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A BRIEF HISTORY OF THE OFFICE OF ENERGY RESEARCH & DEVELOPMENT -
FEDERAL ENERGY OFFICE/FEDERAL ENERGY ADMINISTRATION

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November 15, 1974

DISCLAIMER

The Energy Research and Development Office was established in the Federal Energy Office in the Executive Office of the President in early January 1974 with Alvin M. Weinberg as Director, Elizabeth Richardson as Administrative Assistant, Calvin Burwell as Technical Specialist, Jane Zani and Brigitte Seline as secretaries; Robert Duffield joined the group briefly during February and March to assist in selecting staff. Chalmer Kirkbride arrived in late February.

The Charter of the office was to:

1. Advise Mr. Simon and the Federal Energy Office on energy research and development matters, testimony for Congress, etc. Establish liaison between energy policy and energy research and development policy within the Federal Energy Office.

2. Assist the Office of Management and Budget, Energy Research and Development branch, in the preparation of a comprehensive plan and budget for federal energy research and development programs.

3. Establish liaison with energy related agencies, review and appraise their energy research and development programs.

4. Provide energy research and development input to the Project Independence Blueprint.

The office was to consist of a small number of people of competence, experience and judgment. The office operated by open discussion of major issues through staff meetings, meetings of the Interagency Energy Research and Development Committee and by meetings of the Science Adviser's Energy Research and Development Advisory Council. Specific assignments were made by the Director and drafts of documents on these assignments were freely circulated, iterated and reiterated. Part-time consultants include Louis Roddis, Peter Auer, H. G. MacPherson, Henry Linden, Ed Schmidt, and Eric Reichl.

By April 1, 1974, the full staff included Water Hibbard, Deputy Director, (coal, Department of the Interior), Calvin Burwell (research and development program review, OMB), Chalmer Kirkbride (oil, gas, oil shale, patents), Philip Palmedo (energy systems analysis, research and development program review), Robb Thomson (NBS, NSF, solar, basic research and conservation), Vaun Newill (EPA, CEQ, health and environmental), Frederick Weinhold (Project Independence, geothermal), David Cope (AEC, nuclear), George Daly (economist) and Nancy Newgent (research assistant). The office clerical staff included: Eldyne Bordner, Harold Fornoff, Sheliah Anderson, Leah Weiss, Jean Rice, Betty Hess and Sonya McElwee.

During the period April 1 to October 1 the office functioned effectively at full strength and developed the following document:

1. An analysis of the 1976 energy research and development program and budget and its relationship to Project Independence goals. (Burwell and Palmedo)

2. An appraisal of six key issues for energy research and development. (Weinberg and Staff)

3. The role of energy research and development in Project Independence and appraisal of various parts of the Project Independence Blueprint. (Weinhold)

4. Testimony presented to Congress on many issues and bills including solar, geothermal, oil shale, uranium, nuclear parks, oil recovery, off-shore leasing, ERDA, etc.

In early April Mr. Simon became Secretary of Treasury and Mr. Sawhill replaced him. In late June the Federal Energy Administration was established as a separate agency, the Federal Energy Office was abolished. The Office of Energy Research and Development was removed from the Executive Office of the President on July 1, 1974, and was attached to the Federal Energy Administration.

Certain personnel were on a temporary or loan basis. George Daly left to head the Economics Department at the University of Houston on September 1 and was not replaced. Brian McCauley joined the office as specialist in international matters and administration in early September. Vaun Newill left October 1 to head environmental matters for Exxon and was replaced by Joseph Blair. Walter Hibbard became Professor at the Virginia Polytechnic Institute. Philip Palmedo returned to Brookhaven National Laboratory. Calvin Burwell and Elizabeth Richardson returned to Oak Ridge.

In November following passage of the Energy Reorganization Act, creating the Energy Research and Development Administration, an observations paper was prepared for the new Energy Research and Development Administrator. In addition, issue papers were prepared on automotive research and development and basic research. In mid-

November Robb Thomson will return to the National Bureau of Standards.

The office under Dr. Weinberg's directorship is planned to be phased out by mid December 1974 after an effective life of nearly 12 months. However, it is expected an R&D office within FEA will continue to maintain liaison between FEA and the rest of the energy research and development community.

Attachments:
Issues Paper, July 1974
PIB Chapter IX
Auto R&D Paper
Observations Paper
Prospectus dated May 1, 1974
Selected Congressional Testimony (nuclear parks, solar, geothermal, ERDA, etc.)

IMPORTANT ISSUES IN ENERGY RESEARCH AND DEVELOPMENT

Energy Research and Development Office
Federal Energy Administration
Alvin M. Weinberg, Director
July 1, 1974

I. INTRODUCTION

The purpose of this paper is to identify and briefly examine a number of "Important Issues" in energy research and development which warrant special attention by the Energy Research and Development Office (ERDO). Since ERDO is small, it seems best to settle on a few outstanding questions to whose resolution ERDO's contribution can be especially helpful. In addition to identifying these "Important Issues," we shall try to indicate what ERDO might do to further action on them.

To anticipate our main conclusions, we have identified the following six matters as being of sufficient weight to be labeled "Important Issues":

1. Nuclear Reactor Siting Policy: Nuclear Energy Centers.
2. The Development of Solar Electric Power.
3. Exploitation of Western Oil Shale.
4. Improvements in Mining Technology for Coal.
5. Assuring Uranium Fuel Supplies.
6. Automotive Energy Systems.

In addition to these six issues we recognize that the environmental consequences of energy production are all-pervasive and require special attention. However, the environmental issue is so very large that we have decided to treat it separately rather than include it among our "Important Issues."

In choosing such a small list from the entire energy research and development program of the U.S., we have had to be somewhat arbitrary. Unfortunately, each energy modality presents differing questions and considerations which cannot be resolved by the application of simple and uniform criteria. In each area, however, we have attempted to both ask and answer the following question: Does the nature of the present research efforts and/or related policies in the area reflect the urgency which, in our opinion, the area deserves? On this admittedly judgmental basis we were able to compose our list of issues.

For this reason, the absence of an area or modality from our list does not imply that we regard it as irrelevant to the nation's energy future; rather, it reflects our opinion that, relative to other areas, it is presently receiving adequate attention. It is for this reason, for example, that neither fusion, geothermal, the breeder nor solar energy for heating and cooling is on our list.

The initial part of this paper indicates in general terms how these issues fit into the overall strategy for energy research and development and why these particular issues were chosen. The latter part of the paper examines each issue in a preliminary way, and indicates what ERDO can do to help resolve the issues.

II. PERSPECTIVE AND GOALS FOR ENERGY RESEARCH AND DEVELOPMENT

Current strategy for energy research and development in the U.S. is largely based on the comprehensive Dixie Lee Ray study, "The Nation's Energy Future" (NEF). The FY 1975 President's budget is, with rather few exceptions, largely an embodiment of the findings of NEF.

Since NEF appeared, our short-range energy policy has crystallized, perhaps to a sharper extent than was implicit in NEF, around Project Independence. Though the blueprint for PI is in process of being written, it seems clear that our commitment to PI gives to our energy R&D program even greater urgency than was assumed in the formulation of NEF.

Actually, our energy research and development has two somewhat distinct goals: those that flow from our commitment to PI, and those generally long-range goals that are extremely important and which transcend the specific aims of PI. Three of the six "Important Issues"--coal mining, uranium ore supply, and automotive energy systems--are quite directly related to the achievement of the shorter-term goals of PI, as well as having longer-range implications. The others--nuclear energy centers, solar energy, and possibly oil shale development--are primarily longer range in impact but may have some influence on the achievement of PI.

A. Short-Range Goals: Project Independence.

We can summarize the short-run goal of energy R&D as it relates to what is expected to emerge from PI in the following words:

TO HELP ACHIEVE AN APPROPRIATE DEGREE OF SELF-SUFFICIENCY IN THE NEAR TERM FUTURE BY DEVELOPING MORE EFFICIENT WAYS OF USING ENERGY AND EXTENDING DOMESTIC SOURCES OF ENERGY.

More specifically, the basic strategy for achieving this goal is three pronged:

1. Conservation of energy.
2. Increased domestic production of oil and gas.
3. Substitution of coal and uranium for oil and gas.

As was indicated in great detail in NEF, many different elements of R&D could help us achieve each of the three near-term objectives. Is it possible to choose, out of the many dozens of elements that constitute the near-term energy R&D strategy, a few specific elements that are particularly critical either because of their intrinsic importance, or because they are not now being addressed in a fully effective manner? If, for example, the governmental structures responsible for the technology are too fragmented or the marketplace fails to provide adequate incentives for pursuing the technology, we would consider these as arguments for including the technology in our list of "Important Issues."

Consider conservation, perhaps the most important single path to achievement of self-sufficiency. Unfortunately, conservation, with one or two exceptions, hardly lends itself to a massive, possibly centralized R&D effort; instead, it involves many, relatively small improvements--in processes, in construction, in individual habits. One outstanding exception is automotive transport. An increase in the efficiency of our automotive transport system--say by 40 percent in ten years--would do more to reduce our dependence on foreign oil than any other single action. This in itself justifies our designating automotive propulsion as an "Important Issue." Moreover, the present organization of automotive propulsion research, motivated almost entirely by the marketplace, is not clearly adequate to achieve the needed goals: this is an additional reason for designating automotive propulsion an "Important Issue."

With respect to increasing domestic oil and gas production there are obviously many immensely important short-term matters. Many of these have to do with Government and industry policies. In our judgment, most of these are presently being addressed in an adequate fashion. The main exception is the establishment of environmental base lines for new fields; this we believe deserves attention.

Finally, we point out that the basic near-term strategy of replacing oil and gas with coal and uranium presupposes the availability of adequate supplies of these latter fuels. But, as has been pointed out in many other contexts, neither our coal nor our uranium supplies are assured in practice, even though they may be assured in principle. We, therefore, believe that in any ordering of priorities for the short run, the urgency of assuring such supplies be recognized as being of utmost importance. To the extent that R&D efforts and related policy matters can help assure supplies of these raw materials, we would designate R&D on coal and uranium mining as "Important Issues."

B. Long-Range Research Goals.

Our long-range goals are of two sorts: first, those that flow from the need to depend primarily on domestic energy sources; and second, those that would be of great ultimate significance whether or not we had committed ourselves to a policy of energy self-sufficiency. In considering the first category, we must recognize that greater dependence on domestic energy sources necessarily imposes certain economic, environmental, and social costs that would not have been incurred had we continued to depend on low cost foreign oil. Thus, we can state our long-term energy R&D goals in two parts:

I. TO MINIMIZE THE ECONOMIC, ENVIRONMENTAL, AND SOCIAL IMPACT OF OUR SHIFT FROM HERETOFORE LOW PRICED IMPORTED ENERGY TO HIGHER PRICED DOMESTIC SOURCES.

II. TO ACHIEVE A RATIONAL LONG RANGE ENERGY SYSTEM, AND TO ESTABLISH AS QUICKLY AS POSSIBLE THE VARIOUS COSTS OF MAJOR ENERGY SOURCES AND THE ENERGY UTILIZATION OPTIONS THAT WILL UNDERLIE THE LONG RANGE ENERGY SYSTEM.

We have identified one "Important Issue" that bears to some degree on goal I: namely, the development of oil shale, particularly by in-situ methods. Most PI scenarios assume some contribution from oil shale (which is, after all, our largest potential oil reserve). Thus, it is a matter of great national urgency to establish both the commercial feasibility of the development of this reserve and the environmental consequences of such an action. Only then can we rationally determine whether and to what extent we should exploit this potential resource. In particular, are in-situ methods, which minimize environmental impact, commercially viable? This crucial question is unanswered at present. We, therefore, include the question of oil shale development as an "Important Issue."

We have also identified two "Important Issues" that seem to us to bear strongly upon the very structure of our long-range energy system. To identify now issues that are overriding in the very long run (say 50, 100 or more years in the future) is manifestly impossible since the actual mix of energy sources 50 or more years from now can hardly be predicted with certainty. For example, can we predict when, if ever, fusion will be feasible; or whether our society will turn away from nuclear reactors if there were ever a catastrophic nuclear accident; or whether our climate would be altered unacceptably by production of heat or carbon dioxide?

Nevertheless, from what we know now, we judge certain scenarios to be more likely than others, and we have made our choice of Important Issues accordingly. It seems to us that the most plausible future mix will be primarily based on coal and nuclear fission with a relatively small contribution from geothermal--unless solar and its children (wind, bio-conversion, ocean gradients, for example) prove to be economically viable or fusion proves to be scientifically and technically feasible. Nevertheless, we do not include geothermal or fusion in our list. Fusion, we believe, is being adequately pursued in the present budgets. Geothermal is a considerably smaller potential energy source than either solar, the fission breeder or fusion, and we believe it is also being pursued adequately.

We view fission and solar as central because they are the only primary energy technologies that are at once technically feasible and essentially inexhaustible energy sources. Moreover, solar appears to be relatively benign, environmentally. Thus, in the long run it seems not unlikely that a choice may ultimately be made between them. Because of the profound importance and consequences of such a choice we believe it appropriate to designate as "Important Issues" the most crucial unresolved questions concerning fission and solar. In the case of fission, we believe this issue is reactor siting, and particularly the evaluation of the practicality of a national siting plan based on energy centers. In the case of solar energy, the issue is considerably broader: Should the U.S. make a much heavier commitment to solar, particularly solar electric power than it has made so far? Such a commitment may be necessary if we are to judge much more accurately than we now can, the true costs and ultimate potential of solar power. Only then can we assess fairly the relative costs and benefits of solar and fission and plan for the long-term roles of these two modalities in our ultimate energy system.

III. DESCRIPTIONS OF THE "IMPORTANT ISSUES"

In this section, we discuss each of the "Important Issues" that we have identified in Part II. Some of the issues--nuclear siting, the role of Government in automotive research, or assuring our uranium supply--are not primarily matters of allocating R&D resources but rather of broader Government policy. Other issues--coal supply, oil shale, and solar--are primarily matters of allocating adequate R&D funds for their development. However, this distinction between "policy" and "budgetary" issues must not be drawn too sharply. Eventually, a policy issue, even one with such broad implications as whether to deploy nuclear reactors in energy centers, carries with it budgetary R&D commitments--since the feasibility of such a policy depends on answers from R&D. Conversely, a budget allocation to development of a particular modality--say solar power--probably would create a new energy option which might affect the structure of our long range energy system and thus ultimately energy policy. Thus, while the R&D component of the issues discussed below varies considerably, it has important implications for each.

1. Nuclear Reactor Siting Policy: Nuclear Energy Centers

At present approximately 120 sites for nuclear power generation have been selected and the plants for these sites are either planned, in operation and/or under construction. If the nation is to achieve its projected nuclear capacity of approximately one million megawatts in the year 2000, an additional 1,200 reactors will have to be in operation or under construction by that time. If the present practice of dispersal is continued the number of sites will rapidly proliferate, numbering perhaps as many as 500 by the year 2000. Public concern regarding safety, diversion and waste disposal is likely to intensify as the number of nuclear sites increases. This suggests that alternatives to our present siting policies be seriously considered. In particular, the advantages and disadvantages of the chief alternative to the present policy of dispersal--the concentration of reactors and their supporting fuel recycle and waste disposal systems within a smaller number of nuclear energy centers or parks--should be carefully examined.

The primary advantages of such centers are:

a. The sites would be very secure, and lines of outside transport would be minimized. Thus, the possibility of diversion of fissile material would be minimized.

b. The sites would be manned by large cadres of highly skilled operators and managers thus allowing more effective use of technical personnel. This would reduce the possibility of human error, increase safety and thus reduce the likelihood of environmental damage.

c. Since the sites would be built over many years, the construction force would be relatively stable and experienced. This accumulation of skills would mean that the reactors and supporting facilities would probably be constructed more rapidly, efficiently, and safely. Semi-factory types of operation could be employed which should produce additional economies.

d. The sites would be chosen as part of an overall long-range plan thus, hopefully, resulting in more rational land use. Moreover, confining high level radioactive operations to relatively few places would reduce the amount of land that could potentially be contaminated by radioactivity.

e. The sites would be expected to be permanent, and, therefore, would be more suitable for management, control, and storage of radioactive wastes than would non-permanent sites.

f. After the initial regulatory reviews the use of nuclear energy centers should speed up the licensing process.

