Operate Equipment A-1. Boilers A-2. Pressure Vessels A-3. Elevators	A. & B. All facilities with certain types of equipment such as boilers, pressure vessels, etc.
B. Miscellaneous Industrial Safety Permits	
C. CAL-OSHA Permit	C. Construction of trenches or excavations 5 feet or deeper where personnel have to descend. Construction or demolition of any building, structure, falsework or scaffolding more than 3 stories high or the equivalent.
D. CAL-OSHA Requirements (Adherence, Interpretation of and variances)	D. Adherence required for all facilities, subject to spot checks at any time and inspection and or review in case of fatality or complaint.
9. California Energy Resources Conservation and Development Commission	
A. Notice of Intent B. Site and Facility Certification	All power plant sites and thermal generation facilities with a capacity of 50 MW or more and related transmission lines.

Agency/Authorizations and/or Agreements	Needed For:
10. State/County Pollution Control Financing	
Review	Some Pollution Control Facilities qualify for special tax treatment
11. American Society of Mechanical Engineers	
Owners Certificate of Authorization (Renewable every 3 years)	All nuclear facilities. Required prior to the installation of nuclear components. (ASME Boiler & Pressure Vessel Codes, Sectión III.)
12. State Department of Motor Vehicles	
Registration of new vehicles & annual acquisition of license tabs (Project vehicles assigned or owned).	All projects with vehicles assigned to or owned by the project. (Includes registration, tracting, sales, trade-ins, etc.)
13. Air Resources Board	Review of regional decisions appealed
14. Regional Planning Organizations	
Comprehensive Planning Organization, Southern California Association of Governments (San Bernardino, Riverside and Imperial Counties)	Consultations on air and water quality and transportation planning
LOCAL AGENCIES	
1. Regional Water Quality Control Board	
A. Industrial Waste Discharges Permit (NPDES)	A. All California facilities with a waste water discharge requirement.
B. Minor Discharge	B. All facilities with a discharge of less than 50,000 gallons/day
2. County Air Pollution Control District	
A. Authority to Construct B. Permit to Operate	Facilities with equipment that can emit air pollutants to the atmosphere.

Agency/Authorizations and/or Agreements	Needed For:
3. County Flood Control District	
A. Permits for Crossings	A. & B. All facilities on or crossing County Flood Control District land.
B. Easements for Crossings	
C. Discharge Permit	C. All industrial waste discharges into County Flood Control channels and/or storm drains.
4. City or County Department of Health - Sanitation District	
Sanitation Approval	Any construction involving sanitation facilities
5. City or County Department of Health	
Well Permit (core and exploratory drilling and cathodic protection wells)	Required for new construction, reconstruction, renovation, and destruction of all water wells. Also required for all exploratory drilling in areas of potable water wells.
6. County Water Pollution Department	
Waste Discharge Review	Facilities with minor waste water discharges that could affect ground or surface water.
7. City or County Department of Building and Safety	
A. Grading Permit	1970 Uniform Building Code, Chapter 3, Section 301 (a) "Permits Required. No person, firm, or corporation shall erect, construct, enlarge, alter, repair, move, improve, remove, convert, or demolish any building or structure in the city, or cause the same to be done, without first obtaining a separate building permit for each such building or structure from the Building Office." All areas.
B. Miscellaneous Building Permits (foundations, building, tanks, etc.)	
8. City or County	
A. Planning Commission	
1. Zoning/General Plan Compliance	All Projects

Agency/Authorizations and/or Agreements	Needed For:
2. Preliminary Environmental Assessment Questionnaire	All Projects
3. Conditional Use Permits, Variances, Zone Changes, etc.	All facilities and areas should be reviewed.
B. Board of Supervisors or City Council	
Zone Changes and appeals from the Planning Commission decisions	Zone changes and appeals from Planning Commission decisions
C. Court Appeals	
Appeals from the Board of Supervisors or City Council decisions	Zone changes and appeals from Board of Supervisors or City Council decision
9. City or County Fire Department	
Fire Protection Review and Approval	Whenever a Building Permit is required. In addition, the Fire Dept. reviews fuel storage and pipeline plans.
10. City or County Road Department	
A. Overload Approvals	A. Facilities requiring transportation of excessive loads over city streets and/or county roads.
B. Construction Permit	B. Facilities requiring construction of new city streets and/or county roads.
C. Excavation Permit	C. Facilities requiring construction on and/or under city streets and/or county roads.
11. City or County Agency	
Easement Franchise for Pipelines and Transmission Lines within or adjacent to city streets and/or county roads.	All facilities where use of dedicated R/W is involved.

Agency/Authorizations and/or Agreements	Needed For:
12. City or County Agency	
Position Statement required by PUC Gen. Order 131	All transmission lines in excess of 200kv