While these advantages are impressive, important questions regarding such sites must be resolved. These include the following:

a. Technical questions: How much power can be transmitted from a single site? What are the climatological effects of such concentrated siting? Will the radioactive and chemical releases unduly constrain the size and/or composition of such centers? Are there a sufficient number of potential locations for such sites which possess adequate quantities of cooling water? How can such power centers fit into the electrical power growth requirements of the region served? What is the potential for common-mode failure?

b. Institutional, financial, contractual and organizational arrangements: For example, who would own and operate the centers? How might the centers be managed to jointly serve several utilities? What legislative regulations and/or tax provisions might induce or inhibit the growth of these centers? What would be the impact of such centers on insurance requirements and programs?

c. Social impacts: How might such centers influence the location and nature of residential, commercial, industrial and recreational activities? Do such centers significantly increase the nation's vulnerability to enemy attack?

d. Time lags: .What sorts of lead times would be required for setting up organizational structures, conducting advance planning, obtaining governmental approval, et cetera?

In retrospect, it probably would have been desirable to locate light water reactors (LWR) in nuclear energy centers. Because of the way the LWR industry has developed, it is not practical to incorporate all existing reactors into such centers. However, if action is taken immediately it should be possible to establish an acceptable pattern under which practically all reactors constructed after about 1990 would be placed in nuclear energy centers.

This is especially true of breeder reactors since the opportunity exists to do something before they proliferate in large numbers as commercial central station power plants. Such a pattern has been established to a degree since the Liquid Metal Fluid Fuels Test Facility (FFTF) is located on the AEC's Hanford, Washington, reservation where there already exist many of the ingredients and characteristics of a nuclear energy center; and the Clinch River Breeder Reactor (CRBR) and fuel recycle demonstration plants probably will be located at Oak Ridge, Tennessee, where a similar situation exists. Therefore, it will be relatively simple to locate LMFBR's and other breeder reactors in a NEC environment from the beginning with the prospect that all future breeder reactors will be located in nuclear parks.

From the present evidence ERDO believes the rational deployment of nuclear energy into Nuclear Energy Centers to be a potentially desirable goal of national energy policy. Further, we believe that for several reasons such centers are unlikely to emerge rapidly enough from the normal interplay of legal, political, technical and economic forces. At the same time we recognize the existence of a sufficient number of unanswered questions to make this judgment tentative, particularly in light of the potentially profound consequences such a decision could have on our social institutions. Accordingly, we recommend that vigorous research on the remaining critical questions concerning Nuclear Energy Centers be undertaken. In anticipation of a favorable resolution of these questions ERDO recommends that a commitment to site all new reactors in energy centers beginning in about 1990 be established as national policy.

2. The Development of Solar Electric Power

The potential advantages of solar energy (and its children--bioconversion, ocean thermal gradients, wind, etc.)

are apparent and well known: It is a virtually inexhaustible energy source; its production emits neither sulphur dioxide nor radioactivity; it is regarded as the least likely energy source to bring about significant climatological changes; moreover, it has already been shown to be practical for space heating and possibly cooling. While these advantages are impressive, their existence does not address a fundamental policy issue: Can solar energy become a truly major source of energy for central electric power generation? If we judge this to be true then the Government should assign a priority to solar electric power commensurate with those presently associated with fusion or perhaps even fission. Of course, since research on solar is probably less expensive than that on fission or fusion this does not necessarily mean that solar should be funded at the same level as nuclear research.

ERDO considers solar electric power as a major issue because while it appears to have significant potential, it is impossible to judge at this time whether solar energy can ever be a serious competitor with fossil and nuclear energy as a primary source of electric power. Until such a judgment can be made with reasonable certainty we will be unable to rationally allocate R&D efforts among these alternative modalities.

Present estimates of the costs of producing solar electric power are so crude and vary so greatly that no reasonable judgments can be made on the basis of them. Moreover, it is difficult to predict how technological advances in solar or its competitors will affect cost comparisons made between them. And, because of the great uncertainties regarding the economics of solar energy there appears to be little incentive for the private sector to initiate research here. Ultimately, however, a choice may have to be made by society between "infinite" energy sources--nuclear and solar. It is imperative that this choice, if it is made, be based not on speculation but rather on realistic estimates, backed by extensive research, of the possibilities of solar electric power.

For these reasons ERDO believes that research aimed at determining the importance of solar energy as a long-term alternative source of electricity to be a crucial element in a rational deployment of our nation's R&D resources. We further deem it appropriate to review the present Federal solar energy strategy in view of its overall funding level and the balance between the near- and long-term goals. Budget recommendations for a five-year solar energy program are currently being prepared by NSF. These plans will be reviewed in the light of the goals stated here, and recommendations made in time for the fall budget exercise.

Given the potential magnitude and ultimate importance of solar energy, a related issue that should be considered is the desirability of establishing one or more National Solar Energy Laboratories. The critical issues surrounding solar are long term in nature and their resolution will require a sustained and continuous effort. Most likely, this will be achieved by an institutional structure which has both longevity and a specific commitment to this modality. The situation shows rather broad similarities with fusion where we are attempting to develop a long-term energy source which may not prove to be either scientifically or commercially feasible. Accordingly, ERDO feels that the AEC pattern of locating actual work on fusion in a few centers of strength deserves strong consideration as the appropriate institutional format for solar energy work.

3. Exploitation of Western Oil Shale *

While it is expected to be of diminishing relative importance, petroleum will continue to play a vital role in the nation's energy future. The desirability of

*A more complete and detailed description of the techniques for recovering shale oil is contained in a paper prepared by Dr. Kirkbride of ERDO.

enhanced energy self-sufficiency requires that we, therefore, more vigorously explore for and exploit our domestic reserves of this resource. The single largest source of these reserves is the oil shale deposits in the Green River area of Colorado, Utah and Wyoming.

Specifically, these deposits have been estimated to contain a potential oil yield of 1,800 billion barrels. However, only 6% of these deposits are in thicknesses of 30 feet or more and contain 30 gallons or more of oil per ton of shale. This indicates that, at current petroleum prices, only 100 billion barrels of this vast reserve can be profitably recovered with methods which are commercially feasible at present. Thus, if this vast potential resource is to significantly alter the domestic energy picture, advances must be made in the technology used in exploiting it.

In the past 20 years a great deal of manpower and other resources have been invested in attempts to develop technologies for exploiting shale oil. Most of these efforts have been devoted to processes involving room and pillar mining and above ground retorting. Pilot plants have been built and operated by Union Oil, Tasco, the

Bureau of Mines, Colony, Mobil and others. Currently several industrial organizations are in the process of scaling up this work to build commerical units (50,000 bbls/day) in order to exploit leases they have purchased.

At the present time, only the mining/above ground retorting technology has advanced to the stage of commercialization. Unfortunately, this technology faces a variety of logistical and environmental problems which, collectively, cast serious doubt on its ability to importantly affect U.S. petroleum supplies. The process requires large amounts of water (three to four volumes of water for each volume of oil removed*), a resource which is very scarce in the region in which the shale is located; moreover, the water often used is contaminated with salts of various kinds. The disposal of spent shale constitutes a significant (and energy using) task. It has been estimated that about 500 million tons/year of shale would have to be mined for a one million bbl/day shale oil output; this is about the same tonnage as the entire coal production of the U.S. in 1973. The disposal of this spent shale consumes large amounts of water to alleviate dust formation and to provide for vegetation. Further, as noted earlier, the mining/above ground retorting technique is commercially feasible only for relatively easily accessible deposits.

*This includes water used for crushing, retorting, refining land reclamation and for meeting the needs of the population.

Because of these problems associated with above ground retorting we conclude that if more than 100 billion barrels of shale oil are to be recovered from the Green River area, in-situ processing must be commercialized successfully. At present there are three major in-situ processes all of which require substantially less water and involve less environmental risk than above ground retorting methods. The first two involve rubblizing shale in a cavity or natural retort and passing a fire front through the rubblized shale. Alternatively, the shale may be fractured by hydraulic and explosive techniques and the oil recovered by fire flooding. Such processes have been explored experimentally by a number of organizations. The quality of the oil produced by this in-situ process is similar to that produced by above ground retorting.

These particular in-situ processes face several potential problems. In many instances they are likely to be commercially viable only <u>after</u> prior room and pillar mining where they can be used to extract oil from the pillars and remaining strata. In these cases they should be regarded primarily as a companion to above ground retorting methods rather than as a replacement for them. Recovery efficiencies are estimated at 60-85%. Channeling can occur during these processes; this would cause bypassing of substantial shale and increase unit costs. In addition, in some cases the pressure drop increases due to the packing of spent shale. When this occurs, the cost of getting air to the fire front increases and, accordingly, the unit cost of the oil increases as well.

The third in-situ process, sponsored by Shell Oil Company, is in an earlier stage of technological development. It uses hot water and high temperature steam to extract the oil from shale. In this process a well is drilled into a stratum of shale, after which it is filled with hot water. The water dissolves certain water soluble materials (nahcolite and possibly dawsonite) and when the resulting solution is removed, steam of 600^{o} and 1500 psig can be admitted to the now honeycombed formation. The oil is recovered by pumping it from the bottom of of the cavity.

Although our knowledge is very incomplete at the present time, this latter process appears to have a number of potential commercial and environmental advantages over the processes described earlier. The oil recovered is said to be of higher quality and, unlike that produced by other in-situ and above ground processes, has a low enough pour point that it might be directly shipped to refineries through pipelines. This would allow great economies in the process by permitting denitrogenation and desulphurization at the refineries rather than at the mining site and would greatly reduce the water requirements of the mining process. Such a process can be used to extract oil from deposits of such depth that their exploitation by other methods would prove unprofitable and the nahcolite and dawsonite recovered as byproducts are both of commercial value. In addition, the Shell process probably does not require as much water nor cause as much damage to the environment as does above ground retorting. Finally and perhaps most importantly, while Shell estimates that there is a potential recovery of shale oil by this process of over 20 billion barrels from the particular site they are presently exploring, there is a reasonable chance that the process will be applicable to other shales which contain significant quantities of water soluble minerals.

While these advantages are impressive, substantial uncertainties still surround this process and commercialization is several years in the future. Thus, the utility of the steam-water process may depend upon the existence and distribution of water soluble minerals in the shale to be exploited. Technical difficulties such as channeling or others as yet unanticipated may make its application infeasible in many areas. Legal complications are likely to arise since most of the exploited shale deposits are on Federal lands and leases for the dawsonite and nahcolite deposits are already held by other firms. Nonetheless, it is ERDO's view that the prospects of this particular process are sufficient that its commercial feasibility ought to be explored vigorously.

It is the belief of ERDO that several conclusions emerge from the considerations raised above. First, because of the substantial environmental risks and water requirements of above ground retorting and because such processes are already at the stage of commercialization, governmental involvement in the development of technology for shale oil should be largely concentrated on in-situ methods. Secondly, ERDO recognizes that a great deal of time and effort will have to be invested before commercially feasible in-situ processes are developed. Nonetheless, we believe that the enormous magnitude of domestic shale resources combined with the technological promise of the various in-situ methods for exploiting them justify the commitment of a substantial R&D effort to the further development and commercialization of these methods. For this reason we believe that the Government should support and encourage research in this area including programs involving cooperative efforts with industry.

4. Improvements in Mining Technology for Coal

A central feature of our energy policy is the substitution of coal for other fossil fuels. This aspect takes on even greater urgency with the advent of Project Independence and the reductions in our projected output of nuclear electricity. New technology is required to reach the forecast coal production. For these reasons, an essential task of energy R&D must be to provide technological advances that will increase the production of coal in ways that are both economically and environmentally efficient. It appears unlikely that the private sector can or will respond to this need: it is highly fragmented, has little history of or experience with technological advances and is beset by a variety of regulatory and organizational difficulties. Accordingly, we feel that the Government must take a major initiative in the provision of R&D in this energy modality.

Consider the sheer magnitude of even the short-run tasks confronting this industry. Estimates regarding our 1985 needs for coal range from 1 to 1.5 billion tons; in 1973 590 million tons were produced. To achieve such an increase will require that, on average, one new underground mine (2×10^6 tons/yr) and one new surface mine (5×10^6 tons/yr) must be brought into production every month for ten years; in contrast, only 13 mines with capacity greater than 2 million tons per year were brought into production during the decade of the 1960's. Eighteen months are normally required to develop a new surface mine and orders for the capital equipment used in this task presently face a backlog of 5 years. The development of a new underground mine typically requires from 5 to 9 years and there are serious manpower shortages in mining engineers and, in many areas, miners as well.

Given these and other obstacles and bottlenecks, the fulfillment of our 1985 needs will require enormous efforts. If these needs are to be met major new technologies must be developed and adopted within the industry in order to (I) increase the output of existing mines and (II) accelerate the development of new ones. Our recommendations in each of these areas are as follows:

I. In the former category we list:

a. Increase operating time of continuous miners from 25-30% to 50-60% by:

(1) Methane drainage in advance of mining. This allows operation of the mine at several mining faces concurrently.

(2) The use of diesel haulage and shuttle cars. This permits more efficient transport of mined coal from the continuous miners to the surface belt transport.

(3) Continuous belt transport from mine face to surface.

b. Develop remote control operated roof bolters, shuttle cars and continuous miners to improve efficiency and reduce labor requirements and improve safety.

II. In the second category (developing new mines) we list:

a. Adapt large diameter continuous boring equipment now available for metal mines to develop shafts and entries for new coal mines.

b. Develop surface mining equipment for both removal and restoration of overburden at rapid rates.

c. Develop geological methods for more efficient evaluation and planning of new coal mine development.

d. Adapt European shortwall and longwall mining equipment to U.S. needs.

In addition, three other things could be done that would significantly increase our production of coal, regardless of its source:

a. Develop the capability for evaluating environmental impact of coal mining quickly and developing and complying with the regulations rapidly.

b. Speed SO_2 stack gas removal technology so that existing coal mines with high sulfur can be used to the fullest extent possible.

c. Accelerate the supply of mining engineers and the vocational training of miners through educational programs.

Obviously, any additional R&D expenditures in this area will represent a superimposition of effort upon those which are already underway in the Bureau of Mines. In this regard, it should be noted that the present underground coal mining R&D program has as its objective an increase in productivity of from 12 tons/man-shift to 30 tons/man-shift. The surface mining program is concerned largely with environmental protection. Both programs schedule demonstration units in the period FY 1978-1979. However, with present long lead times and the high costs of capital equipment it seems unlikely that any new technologies arising from these programs can exert a significant impact by 1985 under present circumstances.

The crucial needs in this area, therefore, are for policies designed to increase both the development of these technologies and their rate of diffusion throughout the industry. Thus, for example, it would appear possible to (1) make methane drainage methods commercially feasible by FY 1977-78 and (2) demonstrate various equipments by FY 1977, thus allowing their commercialization by as early as the FY 1978-79 time period. Only if such an acceleration can be achieved is it likely that the resulting technological advances will be able to importantly influence coal production by 1985. For these reasons ERDO proposes to resolve the question of accelerated funding and to develop policy commitments to mining technology both in FY 1975 budget decisions by the administration and in the statements of energy policy by the White House, FEA, DOI and ERDA.

5. Assuring Uranium Fuel Supplies

Virtually every portrayal of the nation's energy future, whether short or long term, pictures a rapid expansion in nuclear energy. A representative estimate predicts a nuclear electric generating capacity of about 325,000 Mwe by 1985 and over 1,000,000 Mwe by the year 2000. Based on these projections, the cumulative fuel requirements for the necessary reactors will be about 500,000 tons of uranium oxide (U_3O_8) by 1985 and 2,400,000 tons by 2000. Further, the 30-year lifetime requirements for these same reactors will be approximately 2.0 million tons and 5.0 million tons, respectively.

The viability of the nuclear option and the increasing role it is expected to play in our energy future is, therefore, dependent upon our ability to meet these anticipated demands for uranium. This ability in turn, depends upon the existence of adequate environmentally and commercially recoverable reserves and mining and milling capacity. According to the AEC, domestic uranium reserves are as follows:

ORE CON. PPM U_3O_8	CUTOFF PRICE $/LB. U_3O_8	REASONABLY* ASSURED (CUMULATIVE)	ESTIMATED* ADDITIONAL (CUMULATIVE)	TOTAL*
1600	$10	427	700	1,127
1000	15	630	1000	1,630
200	30	800	1600	2,400
60	50	4800	3600	8,400
25	100	8800	8600	17,400

Note: $10 through $50/lb. includes copper leach residues and phosphates. $100/lb. includes Chattanooga shale.

Source: Wash 1242 and 1243.

*In 1000 tons of U_3O_8.

Estimates by the Bureau of Mines suggest that 1.1 million tons of U_3O_8 are available at $15/lb. or less and thus corroborate the AEC findings. In truth, the amount of our uranium resources at any price is not really known. The U.S. Geological Survey estimates that on the basis of the abundance of uranium in the earth's crust, the potential resources could be much greater than known reserves. However, they, too, are concerned about the adequacy of uranium resources for meeting requirements. Others place the figure not far above the AEC's current estimates. In view of these uncertainties it is clear that assurance of our uranium supply is a matter of vital importance.

Comparison of the above projected reserves with the anticipated uranium demands suggests that by the year 2000 we may be forced to use uranium mined at 60 ppm or less. Though this may not greatly increase the cost of nuclear electric power (because of the relatively small component of total generating costs represented by uranium), such mining might impose serious environmental costs.

Given the extraordinary growth that will be required in the uranium exploration and mining industry and the fact that nuclear plants are expected to last 30 or more years, policies applicable to other extractive industries (e.g. 10 years forward reserves based on current mining rates) are clearly inappropriate in the uranium industry. Further, we are troubled by the fact that, for a variety of reasons, market forces have not responded forcefully to the vast increase in projected uranium demands.

It is clear that, at present rates of progress, the domestic uranium industry faces a potential crisis and one which could compromise the nuclear option. What is required are the assurances of: (1) the existence of adequate domestic reserves and (2) the capacity to convert these reserves into above ground uranium at a rate and cost consistent with the projected expansion of nuclear power. Such a conclusion is consistent with a variety of other studies including those undertaken by the AEC, NAE and the Cornell Workshop on Energy Research and Development.

For these reasons, ERDO believes that the matter of uranium availability is of greater urgency than is presently recognized. We, therefore, propose the initiation of new programs in this area and the stregthening of existing ones. Among our specific recommendations are:

a. The determination of the availability of domestic resources and the estimated minimum prices at which these resources will be supplied by the industry.

b. The development of new and improved exploratory techniques for deep uranium.

c. The development of new techniques for the recovery of low grade ore and of incentives to encourage such recovery.

d. The development of environmentally acceptable techniques for mining uranium ore and, in particular, the low grade ores which require massive excavations.

e. The examination of the role of Government policy in encouraging or inhibiting domestic uranium production. Particular attention should be paid to the consequences for domestic production of importing foreign uranium (a total embargo presently exists) and, possibly, to the policy with respect to Government stockpiles.

f. The determination of the cost and practicality of extracting uranium from sea water.

6. Automotive Energy Systems

The automobile is a prodigious user of energy (13% of all energy consumed within the U.S.) and it is the major user of petroleum (30%), the fuel in which the most critical shortages presently exist. (These figures would be increased by approximately 20% if small trucks were included in the calculations.) Moreover, it is in the automotive sector that inter-fuel substitutability appears to be lowest. Unfortunately, the fuel economy of automotive vehicles has been falling and has now reached a low of 13 vehicle miles per gallon.

ERDO believes that sound research and development aimed at increasing the efficiency of personal transportation systems is necessary for the development of rational future energy systems. In surveying federally supported research in this area we observe that it is fragmented across agencies and that most of it is devoted to areas other than fuel conservation (see Table below). The most significant program is that under EPA under the development of alternative automotive power systems (AAPS).

FEDERAL FUNDING FOR AUTOMOTIVE R&D

	FY 1974	PRELIMINARY FY 1975
EPA	$12.1	$17.1
DOT	1.8	6.8
NSF	2.6	2.6
NASA	2.0	2.0
DOD	4.2	4.2
AEC	.1	.1
TOTAL	$22.8M	$32.8M

The major automobile companies possess vast R&D resources. In the past, such resources have been utilized in areas such as exhaust emissions, safety and, very recently, fuel economy. In general such research has been undertaken in response to frequently changing Government regulations. Major questions exist, however, as to whether in the current economic environment this industry will be led by market forces to devote adequate resources to research on fuel conservation and, in particular, to those long-range options which involve substantial risk. Because of the urgency of the problem, the uncertainty surrounding the private sector response to it and the serious social and economic consequences that might result from a less than vigorous response, ERDO believes that an important role must be played by the Federal Government in the automotive sector.

It is one thing to defend the necessity and/or desirability of such a role; it is quite another to precisely define and implement it. The economic, technical and institutional issues are complex and subtle, the governmental responsiblities are spread across a number of agencies, the leaders of the industry are sensitive to any Government involvement. The issue is made even more complicated because all important policy decisions must ultimately face and answer the energy-environment trade off.

Due to these complexities, the actual design of Government policy will be difficult. ERDO will hopefully play a role in bringing together the divergent interests and views. To this end a paper addressing the specific technical, institutional, economic and budgetary elements and recommending general guidelines for Federal involvement will be prepared in time for the fall budget exercise.

IV. THE ENVIRONMENTAL ISSUE

The single most important cause of environmental pollution is production, conversion and consumption of energy. This alone distinguishes the environment from other issues since it cuts across the entire energy picture. For this reason, the long-term environmental and health impacts of particular ways of producing and using energy must be analyzed and compared as a prequisite to the rational allocation of funds among the various energy modalities.

Any energy modality which produces substantial adverse environmental consequences may ultimately have to be abandoned. Similarly, simple economic estimates for a modality which measure its private costs while ignoring its social costs can lead to irrational and wasteful policies. Thus because this issue is not only an "Important Issue" but is in reality many issues, we believe that it requires separate treatment. Indeed, we have already prejudged its importance by including it among the two major aspects of long-term energy R&D.

One major subissue is "How should the environmental impact and health effects research be done?" There are two basic approaches: (1) perform the health and environmental research in close proximity to the technical development; (2) perform this research in close proximity to related health and environmental research. The first approach is exemplified by the AEC where first class in-house capability in the biological effects of nuclear radiation has been developed in close association with nuclear energy development. A potential weakness of this approach, however, is that the environmental and health impacts may be underplayed by technologists who usually direct the overall effort. The other alternative approach is best exemplified by the HEW or NSF. The basic problem here is that the work supported by these institutions may not really be relevant to the needs of the developing technologies.

Clearly, both approaches have advantages and disadvantages and choosing between them is a complex matter. But in view of the great success of the AEC experience, ERDO would favor the general policy of conducting environmental and health research in close proximity with the technology it supports.

The adoption of any new technology inevitably involves new and unknown health and environmental consequences. A priori judgments regarding such consequences must be followed by surveillance to either validate or refute these judgments and to discern other effects that were not initially predicted. Such work is often tedious and long range; it will be done more adequately by stable institutions committed to this work. Thus, as ERDA comes into existence, there should be established clearly identified groups of adequate size with assigned research responsiblities for the health and environmental effects of each of the major energy modalities. This, we feel, would be preferable to present institutional arrangements in which the environmental impacts of energy are studied in a variety of agencies with inadequate vehicles for exchanging information or developing consistent and comprehensive policies.

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V. ADDITIONAL ISSUES

We fully recognize that adequate treatment of R&D issues in energy requires more than simply an identification of areas where additional R&D resources should be committed and where new policy considerations are appropriate. We mention, very briefly, three such issues that will have to receive close scrutiny by the Administrator of ERDA.

A. The Government-Industry Relation

ERDO recognizes that public policies and funding decisions can influence private ones and that ill-conceived or implemented policies might well have the unintended result of reducing the private sector's R&D efforts. One implication of this and one which is reflected in our choice of issues is that Federal involvement in R&D should be concentrated in those areas where private sector response, for any of a variety of reasons, appears to be inadequate.

A second implication of this observation is that all policy and funding recommendations should be made in awareness of the potential private sector response they may stimulate. For example, it should be recognized that Government policy with respect to patents can exert an enormous influence on the incentives for particular types of private R&D and thus greatly influence the size and composition of such efforts. Joint business-Government involvements and policies concerning the disposition of any valuable proprietary rights emerging from such efforts is another critical area. Similarly, a wide variety of techniques--ranging from direct Government research to tariff policies designed to induce comparable efforts in the private sector--are available as policy options and their utility should be examined in each individual case.

The general question of just how the Government should manage its involvement in energy research and development so as to enhance, rather than hinder private participation has been studied and discussed extensively during the past year--for example, by the panel on Institutional Patterns of the Cornell Workshop. Our purpose in raising the issue is simply to reiterate again that this matter will need continuous scrutiny by FEA, ERDA and all other organizations concerned with energy R&D policy.

B. Long-Term Electrification

Most new energy technologies (fission, fusion, wind power, ocean thermal gradients, etc.) are best suited to the production of electricity. Thus, scenarios of the future development of the energy system typically indicate an increasing fraction of the energy system being devoted to electricity. There are, of course, alternatives to increased electrification, say through emphasis on synthetic fuels from coal and decentralized solar energy. Even with increased electrification, the use of electrolytically produced hydrogen allows direct fuel combustion at the point of end use. The full implication of these various alternatives should be evaluated in a systematic way; and individual R&D programs should be developed with overall systems view in mind.

One particular possibility should receive emphasis in the next decade. The average overall efficiency of the electric generation in central power plants today is around 30%. If the average efficiency could be raised to 50% thermal pollution would be much reduced as would our coal requirements. Thus, an important part of our future R&D on electric modalities should be aimed at achieving higher efficiency in central power plant generating stations.

C. Centralized Laboratories for New Energy Modalities

An important issue during the formation of ERDA which must be raised is the role of the large laboratories in research on new energy modalities. ERDA will be a conglomerate of many agencies each having different traditions, different ways of doing business. At the one extreme is the AEC which on the whole does its business through very powerful well integrated central laboratories. At the other extreme is the Office of Coal Research which does its business through many relatively small contracts.

Different technologies may require different institutional arrangements for the achievement of maximum research and development output. There are distinct advantages as well as disadvantages associated with both centralization and decentralization. However, it is ERDO's view that on the whole even where many individual contracts are let, we would be better off with powerful lead laboratories in each of the major modalities: fission, coal, certain aspects of oil and gas, solar, fusion, and geothermal. Central fission and fusion laboratories already exist; we have previously argued that central solar laboratories be established. We raise the point in connection with the other modalities as an issue that deserves attention by ERDA.

VI. CONCLUSIONS

The foregoing paper represents as much as anything an agenda of action for the Energy Research and Development Office. As has been stated previously, the issues which we have identified appear to us to warrant special, urgent attention; the list is by no means complete, nor are the discussions of each issue exhaustive. Nevertheless we believe that in setting forth these particular matters as those which are deserving of special attention, we have outlined a course of action for ERDO which is both feasible to accomplish and, if accomplished, will make an important contribution to rationalizing our country's energy research and development policy. We would urge that, when ERDA is established, the issues raised in the paper be given serious attention by the Administrator of ERDA.

CHAPTER IX
BEYOND THE YEAR 1985: THE ROLE OF RESEARCH AND DEVELOPMENT

I. Introduction

Previous chapters of the Project Independence Blueprint described possible U.S. energy futures between now and 1985 and examined policy options for achieving them. This chapter discusses energy futures beyond 1985 and the role of research and development (R&D) in both the short and long-term. It does not, however, attempt to lay out a detailed Federal energy R&D program.

The programs and actions required to achieve Project Independence affect our energy research and development efforts. Thus, R&D strategy should be consistent with out view of the future both in the near term, as projected in the Blueprint analysis, and in the long-term as projected in a simplified systems model that will be described later.

The strategies and priorities for near term and long-term energy R&D differ to a degree, so two issues should be addressed:

- What can energy R&D contribute in the short-range covered by the Project Independence Blueprint (to 1985)?
- What additional R&D ought to be adopted now to help assure acceptable energy options in the time beyond 1985?

Behind each of these are policy questions: to what extent will adequate energy R&D occur solely through the operation of the marketplace? And how much additional impetus should be provided by government action? These matters must be discussed case by case. In some instances, for example, where time is of the essence, government support of a high-risk development may be valuable to the Nation; in others government involvement may not be desirable. Involvement through government purchases and financial incentives may be appropriate in cases where direct government support is not needed.

II. Short Range Contributions of R&D to Project Independence

Many years are required to bring a new technology from the laboratory through demonstration into widespread use. Only existing technologies and those on the verge of commercial operation can make a serious contribution by 1985; conversely, because of this lead time, such developments must be undertaken now if they are to pay off after 1985. Depending on the lead-times, improvements related to existing facilities and technologies can increase supply, reduce demand and make the energy system more flexible with respect to fuel sources by 1985. The following discussion illuminates the policy issues raised by commitments to these technologies.

A. Increasing Domestic Supply of Liquids and Gases: Near Term.

Between now and 1985, the widening gap between the domestic supplies and demands for liquids and gases can be reduced if we improve the recovery of oil and gas in the ground, extract oil from shale, and convert coal to synthetic oil and gas. In the following table we estimate the "take-off" dates at which some of these newer technologies can begin to make an impact, assuming full commitment to their development. By "take-off" date we mean the estimated year in which the technology is expected to reach the market place as the result of business decisions. For large scale technologies, such as central power plants, it is defined as the year in which the second commercial plant becomes operational in the United States. For mass produced devices, such as automobiles, it is defined as the year in which the second production line becomes operational.

Table IX-1
Near Term Liquid and Gas Technologies

Fuel	Process or Product	New Technology	"Take-Off" Date
Oil and natural gas	Oil recovery	Thermal methods	Now
		Advanced methods	1977
	Gas recovery	Massive fracturing	1977
	Drilling and exploration	Methane from coal beds	1977
		Discovery methods for stratigraphic traps	1980
		Deepwater drilling methods	Now
Oil shale	Recovery	Surface retorting	1980
Synthetic fuels from coal	High Btu gas	Fixed bed (Lurgi)	1980
	Low Btu gas	Fixed bed (Lurgi)	1977-80
		Slagging-entrained flow (Kopperg Totzek)	1977-80
	Liquids	Fixed bed (Fischer-Tropsch)	1980
		Methanol	1980

Oil and Natural Gas. Research and development can help increase the near term supply of oil and natural gas through enhanced methods of oil recovery, and better methods of production from tight gas sands, heavy oils and tar sands. Each of these new technologies is projected to have a significant impact on overall gas and oil production during the 1980's, if oil prices remain high and gas prices increase. At $11/barrel, we estimate that in 1985 2.65 million barrels/day can come from tertiary recovery and 0.44 million barrels/day from heavy crude oil and tar sands. Additional supplies from these sources, totaling 1.43 million barrels/day, are projected by 1985 under the Accelerated Supply Case. Alternatively, at $7/barrel oil, the amount of tertiary recovery and heavy crude oil production would be minimal. Over the longer term, advances in these technologies combined with additional exploration will help to determine the extent of the Nation's recoverable oil and gas resources more precisely. Such information would be extremely valuable in pacing the deployment of alternative technologies.

Normal market forces should provide most of the needed technology by the late 1980's, but the development and use of enhanced oil recovery methods and the production of oil from heavy oils, tar sands, and gas from tight formations may require a cooperative government-industry R&D effort. Government participation should be largely confined to support for field testing, thus reducing the risk of the individual firm, and facilitating public dissemination of the results.

Since most of the accelerated production will come from OCS and Arctic operations, R&D on environmental controls will also be needed to assure that development will not create unacceptable environmental impacts. This too may require cooperative efforts between government and industry.

Oil Shale and Synthetics from Coal. Shale oil and synthetics from coal could have an important impact on energy supplies if the existing above ground shale retorting and German-developed coal conversion technologies were deployed rapidly. The economic, environmental, technical problems, and equipment shortages inherent in scaling up such massive technologies will probably limit their deployment. The Blueprint analysis suggests that shale oil production based primarily on above ground methods could reach 250,000 barrels per day in 1985 under the Business-As-Usual Case and 1,000,000 barrels per day in the Accelerated Case. Synthetics from coal, both liquids and gas, would reach the equivalent of only 200,000 barrels per day under the Accelerated Case.

Resolution of the environmental and scale up problems is needed in addition to a favorable economic climate, if these technologies are to reach the projected levels of production. More traditional R&D during the Project Independence period should be focused on advanced methods, such as in situ oil recovery, which place less pressure on the environment and may be cheaper. These techniques will not have a substantial impact until after 1985.

B. Shifting Demands from Oil and Gas to Coal and Uranium. A shift in our pattern of energy use toward coal and electricity would reduce demand for oil and gas and increase the flexibility of our energy economy. The impact projected for this shift between now and 1985 depends primarily on the implementation of existing technology but it also involves developments in coal combustion, stack gas clean-up, coal mining and nuclear power. The following table lists near term technologies that could be expected to "take-off" by 1985 or earlier:

Table IX-2
Shifting Demand Technologies

Process	New Technology	"Take Off" Date
Coal combustion and pollution control		
	Limestone stack gas scrubbing	1975
	Advanced stack gas clean-up	1977
	Fluidized-bed combustion	1980
	Fine particulate control	1980
	Advanced methods of removing sulfur from coal	1980
Coal mining	Continuous face mining	1980
	Reclamation techniques for arid regions	1980
Nuclear power	Centrifuge uranium enrichment	1980-85
	Advanced methods for finding uranium	1980
	HTGR thorium fuel cycle	1985

1. Coal Combustion and Air Pollution Control. The Blueprint assumes that stack gas clean-up processes will be operational in the very near future, so that electric utilities can increase their use of coal. Though not expressly considered in the Blueprint Analysis, coal use in industry would also increase. However, scrubbers are still not sufficiently reliable for utilities, are expensive, have adverse environmental impacts, and may be difficult to install in existing plants. These deficiencies must be resolved if stack gas clean-up is to be counted on. Over the longer term alternative approaches to air pollution control involving advanced coal cleaning and controlled combustion can be applied.

2. Coal Mining. The Project Independence analysis indicates that the production of coal could increase to as much as 1,100 million tons per year by 1985 (including exports). We should, therefore, assign high priority to any developments that are lkiely to increase our capacity to extract the needed coal. Especially in underground mines, new technologies are needed to increase productivity, improve the health and safety of coal miners, reduce damage to land and protect natural water supplies. Satisfactory methods for reclaiming arid lands must be demonstrated if we are to use surface mining for large new supplies of western coal.

3. Nuclear Power: Converter Reactors. The light water reactor is expected to account for about 30 percent of the electric power generated in the United States by 1985, and as much as 70 percent by the year 2000. Some remaining issues involving the safety of existing plants and improvement of certain steps in the fuel cycle (e.g., plutonium recycle, enrichment and high level waste disposal) require continued research. These issues ought to be resolved as soon as possible so that the projected growth of nuclear power can be realized. In addition, R&D, aimed at improving performance and reliability, and speeding construction, could have large short-term benefits.

Our estimates of total uranium reserves are uncertain and the matter requires considerably more scientific investigation. Plutonium recycling and improved reactor efficiency will help to reduce the need for more uranium ore. New methods for finding uranium are needed as well as new ore processing methods if we must mine uraniferous shales instead of conventional ore.

Advanced reactors, such as the high temperature gas cooled reactor (HTGR) and the light water breeder reactor (LWBR) could come into operation in the early 1980's. Continued R&D is required, particularly for the fuel cucle, since the HTGR and LWBR fuel cycles are based on thorium rather than uranium. The use of higher temperatures and helium coolant gives the HTGR additional capabilities which may eventually increase the flexibility of nuclear power use. Direct cycle gas turbines combined with steam could increase the efficiency of the generation of electricity, and the reactor could provide industrial process heat in the longer term.

C. Conservation Technologies: Near Term. By 1985, we can expect improvements in the efficiency of energy use in three major sectors: transport, industrial, and household and commercial. During the Project Independence period, the primary conservation efforts should be directed toward reducing energy intensive activities and toward more widespread use of existing efficient devices. In addition, some new technologies, examples of which are listed in Table IX-3 can begin to have an impact.

Transportation. Transportation, especially the automobile, is a prime target for conservation. Improving the energy efficiency of cars from the current average of 13 miles per gallon to 20 miles per gallon is an important objective. This goal can be accomplished through a combination of reduced size and weight, more efficient engines, improved drive trains, and reduced road load (tires, aerodynamic drag, etc.). Light weight diesels and stratified charge engines could come into widescale use by mid-1980's if policies favoring technological improvements were chosen to reach the goal.

Table IX-3
Near Term Conservation Technologies

Demand Sector	Consumption Device or Process	New Technology	"Take-Off" Date
Transportation	Automobile		
		Energy efficient design (current engine types)	1977-80
		Advanced engines, e.g., stratified charge	1980
		Light weight diesel	1985
		Others	After 1985
	Aircraft	Advanced turbofan and supercritical wing	1980
Industrial	Steam processes	Packaged on-site coal-fired electrical steam systems	1980
		Solar-heat pump steam generator	1985
	General processes	New energy efficient processes	1977-80
		Improved recycling processes	1977-80
Household Commercial	Heating and cooling	Reliable heat pumps	Now
		Total energy systems	1977
		Efficient construction design	1980
		Solar heating	1980
		Solar airconditioning & heating	1985
	Appliances	Improved & uniform efficiencies	1977-80

Industrial. The industrial sector should achieve reduced energy growth in response to higher energy prices. Much of the savings will result from better management and design practices that exploit existing technology, but new developments can also have some impact.

R&D aimed at more efficient production of process steam from coal -- possibly in conjunction with electricity -- could have a significant effect in the next ten years. It may also be possible to develop energy-efficient systems which generate process steam using solar energy and heat pumps.

A number of more limited improvements in industrial processes and recycling technology are needed to achieve the accelerated goals for industrial energy conservation. New processes for extracting metal from ores, such as the one recently developed for aluminum can go well beyond the 10-15 percent savings achievable through good energy management practices. Advances in combustion efficiency, low temperature waste heat recovery and insulation can play an important role. Technology that facilitates recycling aluminum and other materials could also produce large savings.

A major unanswered question concerns the extent to which the government should encourage these developments. The government's experience in stimulating such technologies has been quite limited. Cooperative Government funding of individual research, development, and demonstration projects, with public dissemination of the results coupled with financial incentives for their deployment, may be appropriate.

Household and Commercial. The energy consumed in buildings is large: there is a promising target for conservation. In the near-term, widespread application of existing technologies--insulation, heat pumps, and total energy systems--coupled with design improvements in buildings and appliances offer the biggest payoff.

The most significant new technology being developed for saving energy in buildings is solar heating and cooling. While some may classify all solar energy applications as new supplies, the collection and use of the solar energy which falls on a building is a form of conservation, since it reduces demand for other fuels. There has been considerable progress recently in moving toward commercial use of solar heating, but solar systems have yet to be designed, demonstrated, and manufactured on a large scale. Solar air conditioning requires additional R&D before it is ready for widespread demonstration. Because of the large number of existing buildings with a long life, the initial impacts may be small but the long-term impacts are large.

III. Long-Term Energy Projections and Their Implications

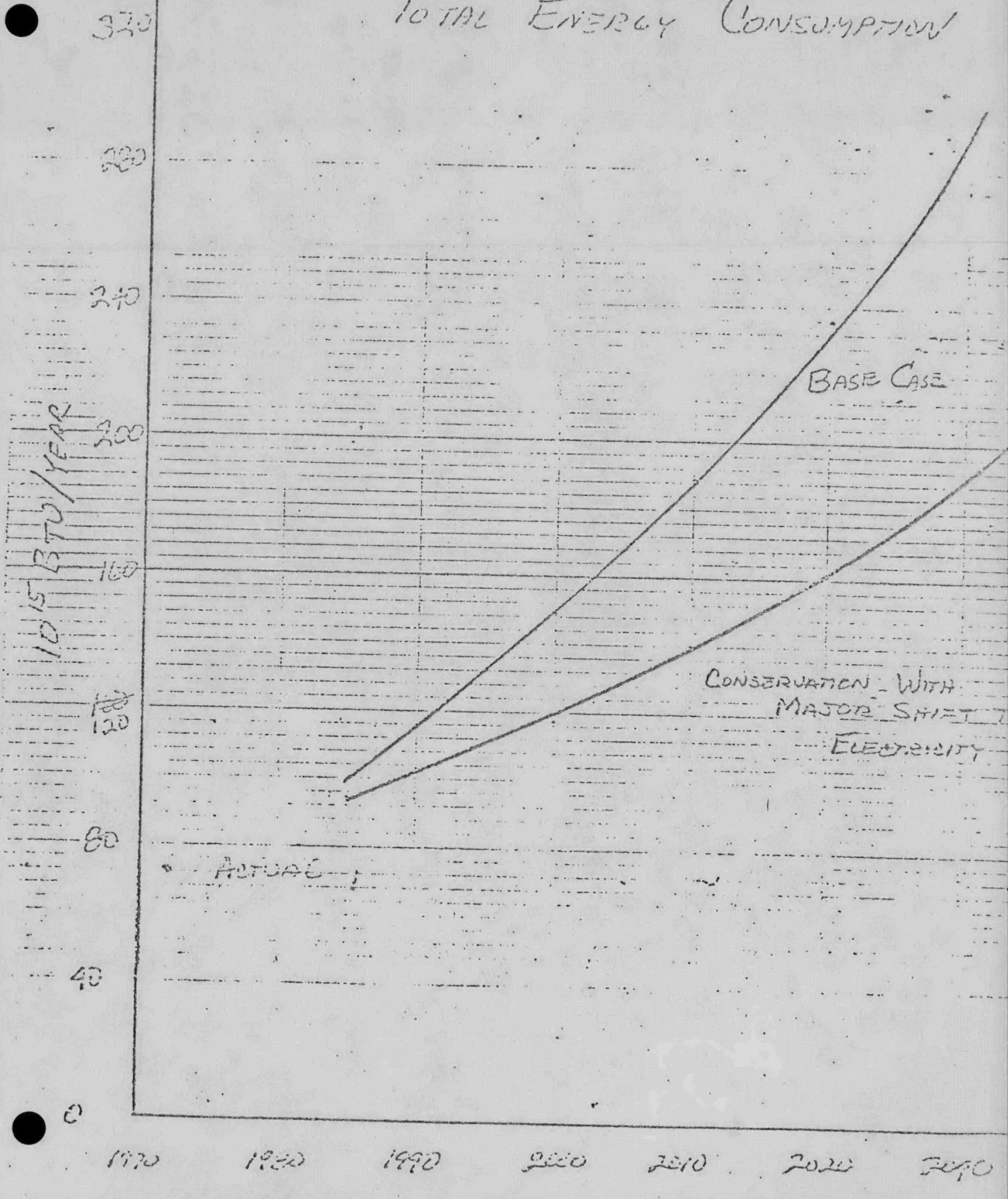
Our short-term energy R&D has been aimed at achieving the 1985 goals set forth in the Blueprint analysis. In corresponding fashion, we shall develop our long-range R&D strategy to achieve the goals implied by longer-term analyses. Our long-term energy model projects future demands and domestic supply options separately, and then combines supply options (including imports) to meet the projected demands. The analysis depends heavily on extrapolation of historical trends, technical possibilities, and availability of resources, so has large uncertainties.

Though this approach has generated many different combinations of supply and demand to illustrate the implications of various policies, we focused on the two long-term supply and demand scenarios (called "Base Case" and "Conservation-Major Shift") which parallel the near-term cases analyzed in the rest of the Blueprint. The long-term Base Case represents a continuation of the trends emerging in the near term case which continues present policies with only minor changes. Overall energy consumption grows at a rate of about 2.5 percent per year from 1985 through 2020. The Conservation-Major Shift Case parallels the lower growth Blueprint strategies and projects a 1.6 percent per year overall growth rate. This strategy combines conservation with a shift to energy sources that are not in short supply. In these analyses we are concerned not so much with total energy consumption (Figure IX-1) as with the demand for liquids and gases which are in short supply; and demand for electric power which can to some degree substitute for liquid and gases.

The most serious constraint in the post-1985 period appears to be the recoverable oil and gas in the ground. For long term analysis it is necessary to use estimates of what might be discovered in addition to the proved reserves discussed in Chapter II. According to the United States Geological Survey between 200 and 400 billion barrels of recoverable oil and between 1,000 and 2,000 trillion cubic feet of natural gas remain to be discovered. Although some industry estimates are less than half of the lower Geological Survey projection, we used a resource base approximating the lower Geological Survey estimates. Domestic oil and gas production therefore peak in the mid to late 1980's. The net effect of having the lower resource base is greater oil and gas shortfall in the late 1980's through about 2020, reaching a peak of about 12 million barrels per day in 2000. The high resource base would be sufficient to maintain a level slightly above the 1985 rate until about 2020, after which production would fall off. Synthetic liquid and gas from coal or shale are the most readily available domestic sources to replace oil and gas but the coal and high grade shale resources as well as the water needed to convert them are also limited over the longer term.

Electric power appears to be less severely constrained by resources or technology within the next 20 to 30 years, since electricity can be generated from existing sources in the near-term--coal, uranium and hydroelectric power and hopefully from new ones in the future--fusion, geothermal, and solar power. How much coal will be used to generate

TOTAL ENERGY CONSUMPTION



electricity depends to some degree on how large our synthetic industry will grow; how much electricity can be generated in light water reactors depends on the amount of uranium that can be produced at acceptable economic and environmental costs, while the longer range technologies are beclouded with many uncertainties.

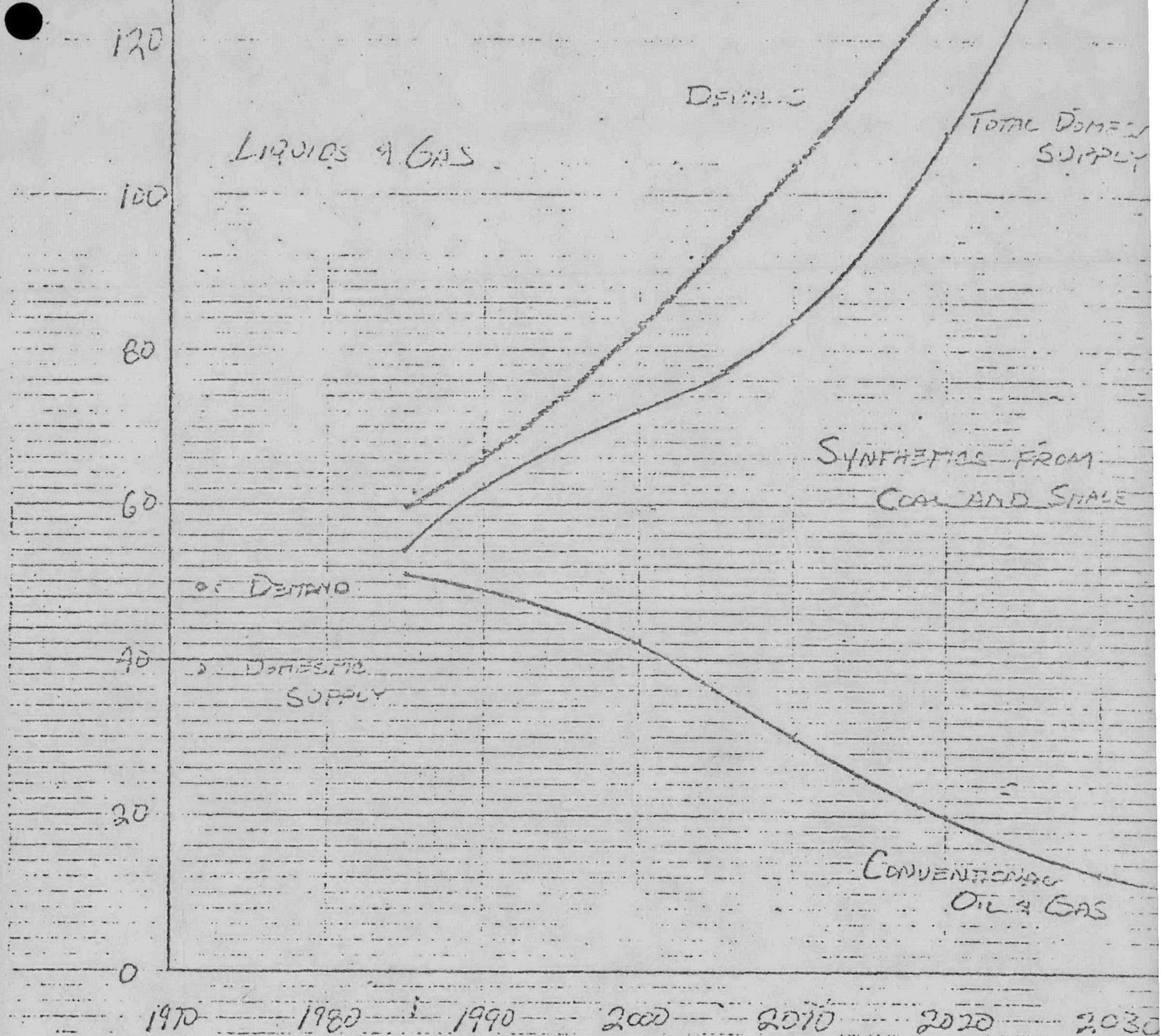
The Base Case demands for liquids, gas, and electric power are shown on Figure IX-2. The production of conventional liquids and gases falls in the late 1980's and becomes relatively insignificant after 2030. Rapid development of oil shale and coal synthetics could conceivably make up for this projected shortage. The projected electric demand is provided primarily by conventional converter reactors, coupled with hydroelectric power and coal-fired generation. The model assumed that oil and natural gas would not be used for electricity generators in the post-1985 period. Some of the electric power needed to meet intermediate and peak load requirements will be generated from liquid or gaseous boiler fuels made from coal.

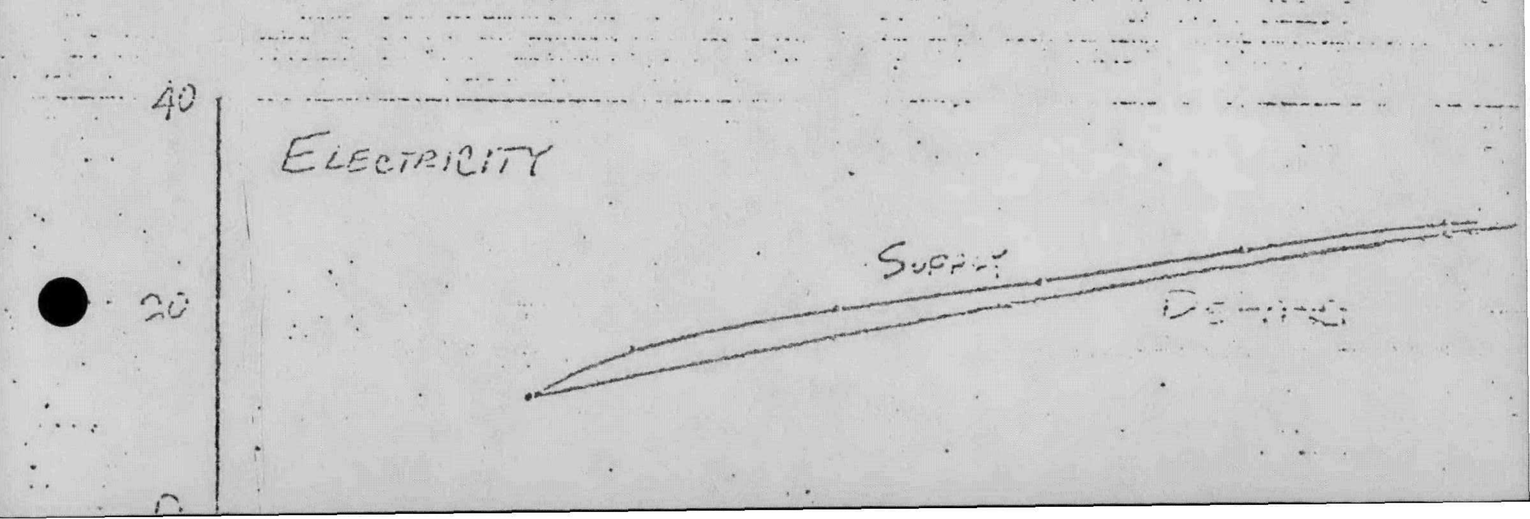
This conventional approach to supplying future energy demand, even at lower growth rates than have been experienced recently, places a great strain on synthetic fossil fuel production. By the year 2010 the equivalent of 25 million barrels per day of liquids and gas from coal and shale are projected. Even then, imports are estimated to be nearly 10 million barrels of oil equivalent per day. This shortfall could eventually be limited if coal and synthetic fuel production were to grow at 6 percent per year, but by 2010 about 3.5 billion tons of coal would have to be mined each year. This would rapidly deplete our coal resources, and exhaust available water supplies in the shale areas as well as place very serious burdens on the environment unless there were some technological breakthroughs.

Electric generation from conventional coal, hydroelectric and nuclear sources satisfies electrical demand in this case without much trouble. Thus, one asks whether the entire supply-demand imbalance could be met by combining conservation with massive shifts to electic power. Figure IX-3 (Conservation-Major Shift), shows that the demand for liquids and gases can actually be reduced by the 21st century through a combination of conservation, solar space-heating and cooling, electric vehicles, and other shifts to electric power. Even in that case, though, it is necessary to provide 8 million barrels of synthetics per day by 2010 and this leads to a 4 percent per year growth in coal consumption. Imports could be eliminated and it would be possible to delay the development of coal synthetics and shale until after 2000 if the conservation and demand shift savings were realized. This strategy would place less strain on the environment.

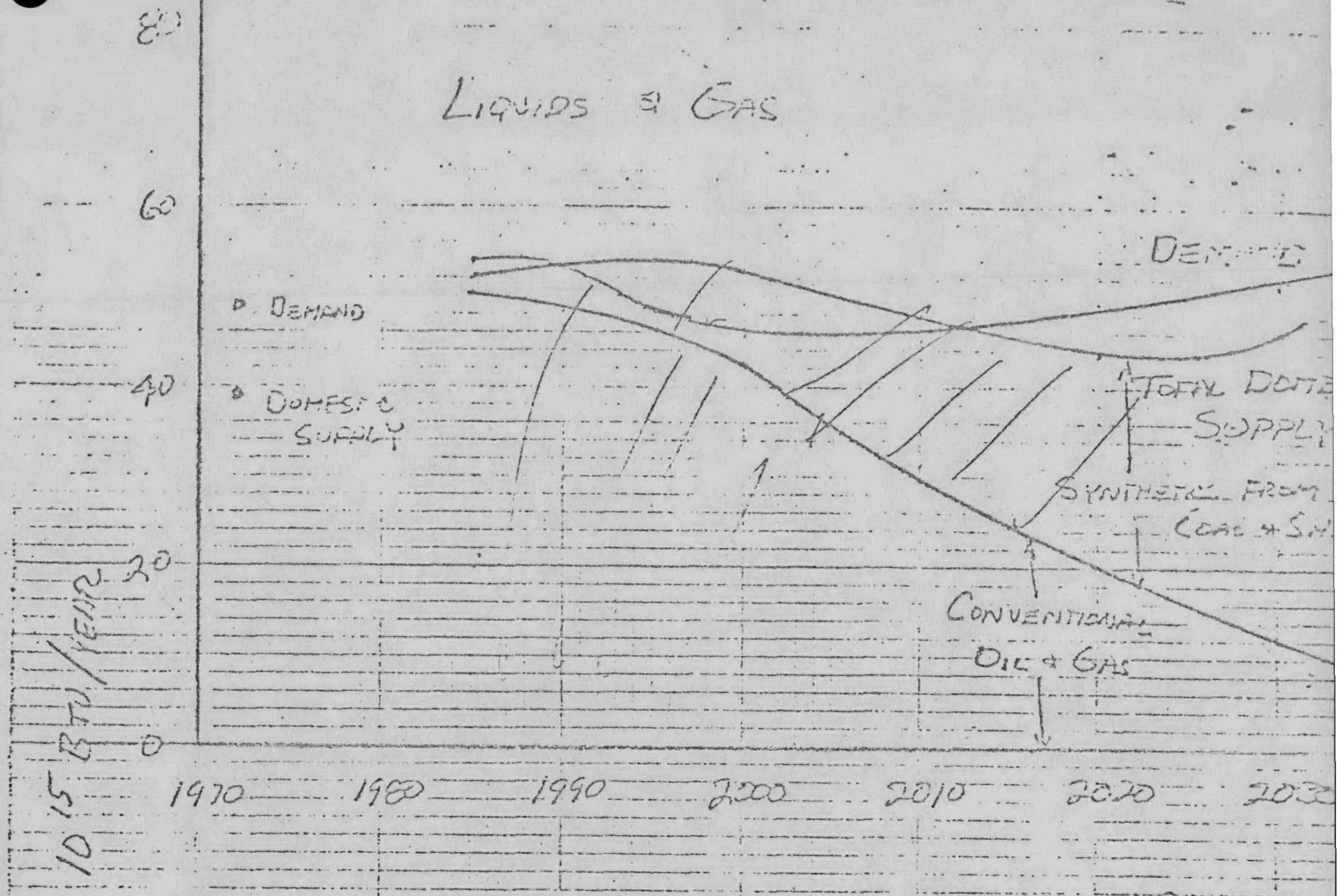
Because demands for electricity are higher in the Conservation-Major Shift Case, new technologies will be required. Geothermal steam and hot water, organic wastes, and eventually, the breeder reactor, fusion, or solar energy are potential new sources for this power while advanced generation technologies offer to increase the efficiency of their conversion to electricity.

BASE CASE SUPPLY AND DEMAND





CONSERVATION WITH MAJOR SHIFT TO ELECTRIC POWER



If we accelerate oil and gas production in the next decade, we could reduce imports quickly. However, unless accelerated exploration reveals a larger resource base than the one used in the long-term model, this benefit will come at the expense of a greater oil and gas shortfall in the early 21st century.

An important lesson of the long-term analysis is that we need to develop new energy consumption technologies that use electricity rather than gas or oil. However, unless new technologies for using electric power economically in transportation and other markets not now served by electricity are developed, electricity will not be able to alleviate our long range supply-demand imbalance. On the other hand, without a shift to electricity, the growing quantities of shale and coal which must be mined and processed will have serious environmental impacts. Thus high priority should be assigned to those R&D programs that will make possible the transition to electricity.

Numerous other combinations of demand and supply options have been evaluated in the long-term analysis. They all show the same basic trends:

- Oil and gas will become increasingly scarce;
- Shale oil and synthetics from coal, while having a limited impact in the near-term, will be needed to make up for the long term shortfall. In any case, such fuels may determine the price of oil and gas late in this century;
- Conservation, especially when combined with shifts to electric power, will become imperative in the long-run;
- Increased reliance on electric power will be necessary, and this implies dependence on nuclear power or other new sources as well as improved conversion technologies.

IV. Energy R&D for the Post Project Independence Period

In the discussion of the short-term R&D options, a recurrent theme is the role of government in accelerating technologies that are already well underway. The question of government involvement is hardly an issue when one considers technologies that are not expected to be available until 1985 or later, especially if large financial outlays are needed for the R&D. Here, except in the most unusual cases, the market cannot be depended upon to take this initiative. We will have controlled fusion, if it is feasible, only if the Government pays for the basic research and development. Thus, a basic objective must be to try to assign priorities to the development of various new technologies likely to meet the long-term projections. R&D becomes increasingly important as the time frame is extended. Much of the Federal energy R&D program now underway, shown in budget breakdowns in Table IX-4, will have little impact until after 1985.

TABLE IX-4

Federal Energy Research & Development Program Budgets

(Millions of Dollars)

OGRAM AREA	Fiscal Year 1973	Program Level Obligations Fiscal Year 1974	Fiscal Year 1975
NSERVATION	32.2	65.0	128.6
. End-use (residential & commercial not including solar)		15.0	27.9
. Improved efficiency (transmission)	2.9	5.0	18.8
. Improved efficiency (conversion)	6.5	15.9	29.8
. Improved efficiency (storage)	1.6	2.9	6.4
. Automotive	7.4	14.2	23.7
. Other transportation	13.8	13.0	22.0
. Industrial			
L, GAS & SHALE	18.7	19.1	41.8
. Production	.3	3.0	17.0
. Resource assessment	4.5	5.0	13.1
Oil shale	3.2	2.3	3.0
Related programs	10.7	8.8	8.7
AL	85.1	164.4	415.5
Mining	1.7	7.5	55.0
Mining health and safety	28.2	27.0	27.7
Direct combustion	1.5	15.9	36.2
Liquefaction	11.0	45.5	108.5
Gasification (high Btu)	32.5	33.0	65.3
Gasification (low Btu)	4.6	21.3	50.7
Synthetic fuels pioneer program			42.1
Resource assessment	1.0	1.2	1.9
Other (including common technology)	4.6	13.0	28.1
IRONMENTAL CONTROL	38.4	65.5	178.5
Near term SO	19.0	39.9	82.0
Advanced SO		4.0	12.0
Other fossil fuel pollutants (including NO_x particulates)	8.8	13.1	[illegible]

PROGRAM AREA	Program Level (Obligations) FY 73	FY 74	FY 75
ENVIRONMENTAL CONTROL cont'd			
d. Thermal pollution	.6	1.5	18.5
e. Automotive emissions	10.0	7.0	9.0
NUCLEAR FISSION	406.5	530.5	724.7
a. LMFBR	253.7	357.3	473.4
b. Other breeders (GCFBR & MSBR)	5.6	4.0	11.0
c. HTGR	7.3	13.8	41.0
d. LWBR	29.5	29.0	21.4
e. Reactor safety research	38.8	48.6	61.2
f. Waste management	3.6	6.2	11.5
g. Uranium enrichment	50.3	57.5	66.0
h. Resource assessment	2.8	3.4	10.4
i. Other (including advanced technology)	14.9	10.7	28.8
NUCLEAR FUSION	74.8	101.1	168.6
a. Magnetic confinements	39.7	57.0	102.3
b. Laser (including military applications)	35.1	44.1	66.3
OTHER	16.5	53.5	157.5
a. Solar (includes building, heating and cooling)	4.0	13.8	50.0
b. Geothermal	4.4	10.9	44.7
c. Systems studies	7.2	17.3	30.0
d. Miscellaneous	.9	11.5	32.8
Total direct energy R&D	672.2	999.1	1815.5
ADDITIONAL FUNDS FOR SUPPORT PROGRAMS			
a. Environmental and health effects research		169.7	303.4
b. Basic research and manpower development		100.8	183.1
Total Support R&D		270.5	486.5
Grand Total	672.2	1269.6	2302.0

Before discussing the major long-range supply technologies now in the National R&D program, we list their "take-off" dates:

Table IX-5
Long-Term Supply Technologies

Category	New Technology	"Take-Off" Date
Synthetics from coal	Advanced systems	1985-1990
Shale	In situ processes	1985
Breeder reactors	LMFBR and other breeders	1990-2000
Fusion	Magnetic and laser	2000
Solar conversion	Electric, hydrogen, bioconversion	1990
Geothermal	Hot dry rocks and offshore	1990

The long-range energy analysis implies that several new supply technologies will be needed in the post-1985 period. During the last 15 years of this century, synthetics from coal and shale oil will be particularly critical in this respect. New sources of electric power not dependent on limited supplies of fossil fuel or uranium will also be needed, especially as we shift toward electricity and away from liquids and gas.

Synthetics from Coal. Our long-range analysis suggests that as much as 25 million barrels per day of shale oil and synthetics could be needed by 2010; even the Conservation-Major Shift Case would require 8 million barrels per day. Whether or not these estimates prove to be correct, it seems clear that a large synthetic fuel industry will be needed in the long-run, and that R&D on such processes must receive a high priority. To the extent that water availability limits shale production, the demand will fall disproportionately on coal.

Coal conversion technology is not new, but it is currently not in commercial use in the United States. As mentioned in Table IX-1, the United States could deploy the German developed Lurgi gasification, Fischer-Tropsch liquefaction, and similar processes during the early 1980's; but the results of the Blueprint analysis suggest that the existing technology should not be widely deployed because it is uneconomical.

For the longer term, more advanced processes being developed offer the promise of increased efficiency and lower costs (reducing the delivered cost by perhaps as much as 20 to 30 percent). Using a traditional R&D approach, it would take until the late 1980's or early 1990's before these technologies were deployed. An accelerated approach could cut 5 to 8 years from that time, so that a rapid buildup of capacities could begin about 1985.

The primary policy issue is not whether to produce synthetic, but when to build demonstration plants using existing technology so we can learn more about large-scale coal conversion. The main Government R&D effort is now focused on development of efficient, low cost technologies. Whether they are deployed in the mid-1980's or significantly later depends on a whole range of government actions involving financial incentives, water, environmental regulations, materials priorities and manpower training in addition to the resolution of technical problems.

Providing the coal to make the synthetics will require coal growth rates on the order of 4 to 6 percent per year well into the 21st century. Therefore, the long-term as well as short-term issue is one of developing and implementing the new coal extraction technology as rapidly as possible.

Oil Shale. Shale oil recovered by conventional technology can play a limited role within the Project Independence time period. Though this technology may be adequate for production levels up to 1 million barrels per day, it may not be suitable for an industry producing 3 to 9 million barrels per day early in the 21st century, because of its requirements for water and impact on the environment. Thus, for the long-term, in situ or underground recovery probably offers the greatest promise, but requires significant additional R&D. As in coal synthetics, the issue is mainly one of timing.

Breeder Reactor. The liquid metal fast reactor (LMFBR) is now the largest project in the federal energy R&D effort. It is backed up by small efforts on alternative breeder concepts. The aim of all of these projects is to develop a system that will use nearly all of the potential energy in uranium and thorium rather than just U^{235} (0.7 percent of natural uranium). Extensive R&D has shown this to be theoretically and technically possible, but the large reactors needed to do it have yet to be built and proven both economic and safe. Several small LMFBR reactors have been built and operated in the United States. A large test reactor is now being completed (Fast Flux Test Facility) and a demonstration plant is being designed. Current plants are for commercial LMFBR's to be in operation in the late 1980's, but it will be another decade or so before they "breed" enough fuel to reduce the demand for uranium ore. Foreign breeder efforts appear to be ahead of this timetable. In fact, the French demonstration breeder (Phenix) has been operating for several months.

The major policy issues involve the pace of the program and management of the demonstration project. A strategy involving conservation with major shifts to electric power, would require a 4 percent per year growth in electricity generation between 1985 and 2000. If the shift were accomplished with less conservation, the growth rate would be much higher. In such cases there would be an urgent need for a new electric generation technology such as the breeder. If electricity use does not increase rapidly, the urgency for these developments is less. Nevertheless, the breeder has other benefits. Once the breeder is developed and in use, the concern for uranium resources and uranium enrichment capacity will largely be eliminated. If R&D costs can be reduced by alternative approaches involving closer cooperation with efforts in other countries, these ought to be investigated seriously.

Fusion. The scientific feasibility of nuclear fusion still awaits demonstration. Fusion, like the breeder, offers the advantage of a virtually limitless fuel supply; it has the further advantage of producing fewer radioactive products than does fission. Two fundamentally different approaches to confinement of the multimillion degree hot plasma are being pursued--magnetic, and inertial (or laser) confinement. Fusion is expected to have no impact before the 21st century.

Fusion is currently funded at a level exceeded only by the breeder and coal conversion, even though its scientific and technical feasibility remain to be shown. While the great gains that a successful fusion reactor would afford suggest that the program should be aggressively pursued, there is a question about its rate of growth in the near term.

Solar Energy. Solar energy and its many related sources, including wind, ocean thermal power and biological conversion are being increasingly viewed by segments of the public as the long-range solution to our energy problems. Solar systems are expected to require large land areas for collection and therefore large capital investments for equipment. Technology exists to recover the energy, but further R&D will be required to find low cost, reliable systems.

Solar heating and cooling could reduce the demand for conventional fuels used in buildings, and was listed as an R&D option for reducing demand in the Household-Commercial Sector during the Project Independence period.

In the longer term solar energy like fusion and the breeder could provide a virtually inexhaustible source of energy. But some form of storage must be developed to provide energy when the sun is not shining or the wind blowing. Even if fusion is successful, a choice may ultimately have to be made between fusion, breeders and solar energy as the primary means of producing electricity. Solar energy R&D has received very little funding in comparison with the nuclear options. In view of its potentially strategic role it is appropriate to spend enough effort on R&D for solar electricity generation to pin down its cost so that educated choices can be made.

Geothermal Energy. A few geothermal plants are now operating around the world, including the dry steam plant at the Geysers in California, but the practical magnitude of our geothermal resource and the technology for economically recovering it are largely unknown at present. We know not only where geothermal sources are, but their temperature and the chemical composition of the geothermal fluids, as well. Accurate predictions of the impact of geothermal energy on the Nation's energy system depend on the ability of research first to find geothermal energy in the form of hot water, steam, or dry rocks and then to develop reliable conversion systems.

The key policy issue is to determine the funding level of applied R&D needed to find and develop geothermal energy sources. In view of the probable ultimate importance of geothermal energy, it seems appropriate to push hard both in mapping potential geothermal reserves and developing conversion technology.

Long-Term Efficiency of Energy Utilization and the Shift to Electricity

In developing a strategy that combines conservation with a shift toward electricity (or other nonfossil fuels), methods for reducing consumption and increasing the efficiency of production of electricity (or other fuels) must play an important role.

Table IX-6 presents the take-off dates for advanced technologies in this category.

Table IX-6
Consumption and Conversion

	"Take-Off" Date
End-Use Efficiencies	
Transport - More efficient heat engines	1990
Non-fossil fueled vehicles (electric, hydrogen, etc.)	1990
Household and commercial - Solar powered total energy system	1990
Industrial - Advanced industrial processes	1990
Transmission, Conversion and Storage	
Large high performance storage devices for electric utilities	1985-90
Cryogenic or superconducting transmission systems	1990
High efficiency closed and combined cycles for Central station electric generation	1990
Large scale electrolytic or thermal production of hydrogen	2000

Development of high performance batteries suitable for automobiles and light duty trucks is important and probably achievable within the next 10 to 20 years. As alternatives to direct use of electric power, hydrogen-fueled vehicles could be developed to enable a shift away from oil. Hydrogen fuels may be particularly appropriate for aircraft. If methods for producing hydrogen from non-fossil fuels at low cost can be developed, then the "hydrogen economy" could compete effectively with increased electrification.

In the residential/commercial and industrial area continuing small improvements will probably provide most of the increases in energy efficiency. However, these improvements typically cover so many different possibilities that we will not specify them. It is important to consider the role of basic process science and research in this area, however, fundamental improvements in the processes and products we use could reduce energy consumption in addition to providing other benefits.

The transmission, conversion and storage of energy form a bridge between supply and consumption. New technologies can help to reduce losses and costs and, therefore, play an important role in the overall R&D program. Long distance underground cryogenic or superconducting systems may be needed in the 1990's to augment alternating and direct current systems as electric use grows and plants are sited far away from consumers. Advanced topping cycles including potassium vapor and gas fired turbines, and magnetohydrodynamics (MHD) could increase the efficiency of electric power generation to over 50 percent, and be introduced in the 1990's. Electricity storage systems such as high energy batteries assume key importance as the energy economy moves away from easily stored fossil fuels. Widespread use of these technologies will probably not occur until after the turn of the century. The need for electric storage systems will depend mainly on our success in finding efficient ways of using electric power evenly throughout the day and year.

On the whole, increasing the efficiency of generating (and transmitting) electricity probably can be achieved with fewer institutional problems than can improvements in consumption efficiency: the former requires a few fairly difficult technical improvements, the latter requires large-scale use of new technologies among many individual consumers. We would, therefore, rank increase in efficiency of generation of electricity as one of the most important aims of our long-term energy R&D.

V. Conclusions

In presenting the conclusions of our analysis, we must make clear the essential uncertainty that underlies all of our projections, especially the long-term ones. It is not possible to predict what the energy demand or resources in the 21st century will be. We do not know what the population or economic growth rate will be at that time, and technological development is always somewhat uncertain. Thus, the basic R&D strategy cannot be considered a unique one: other strategies might be more appropriate if different underlying assumptions had been made with respect to the long-range future.

Nevertheless, we believe that there are certain elements of the R&D strategy that are largely independent of the long-range projections, and the strategies discussed in this chapter largely satisfy this criterion. The R&D strategies are realistic in that they take into account the long lead time required to bring new technologies into widespread use and are responsive to institutional forces.

Impacts Prior to 1985. The most critical technical problems in the Project Independence period involve increasing oil and gas supplies, using energy more efficiently and using available coal and uranium. Research and development can play a secondary, but necessary, role in overcoming these problems.

- Enhanced oil and gas recovery methods offer a large near term payoff in the terms of increased supply and recoverable resource base if the required research, development, and field testing is accelerated.

- Conservation resulting from more efficient consumption of energy will depend primarily on widespread use of existing technology and improved design practices, but R& D aimed at improving consumption technologies and the process of implementing them is needed.

- Greater use of coal will require R&D to solve environmental problems related to its extraction and consumption. Similarly, growing use of nuclear power may be jeopardized unless R&D can resolve the remaining issues of safety and the fuel cycle.

Impact After 1985. The depletion of conventional oil and gas resources dominates the post-1985 period and leads to two fundamental observations:

1. Synthetics from coal and oil shale will be required after 1985 and their use will continue to grow rapidly.

-- Therefore, advanced technologies for producing coal synthetics and shale oil which maximize efficiency and minimize economic and environmental impacts should be developed to meet the post-1985 needs for liquids and gas.

2. The oil and gas shortfall is so large that major shifts in demand, most probably to electric power, as well as strong conservation measures will be needed. To achieve these post 1985 goals, new technologies for using energy more efficiently and for shifting to to electricity instead of oil and gas must be developed.

-- New energy sources not limited by conventional fossil fuel and uranium resources are needed. Technologies, such as the breeder, fusion and solar energy, will take decades to develop and introduce, but it is important to know that we will have one or more of these to support the shift in demand. R&D on these technologies must be pursued as a basis for charting the course of energy development.

THE ROLE OF THE FEDERAL GOVERNMENT IN AUTOMOTIVE R&D

Energy Research and Development Office
Federal Energy Administration
November 6, 1974

CONTENTS

EXECUTIVE SUMMARY

This paper explores the role of the federal government in automotive R&D. Our recommendation is that the government adopt a strong leadership position in this area in order to assure an adequate, but environmentally benign personal transportation system for the nation during the period out to the year 2000 and beyond. The program we envision is one highly interactive with the private sector. It also contains a strong in-house component in order to assure a long term national commitment to the solution of the difficult scientific and technical problems underlying an efficient, non-petroleum based and clean automotive propulsion system. Such an in-house laboratory also provides the sophisticated scientific and technical base necessary for wise government legislation and regulation pertaining to the automotive industry.

The most serious government challenge in the automotive R&D field is to prepare for the time when oil will no longer be availabe as the major fuel base for transportation because of the depletion of the world oil resource. Some estimates predict that decreasing petroleum availability may begin to occur domestically in the late 1980's. This development will require taking a whole new technical approach to automotive propulsion. Two such approaches can be foreseen at this time. One is the use of synthetic fuels from coal and perhaps shale in traditional heat engined vehicles. However, reasonable demand trends for liquid fuels probably cannot be met by realistically projected synthetic fuel availabilities. Thus it will be necessary to develop on the one hand highly efficient propulsion systems for that portion of the transportation system which must rely on liquid hydrocarbon fuels, and to develop on the other hand an entirely new type of transportation mode based on central electricity generation. The electric car is an example of the latter. In addition to these long-term aspects, fuel conservation is also important in the shorter term, where the goal is to conserve petroleum fuels in order to limit the dependence on foreign oil, and to delay the depletion of domestic oil sources. All of these problems must be viewed in the context of the national anti-pollution objectives. Thus, a national program is envisioned which combines the search for highly efficient propulsion systems with minimum environmental impact based on other fuels than petroleum.

Some simple estimates suggest that in order to generate the necessary new technology, a national R&D investment on the order of $150 million per year for the next 25 years or so will be required. Private industry is (prior to the current economic squeeze) investing on the order of one-third of this amount, concentrated in the near-term aspects of development. Furthermore, the integration of the national objectives of energy efficiency, alternatives to petroleum, and minimum environmental impact into a coherent long-term program in R&D requires perspectives and responsibilities well beyond those of the private automobile companies, whose objectives are rooted in the market place. Consequently, we perceive a major government role in automotive R&D with the following goals:

1. Overall guidance of a long term national technical effort to develop propulsion systems of high efficiency based on fuels other than petroleum and of the short-term effort to conserve petroleum. An optimum balance must be achieved between fuel efficiency and environmental effects.

2. Creation of a cooperative R&D climate at the technical working level between government and industry conducive to rapid advancement of the technology.

We believe these goals must be implemented by:

1. A federally financed program directed primarily at the long-range problems of automotive R&D outlined above.

2. Establishment of an integrated in-house automotive research center to ensure the achievement of the national R&D goals through the long term technical commitment and leadership of the government, and to underpin the regulatory and legislative functions of the federal government.

A crucial factor in the development of a successful government role in automotive R&D is the interplay between the private and federal portions of the national program. The government must not only insure that the necessary technical innovations are generated, but it must also insure that the new technology is picked up by the automakers. This process requires a high order of shared planning in the longer term aspects of the work, in order to assure that commercialization will prove feasible in the end. Positive incentives to private industry may also be required. In order to structure the government's program in the most desirable way, considerable preparatory planning will be necessary. We visualize two types of studies which need to be performed. The first serves to guide the detailed technical planning, and should be a study of the entire automotive transportation technology system. The second is to serve as general R&D policy guidance and should be sponsored by the NAE and/or NAS. It should address the questions already partially explored in this paper: the balance between federal and private sector roles, the role and structure of a federal automotive R&D center, the general technical goals of the total national program, and possible federal incentives to the private sector.

I. The National Issues in Automotive R&D

Until very recently, civilian automotive research and development has traditionally been an area to which the federal government has given little attention. The basic reason for this has been that the automotive industry has been vigorous and profitable, and a major participant in American economic growth. However, with the advent of the oil crisis in 1973, automotive efficiency has become a national issue for the simple reason that automobiles are the ultimate users of more than 30 percent of the total national petroleum supply, and the magnitude of this consumption has been growing at a rate of about 4 percent per year. Since current automobiles cannot use any other fuel than gasoline, and since the private automobile must remain for many years the primary form of personal transportation in this country, the impact of this sector on petroleum supply is of overriding importance.

The unique significance of the automotive sector in conserving petroleum has been recognized by two recent landmark actions. The EPA and DOT jointly have submitted to the Congress a study[1/] laying out achievable savings in fuel consumption in the 1980 to 1985 time frame. These savings range from 25 to 40 percent in average miles per gallon over the comparable 1974 rates, depending upon the particular strategy adopted. Second, the automakers have accepted this report as setting the general goals to be achieved voluntarily by them during that period.

However, the automotive issue is not limited to short term actions and marginal conservation measures, because petroleum is a finite resource whose effective end as a major world energy source is in sight. Hence, in the period which is typically required for a research cycle to produce radical propulsion developments, we shall have to develop a viable alternative to the petroleum fueled automobile. The object of this paper is to analyze the government role in

1/ "Potential for Motor Vehicle Fuel Economy Improvement: Report to the Congress," October 24, 1974, Prepared by U. S. Department of Transportation and U. S. Environmental Protection Agency.

automotive R&D, but we shall lay special emphasis on this long term problem, and for this reason we shall work backwards from the long range issues which are not adequately appreciated to the shorter term problems which are currently receiving attention.

1. The Alternatives to Gasoline

The general result of the Project Independence Blueprint analysis, and qualitatively, the result of all other analyses, is that if we are not to import increasingly vast amounts of oil, the American economy must begin to shift from reliance on oil and gas to coal and nuclear power. Our total oil production to 1972 has been about 110 x 10^9 bbls. At that same date, we were estimated to have about 70 x 10^9 bbls. in reserve, and the Geologic Survey estimates that there is from 200 to 400 x 10^9 additional barrels of oil yet undiscovered in the U. S. Using these figures, and the "base case" of Project Blueprint for energy consumption, our petroleum production will peak in the late 1980's. Of course, estimates such as these are subject to error in either direction, and it may be possible to accelerate petroleum production well into the 1990's at the expense of the later years. However, it is clearly prudent policy to begin to develop alternatives for the major modes of petroleum use, in particular transportation, against the probable straitened petroleum picture for the U. S. in the period beginning about 1990.

Present hopes are to increase coal production and nuclear power sufficiently to take up the slack left by the disappearing petroleum and gas. However, if the demand for liquids and gas in the post 1985 period is allowed to continue at its normal rate, a vast requirement for synthetic liquids and gases will result. By 2010, this requirement has been estimated in one scenario conducted by the Institute of Energy Analysis to be of the order to 50 quads per year! This is the equivalent of 25 million bbls. per day of liquids, and even then 10 million bbls. per day are expected to be imported. This production would require a continuous growth of coal production of the order of 6 percent per year from now till the year 2010, and would require a coal production of the order of 3.5 billion tons of coal per year in 2010. At such a rate of increase, the coal resources in the U. S. would be exhausted by about 2050. Thus, even if we switch to coal, considerable conservation will be necessary, and there is the additional question of whether we can produce enough liquids from coal to fuel the transportation fleet after 1990.

The alternative to synthetic fuels is direct ning of coal (presumably in central power stations) and nuclear control power. Thus, a strong shift to electricity is likely to accompany the disappearance of oil and gas.

Further, while these great shifts are occurring, it may turn out that multifuel capability in an engine will be required. For example, an automobile which uses electricity in the city, but liquid fuel between cities may be desirable. And as we get ready for the non-petroleum based economy, a propulsion system which allows a flexible mix of fuels from petroleum and synthetics from coal or shale may be desirable.

Thus in the time span of 15 to 30 years, which is typical of that for R&D to have significant impact, some very basic challenges to the gasoline fueled automobile, and to fossil fueled transportation in general, will have to be faced. In this whole area, the most elementary and important technical feasibility questions remain to be answered, and the most important economic and environmental determinations remain to be made. There is clearly no time to waste in developing a national R&D program which is responsive to these very fundamental challenges.

2. Energy Conservation and Automotive Efficiency

So far as the automobile is concerned, the short-term role of conservation is to alleviate the necessity of filling out the gap between our demands for oil and our domestic supplies with foreign purchases. In the medium term, it staves off the eventual day of reckoning when the ultimate shift from oil becomes necessary, and in the long term, it restrains the overall energy demand from excessive heights.

Automobiles are not only the major national users of petroleum, but the potential for automotive fuel conservation is also large. In more graphic terms, when one plots the energy inefficiencies for the various national energy use sectors, transportation is seen to be the most wasteful (Figure A-1 of Appendix A). The poor showing of automobiles in particular follows from the fact that the fuel economy of American automobiles has experienced a long period of decline, because engine efficiency has been a secondary consideration to performance, comfort, convenience, and more recently, emission control. (See Figure A-3 of Appendix 1.) We refer the reader to the just published DOT-EPA report to Congress for an excellent analysis of the potential for near term savings, and an analysis of the trade-offs of fuel economy against safety and first cost. As we mentioned earlier, in 1980, as much as 60 percent improvement in average miles per gallon is feasible, and by 1985, even further gains are possible. A graph from the DOT-EPA report summarizing their results is reproduced in Figure A-4 of Appendix 1.

The modifications proposed in the DOT-EPA report are by and large within the bounds of present technology. In the medium term, however, after those short-term adjustments have been made, the really hard barriers to improved efficiency appear in terms of the basic inefficiencies inherent in the present form of the gasoline engine powered automobile. These barriers will only yield to extensive and timely R&D, but the potential fuel savings are still enormous. In very general and much oversimplified terms, roughly half of the foreseeable potential savings can be wrought with current technology together with shifts to smaller cars, and another half from new technology. In other words, we may hope to achieve a national average of the order of 20 mpg by going to smaller cars, etc., and of the order of 40 mpg by developing radical new propulsion systems.

Some of the more promising longer term opportunities which have been discussed in the genral literature are:

Development of more efficient power plants
- Establish ultimate limits of gasoline internal combustion engine
- Explore alternatives such as Stirling, turbine, diesel, etc.

Transmission and power train improvements
- Infinite ratio transmission

Improve driving cycle efficiency (Current automobiles are vastly over-powered in comparison with their steady speed requirements, and sustain large losses at partial power due to throttling losses. Stop-and-go is also very wasteful.)
- Variable compression engines
- Hybrid systems
- Regeneration of braking losses

Efficient design for low weight and low drag

3. Environmental Issues

The third major ingredient in the automotive picture is the close interaction of the drive for greater efficiency with the drive for lessened emission. In 1973, the direct costs of emission control were a 10 percent reduction in gasoline economy. When compared with the situation in later years, it is somewhat mixed because GM claims to be able to recoup some of the efficiency losses with its catalytic converters. However, in 1978 the efficiency loss as compared with a similar car without emission constraints is reported to be 30 percent by Ford and 20 percent by GM on a sales weighted average. (This estimate is based on a .4 gm/mi NO_x standard.) The degradation of efficiency due to emission controls varies greatly with the type and size of the engine, but the stringent 1978 standard will pose a severe challenge to any type of internal combustion engine, and will apparently require some degree of efficiency degradation on all. Unfortunately, the gasoline internal combustion engine in its present form is not a very clean engine, and some alternatives appear on paper at least to have a potential for both lower emissions and greater efficiency.

4. Interdependence of Factors

An important principle thus appears in considering the various national issues involved in the automotive scene; namely, that the search for non-petroleum based propulsion systems, and the coupled search for higher efficiency must not be divorced from the search for an environmentally clean system. It is easy to maximize one of these factors without the others. For example, the steam car can be made inherently clean, but present forms of steam are less efficient than the gasoline engine.

A brief mention should be made of safety considerations, since this is also an area of considerable national and federal interest. There is some interplay between safety and fuel consumption, chiefly because of the interplay between weight and safety. However, safety is related more to structural design than to the power train, and can usually be dealt with in a separate way. Thus, we do not discuss it in this paper.

5. Summary

In summary, the switch to a non-petroleum based transportation system, increased inefficiency of automotive energy use, and automotive environmental pollution together compose a set of problems at the very heart of the energy crisis of the greatest national importance. We face the necessity of developing entirely new forms of personal transportation by about 1990 to 2000 because of the depletion of oil reserves, and the automotive area is the one most crucial for decreasing our dependence on foreign oil. Some portions of this issue relate more to the private sector and others more to the government sector, but in their totality they form an issue which must be properly addressed in order for the nation to move through the period to and beyond the turn of the century with an adequate and environmentally benign form of personal transportation. The purpose of this paper is to analyze so far as possible the role of the government in guiding the technical aspects of this process.

II. R&D Programs of Private Industry

Some General Characteristics

We first discuss a general point which is important in developing a philosophy regarding the federal role in automotive R&D. The major technical strength in the major auto companies is in their ability to convert technical ideas into manufactured reality, rather than in generating new technical departures and innovations. Thus, in producing a highly complex mechanical product at a very advanced level of reliability at a minimum cost, in marketing this product in huge numbers and in providing long-term maintenance for it, engineering and technical management skills are displayed at their best in the major American automobile companies. The nature of this remarkable technical achievement, however, creates a tendency toward evolutionary development of the technology rather than frequent technical excursion and experimentation. Indeed, some famous painful experiences have occurred in the market place when innovation was too rapid; e.g., the Chrysler Airflow concept of the 1930's and the Ford safety offerings of the 1950's. Thus, for very good reason the system, though sensitively attuned to the nuances of consumer preferences, is relatively conservative in its response to opportunities for basic changes of technical direction which may be generated by research.

As a result, innovations have come into the American scene by a variety of routes in addition to the automakers. F. Cesario[1/] has noted that auto industry suppliers have been one important route, and that such important inventions as automatic transmissions and power steering were made outside the circle of the auto manufacturers. Also, in fighting for an entrance to the American market, the smaller foreign companies are often able to take larger technical risks and experiment with a wider range of technical alternatives than domestic companies. The result is that many new innovations such as disk brakes, radial tires, stratified charge engines, the small car, etc., have entered the American scene by the foreign car route. In fact, except for the turbine, all the engines which show future promise have been more highly developed in Europe (Diesel, Stirling) and Japan (Electric Propulsion, Stratified Charge (though there may be some argument about stratified charge)), than in the U. S. These comments, of course, are not intended to imply that the automakers themselves are not the source of much new technology, but that innovation is by no means exclusive to them.

[1/] F. Cesario, Transportation Rsh., 8, 373, 1974.

The federal R&D policy should, therefore, complement the obvious strengths of the private sector through policies which encourage the recent trends toward a broader R&D base and decrease the risks of technical innovation, while guiding the longer term developments into directions desirable for the public at large.

Some Financial Data

Because of the intense competition in the automotive market place, private sector automotive R&D plans are very closely held, and it is difficult to form a detailed picture of private R&D investment. Also, the thickness of the proprietary veil varies from company to company, and what some call R&D, others call product development. Thus, our survey of the private sector will suffer from considerable uncertainty.

The largest R&D efforts are organized in GM and Ford, with a much smaller effort at Chrysler. By and large, American Motors relies on GM for its engineering research, and it does no true long range physical research itself.

Figures given in Hearings and Research on Ground Propulsion Systems Sub-committee on Space Science and Applications, February 4-6, 1974, estimating the R&D expenditures by the three auto majors on alternative power systems are given in Table 1. These figures include work on stratified charge.

Table 1

Estimates of R&D Expenditures (1973) for Alternative Automotive Power Systems by the Private Sector

Chrysler	$ 3.5M
Ford	24.5M
GM	$23.7M

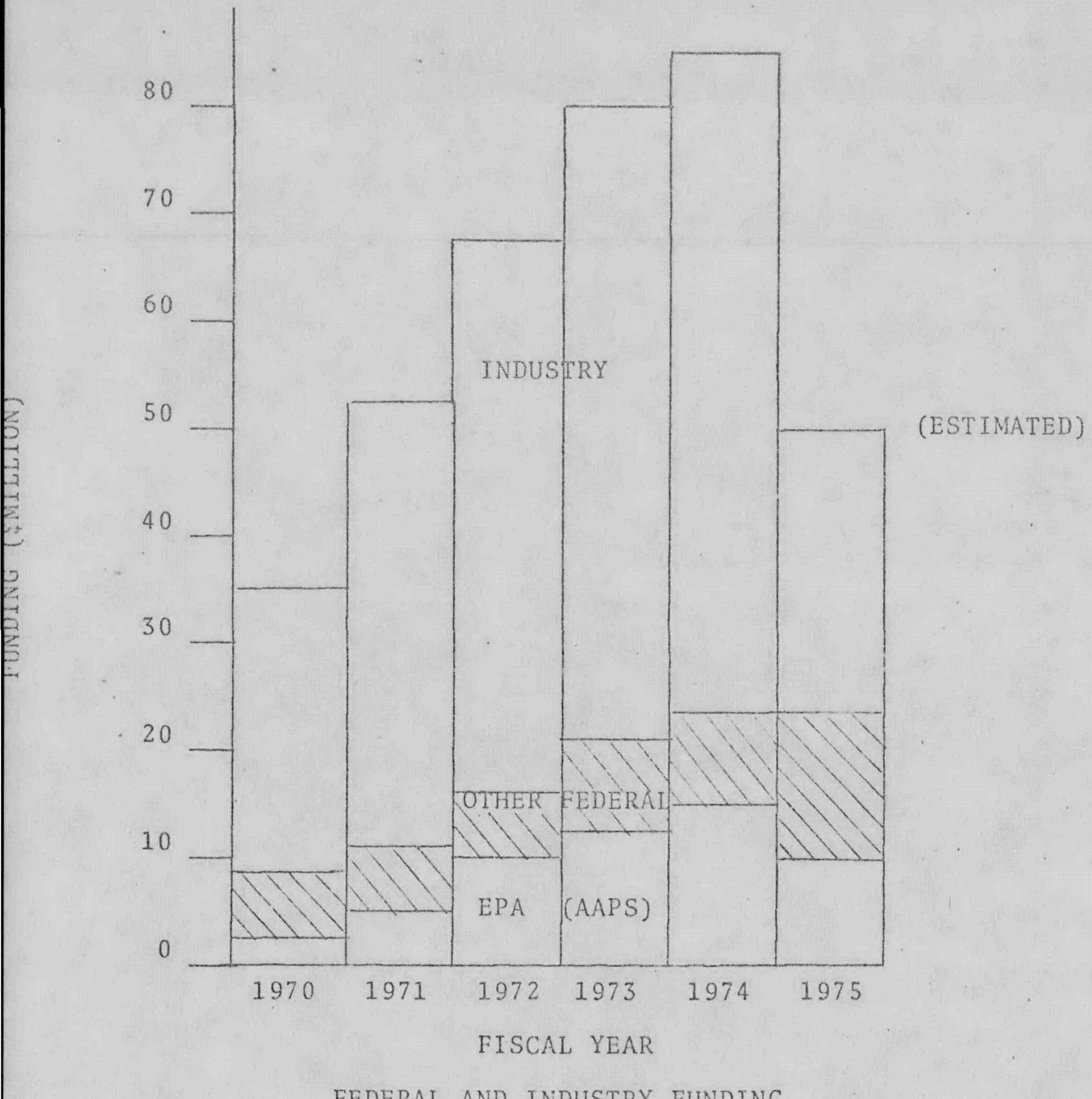
Some figures on the breakdown within GM between various types of research have been given by P. Chenea in a paper presented at a meeting of the GM Public Policy Committee in 1970, and are quoted in Table II.

Table II

R&D Allocations in GM, 1969

Basic Research	$ .6M
Applied Research	33.5M
Development	310.0M
Total	$344.2M

We note the very small fraction devoted to the basic or long-term portion of the spectrum. The EPA has given us some estimates of total automotive R&D which are shown below in the bar-chart, Figure 1, and which show an expected overall sharp decrease in 1975.



FEDERAL AND INDUSTRY FUNDING
OF NEW AUTOMOTIVE POWER SYSTEMS R&D

The Technical Programs

Stratified charge engine work is being pursued at all these companies, but manufacturing decisions are apparently being delayed by uncertainty regarding the future standards for NO_x. In its present form, the stratified charge combustion process is basically a modification of the process occurring in the conventional gasoline internal combustion engine; however, with fuel injection, and higher compression ratios, it can take on many of the characteristics of the diesel, and has the potential for multi-fuel capability.

GM does not rely on government support of its advanced research, and keeps its own council on its long-range strategy. Except for very basic research, GM does not favor government involvement in automotive R&D beyond the minimum necessary to back up government regulatory actions. GM appears to carry on advanced engineering development work across the board in the automotive field. Its engineering establishment is the largest of the automakers, though its basic research has been emphasized only recently. GM has a moderate effort in metallic gas turbines, and work on diesels, as well as other possibilities. For many years, with some government sponsorship, they worked with Philips on developing the Stirling engine, but have given up because of difficulties with the heat exchanger.

Ford believes that the government has an important R&D role in the automotive area because the automakers will not be able to do the complete job by themselves. In particular, Ford has long-range bets on the ceramic turbine and Stirling engine. Ford has present government support of ceramic turbines research by ARPA and will not be able to pursue this development without it. Some of the Ford Stirling engine work is government sponsored. Ford also has work on high temperature sodium-sulfur batteries for energy storage which is being partially sponsored by the government. Ford's pioneering work in this important area was dropped entirely earlier because of pressure from the short-term problems and has only been revived with partial government support.

The most significant program at Chrysler has been the metal turbine program. This work has had a long history at Chrysler, with experimental projects stretching back to the 1950's. Much of this work is now being supported by the EPA.

Some very interesting differences in R&D strategy appear between the three majors. GM has given up on the Stirling engine after many years of experimentation, while Ford has recently begun a major program with serious manufacturing possibilities. Presumably, Ford believes it can lick the cost problem of the heat transfer system. In the matter of turbines, Ford has taken the long view and placed its bets on a quantum jump in operating temperatures with ceramics, while GM and Chrysler are concentrating on (costly and relatively low temperature) metallic turbines with current technology. Current turbines may have a place on trucks where constant speed and long life are the rule, but in the author's opinion, are not likely to achieve widespread use in passenger cars until the higher temperatures and lower costs promised by ceramics become a reality.

Clearly, the differences in approach taken by the major automakers reflect a very healthy state of independent thinking, and this diversity should be fostered by future government actions.

The Technical Prospect

In recent years a number of major impacts on the auto industry have occurred which have left the industry breathless and to a significant degree confused. The first was the challenge of the foreign car makers with the eventual loss of the foreign market and the substantial penetration of domestic market by foreign companies. The second is the sudden entry of the government on the scene, first in safety regulations and then in revolutionary emission regulations. The third is the energy crisis with its fundamental threat to the traditional transportation scene.

Two results are visible from these recent blows. The first is the difficulty the industry is having responding sufficiently quickly to the rapidly changing conditions. The auto industry is geared into a system which requires many years to make a major production change, and these changes are costly in the extreme in terms of capital. In particular, safety has been taken very seriously by the automakers, and much recent attention has been given to the development of safe design principles. But, hardly had large teams been organized to deal in a fundamental way with automobile safety, when emission control became a major issue. In this case, the government legislated technical goals which were well beyond the state-of-the-art, and fundamental changes were required. Timing was an essential element, for although the emission levels called for are probably beyond practicality for the current gasoline internal combustion engine, insufficient time was available to develop a radically different approach. Thus, the add-on catalytic converter was adopted as an interim measure, which is costly in fuel economy. To meet the deadline, tremendous sums of money (about $\$10^9$) have been spent on R&D and testing, and manufacturing commitments have now been made. In the meantime, because the original government standards were not based on clear cut health and environmental bases, as the various costs of meeting these standards have become apparent, some vacillation on the part of the government has led to a very confusing picture for the technical community devoted to automotive R&D. Thus at present, a state reminiscent of Future Shock characterizes automotive R&D policy.

The general situation described has been made much worse by the recent economic downturn in the auto industry. R&D is a form of investment, and with the tremendous investment demands for switching to a larger fraction of small cars in the face of decreased profits, R&D has suffered badly. It is difficult to get data on this point, because of the general industry reluctance to give it, but there is wide admission that R&D spending is down in real terms. EPA's estimate of the situation is shown in Figure 1.

Finally, and of greatest significance to the federal government, we see no important activities in the private sector which face into the longer term problem we have emphasized of switching away from oil based propulsion. Minor work on batteries is going on at Ford and perhaps at GM, but much of it is supported by the federal government. No major attempt to assess and respond to the overall problem of transportation systems based on some combination of synthetic fuels and central electrical power is visible.

III. Required National Funding Level

Having discussed the technical and funding situation in private industry, and before discussing the government programs, it is desirable to establish an idea of the required funding level of the total private and government programs in the light of the general requirements of the national goals in the automotive field. In order to do this, we shall estimate the costs involved in a typical new engine development program. Of course, one program does not cost exactly the same as another, nor take the same amount of time. Nevertheless, there is a general range for these things which we shall present as a basis for our discussion.

Experience in engine development in both the automotive and aircraft fields suggests that it requires in the neighborhood of 15-20 years for the conversion of radical new concepts into manufactured articles. During this period, the costs of the various steps for a single engine program are approximately as shown in Table III.

Thus, the total capital costs involved in a new engine development from start to finish may involve the order of $\$10^9$, and very long times and extensive planning are required. Thus, it is unrealistic to expect more than a very few such complete cycles to occur between now and the year 2000, although additional concepts should be explored through various of the earlier stages.

If we take the 25 years between now and the year 2000, we believe the order of three or four major changes should flow from the R&D of that period. The major effort should be an electric car or similar vehicle. This development in reality may be equivalent to two heat engine developments because of the extensive changes required in the total system. In addition, perhaps one or two additional major heat engine developments should take place - say the turbine and the Stirling engine. One is an internal combustion, and one an external combustion engine, and they are likely to serve somewhat different purposes. In addition, there are R&D issues related to fuel options and other aspects of the vehicle such as transmission, etc. Taking the costs outlined in Table III and spreading these over 25 years, we see that the order of \$150 million per year average during this period will be required to meet the eventual goals. Certainly, the roughly \$50 million in the current national program is inadequate, and as we see, the long-range problem is not addressed at all.

Table III

Development of Typical Engine

	Total Cost	Time Span
Exploratory Development	$10-50M	2-4 years
Concept Selection		
Component Demonstration		
Engine Proto Type		
Engine-vehicle Integration		
Advanced Development	$100-30M	2-6 years
Endurance Tests		
Performance Tests		
Cost Analyses		
Engineering Developing	$200-2,000M	5-8 years

Prospects for Private Industry

On the evidence we have, the automakers will not be able to bear the full burden of sorting out the long-term changes which we as a nation shall be making over the next 25 years in response to these energy and environmental challenges. The reasons are due in the first instance to the nature of the automotive business itself in that it is geared to relatively short-term responses with change occurring primarily in evolutionary patterns. We have already discussed this point, and we have seen that the major government concern as expressed to the automakers is the efficiency picture in the 1980-1985 time frame (DOT-EPA study).

A second reason is the great cost and risk of revolutionary changes. As we see, about $50 million total is currently being spent in the exploratory development stage in private industry on new approaches, and this can only support about two or perhaps three major projects even in the early stages. In point of fact, the majority of the funds is being spent on developing the stratified charge engine, and in the nature of the competitive proprietary situation in the private sector, the private R&D programs will partially overlap one another. Thus, in actuality, this support is underwriting one major program in several places and in addition, several minor ones. With the current economic climate, private industry cannot be expected to increase the 1973 R&D expenditures; and in 1974, our estimates show that this figure has already dropped drastically.

A third and perhaps overriding reason is that the automakers only respond to the market place and government regulation. Hence, the gradual putting together of the technical feasibilities, financial constraints, and political and social desiderata of the long range transportation system is a nexus which far transcends the more parochial interests of the automakers. The government, through regulation, taxes, etc., is already deeply involved in automotive policy, and we discuss next the structure of government R&D which forms a basis for these policy actions.

IV. Government Programs

The DOD

The only long standing government R&D in the automotive field is that of the Army Tank Automotive Command. This group has distinguished itself by its early work on and support of the stratified charge principle, a modification of the gasoline internal combustion engine which is both cleaner and more efficient than its predecessor. Excellent relations exist between the TACOM and the private automakers at the technical level, and generally complementary and constructive roles are played by the two groups in the military field. The good relations enjoyed by the government and private industry in the military field provide an excellent historical background for the consumer field. However, the goals of military and consumer automotive R&D are sufficiently divergent that TACOM should not be made to serve the consumer sector in addition to the military programs. The mutual respect between TACOM and the private automakers on the other hand makes the TACOM an important source of experience and advice while working out the structure of the governmental involvement in civilian automotive R&D.

The AAPS Program

The primary government program in civilian automotive R&D resides in the Alternate Automotive Power Systems program of EPA, now of ERDA. This program was begun in 1970 for the purpose of demonstrating methods of achieving the government's emission goals through alternatives to the standard gasoline engine. This program has been funded as shown in the accompanying table.

Table IV

Funding of AAPS ($ Million)

FY 1971	$ 5.6M
FY 1972	8.5M
FY 1973	9.2M
FY 1974	12.3M
FY 1975	7.2M

In FY 1974 the program was expanded in order to broaden the approach into matters of efficiency and alternate fuels, with the expectation that in in FY 1975 and 1976 these new directions would receive increased funds. Instead, with the uncertainty in the future of AAPS and ERDA, the funding was cut back to its earlier level, and the new directions started will have to be terminated abruptly.

The early program was directed along three paths: 1) stratified charge research, 2) steam engine (Rankine cycle engines), and 3) turbines. The stratified charge work was quite successful, and support has been withdrawn because the major U. S. automakers are close to commercialization of a stratified charge engine, and Honda has introduced a successful example which meets all 1976 emission standards without a catalytic converter. (It does so, however, in a small car!)

The work on steam engines divided into water and organic working fluids on the one hand and turbine and reciprocating drive on the other. Varying success was obtained, and the general point has been demonstrated that Rankine cycle engines can be operated cleanly. Although there is some possibility of using an organic Rankine bottoming cycle on large diesel trucks, the steam engine is not a major contender for automobile propulsion, because of its low efficiency.

The gas turbine program is still being actively pursued and has eventual promise. The current program is aimed at metal turbines which have the disadvantage of being marginal in efficiency and costly to produce. However, some technical basis for the commercialization of metal turbines exists, especially for heavy duty constant speed use as in trucks. Even if the metal turbine does not become commercial, and it proves necessary to wait for the higher temperature, higher potential ceramic turbine, the component work and general background technical work in the metal turbine area will prove of value.

Under its very narrow mandate and limited funding, the Program has been a success. It has in addition served a very useful role in disseminating new information throughout the automotive industry, and in opening up the system significantly to a freer flow of ideas. The Program has now been transferred to ERDA, and its future is tied into the organizational responses and funding futures which will eventually be worked out within ERDA regarding automotive R&D. These issues are, of course, at the heart of this paper.

One of the remaining institutional questions should be mentioned here. At this time, outside of TACOM, no integrated automotive in-house research facility exists. The closest approach to a civilian group is the automotive turbine group organized at NASA-Lewis in support of the AAPS program. In addition to NASA-Lewis, other small groups exist in other laboratories most notably at the Bureau of Mines Bartlesville Laboratory (alternate fuels) and at Sandia and NASA JPL. In addition, electrical energy storage and fuel cell work which is germane to the long term automotive question is going on in other government laboratories, with little visible connection to the automotive issue. We return later to this striking lack of an integrated in-house laboratory in automotive propulsion research relating to the civilian sector.

V. A Cautionary Tale: Emission Control, Costs, and Automotive Efficiency*

We have made a major point about the necessity to include the three goals of alternatives to gasoline, efficiency, and low emissions in one program. In order to demonstrate how necessary these joint goals are, we present a short case study of the government actions of the past several years in emission control to show how badly wrong things can go when the government attempts regulatory actions without due regard to all these factors, and when it does so without a vigorous in-house government technical group which can speak to technical feasibility and the various trade-offs involved.

The 1976 emission goals were imposed by Congress on the basis of desired levels of CO, HC, and NO_X in urban air, and transfer coefficients derived between automobile emission rates and ultimate atmospheric levels. The NO_X level of 0.4 grams/mile is the one most difficult to achieve. The conventional gasoline engine cannot achieve this level without a catalytic converter. The issue posed to the automaker is then whether to opt for a totally different engine, or to take the safer route to the catalytic converter. The answer has been the converter. We will now show that this has been a mistake caused by short lead times, and the necessity to minimize risk.

In the first place, the transfer coefficients originally used are apparently wrong by a factor of perhaps three. Thus, 1.2 grams/mile NO_X would lead to the same atmospheric concentrations as is assumed in the original work, but the original atmospheric standard is itself based on very weak biological evidence, and we do not have an adequate basis for making technical and economic trade-offs on the one side with health damage on the other side.

In order to operate an automobile with a converter, it was thought necessary to decrease the lead content of the fuel to less than about 0.1 grams/gallon, or the life of the catalyst is decreased to an unacceptable level. (See Appendix A, Figure A-11.) There is some current reason to believe this early result is erroneous, but we return to this later. Since tetra ethyl lead is the primary agent by which the octane levels in ordinary gasoline is achieved, to take the lead out is tantamount to lowering the octane level. The story is more complicated than that, because the "clear pool" of gasoline,

[1/] R. K. Proud'homne, American Scientist, 62, 191 (1974).

which is what refineries produce from oil, is only 88.5 octane. ("Regular" gasoline is about 95, and "premium" is about 100 octane.) Other methods besides lead addition can be used to increase the octane ratings, but they are all expensive, and they waste part of the starting crude oil. The current compromise solution is non-leaded product of about 91 octane. In practice, then, about 6 percent more crude oil is used to produce lead-free gasoline than the leaded product. But this waste is not all, because the lower octane and the lowered engine compression ratios (lowered from 9.5 to 8.5 overall aveage) cause lowered engine efficiency. The resulting increased gasoline consumption can be estimated (after saturation to a catalytic converter auto propulsion) to be 16 billion gallons out of a total of a bit over 100 billion gallons. In addition, the capital costs for producing the required lead-free fuel will be an additional $65-80 per year per vehicle in the U. S. The direct costs to the motorist of the 10 billion gallons of wasted gasoline are, then, about an additional $100 per vehicle per year.

On the technical side, the stratified charge engine can nearly meet the NO_X standard without an efficiency loss, and no change in fuel would be required. In a small car, the Honda version meets the 1976 standard without any modification, and Ford proposed that if some relief from the original 0.4 grams/mile were allowed, namely 2 grams/mile (remember the three-fold error in making the original standard) they would convert their entire line to the stratified charge engine.

We will not debate any further the pros and cons of the emission standards. (In the last analysis, the elimination of lead from gasoline may be needed simply because of the biological effect of the lead itself, but this point has been outside the main agreement, and is itself a complex issue.) However, it is clear that a technical solution to the major part of the medium-term problem may exist in other engine types. In retrospect, our national response to this challenge has been a very poor one, costly to manufacturers (about $1 billion to the automakers and to the oil industry) and public alike.

The posture which we sorely need at this date - some 10 years after the auto emission debate started - is a spirit of general partnership between government, consumers, and industry with machinery for working out the objective technical-biological-fuel-tradeoffs on a scientific and technical level before they are taken to the political level for decision. Clearly, we now see what mischief rigid regulatory policies cause in a climate where the automakers alone choose the technical response to ex cathedra government regulation.

The costs and benefits to the automakers in this case have not been the same as the costs and benefits to develop the alternate automobile propulsion systems which will solve the total problem (and penalties for failure!) currently accrue to the automakers and are passed on to the public, while other costs and benefits accrue directly to the public (as well as in this case to the gasoline producers). The automakers, given incomplete guidance from regulations, have choosen the route which minimizes their costs and maximizes their profits, and this route has not been the best one for the public at large. Thus, the government regulatory actions which were intended to reduce air pollution have also forced the adoption of a disadvantageous technology and hindered the development of more lasting and desirable technologies. In defense of the auto makers, it must be said that the short lead time and harsh penalties of the clean air amendments forced them to stick with a technology they were familiar with.

An interesting postlude contributing to an already enormously difficult and frustrating situation has been the discovery that the tetra ethyl lead by itself is apparently not the culprit in the matter of catalyst damage. Very recent Chrysler research indicates the actual culprit is a "scavenger" chemical added with the lead to keep the lead from forming harmful deposits in the cylinder combustion chamber. This work and its consequences are not yet fully accepted, but it may ultimately prove unnecessary to have removed the lead from gasoline in order to prevent damage to the catalytic converter. Unfortunately, this finding if it proves out will have come too late to save much of the enormous capital investment necessary to provide and market the no-lead gasoline, commercially. To appreciate fully this total situation, thus seems to require a very perverse sense of humor.

VI. The Federal Role in Automotive Research

In this section, we present our arguments in a systematic fashion for an expanded role for federal involvement in automotive R&D, integrating as we go the discussions of the previous sections.

In our discussion, we have differentiated between the long term national issues which revolve around the need to replace oil as a fuel altogether, and the short-term issues which relate to conservation and the reduction of oil imports. We have indicated how the short term out to about 1985 is the province of present technology, and that new technology can begin to have impact beyond 1985. Thus, in this paper, the prime center of attention must be the post-1985 period. We see two general technical thrusts in the post-1985 period -- development of new, highly efficient heat engines based on some kind of synthetic fuel (or perhaps a mix of petroleum and synthetics), and a second type of propulsion; such as, the electric car, which is based on central power.

Government involvement is foreseeable in both the short and long term periods, but the form of government involvement in the short term problems is likely to be quite different from its involvement in those of the longer term. Several policy levers are available to the government in furthering the public interest. One lever is fuel price setting. A second is government intervention through taxation and regulation. A third is government development of new technology. These policy categories are not independent of one another; for example, the first two impact on the third, although indirectly, through the public demand for more efficient automobiles.

The central question for federal R&D policy is the extent to which the indirect effects mentioned above will, or will not, provide the long term new technology in sufficient amounts in the required time. In more precise terms, will the private sector react to pressures transmitted through the market with R&D investments of the order outlined in Table III? Secondly, what are the prospects for legislated innovation?

We shall deal quickly with the second question. The legislative route is essentially the approach taken by the government in the emission control area, and which led to the debacle described in Section V. There is no reason to believe that more enlightment would have produced a substantially different result within the confines of that approach. In order to legislate wisely in a highly technical area, the government must be a direct partner in the innovation process, and there is no way to legislate innovation, as it were, "on the cheap." Dealing with this question on a deeper level, the question of governmental incentives is non-trivial and is discussed later.

The ability of the private sector to respond on its own is more subtle, and we shall address it in two ways: First, by demonstrating the "incommensurability" between the public and private interest, and second, by indicating the improbability of the private sector investing in the required large amounts of research over the broad spectrum necessary.

1. Divergence of Public and Private Interest

We have mentioned several times the overriding importance to the nation of facing up to the depletion of oil in the foreseeable future, and to conservation of these limited resources. It is impossible to put a "price" on the national objectives in this area, and very difficult to know if the signals from the market place are being heeded in the research laboratories of the industry. In fact, the price level of gasoline or of automobiles which will be necessary to generate the necessary level of R&D displayed in Table III is probably above that desirable on general economic or political grounds. For example, if the proportion of industry revenues devoted to conservation R&D were constant, the desired level of R&D given in Table III above would require a tripling or quadrupling of industry revenues. Also, the overriding concerns for energy conservation are social rather than private in character, and thus it may well be that the price of gasoline understates its true social cost, and thus, that the price signals of the market do not reflect the true urgency of the problem. Finally, there are strong reasons for supposing that the rate of discount used by automakers in determining the profitability of an investment (e.g., in R&D) are higher than the rate appropriate to social decision making and that this factor as well leads private industry to invest less in automotive R&D than is socially optimal. All of these considerations point to the following: That the overriding national objectives in oil conservation are likely to be inconsistent with the profit maximizing objectives of the industry.

2. The Magnitude of the R&D Task

The primary burden of Sections II and II was to demonstrate that by all present indications, the magnitude of the national R&D challenge is greater than the private sector can address. We have dealt with the magnitude of the required investment and found it to be much larger than present levels in the private sector, and we have indicated the severe financial pressures the industry is now facing. We have dealt with the structure of the industry and shown that their R&D perspective is much too short term in character for the typical industrial operation to do justice to the longer-term problems facing us. We have also indicated that many factors will have to be integrated into a total program: alternate fuels, efficiency, and environmental effects. This spectrum is much too broad for the individual industry member to keep in perspective. Thus, without unforeseen changes in the structure of the industry, there is no real expectations that private industry can deal adequately with the problem of new automotive technology without direct and extensive help and leadership from the government.

3. Federal R&D as a Basis for Regulation

In addition to the major factors listed in 1 and 2 above, there are several additional related policy criteria for government involvement in automotive R&D. The need for federal R&D as a basis for wise regulation is recognized by all parties. This need is also the major point discussed in the case history of Section V, so we shall not belabor it. We note, however, that the proper size of an R&D activity which supports the regulatory function is not trivial, since in order to carry on the type of in-depth interaction across the entire automotive spectrum which is implied in a successful operation leads one to postulate a full scale in-house activity of critical size, with quality comparable to the best private R&D groups. Otherwise, credibility is sacrificed. Secondly, this type of activity cannot be contracted for (unless it be by means similar to the AEC long term contract laboratories).

We note also that the needs of the government for R&D to underlay the regulatory function and the needs to advance the frontiers of technology are entirely complementary. A government program (with an in-house component) which advances the state-of-the-art of automotive technology is also in an excellent position to guide government regulatory activities.

4. Incomplete Appropriability

Automotive R&D at the more basic end of the spectrum shares with all R&D the characteristics that it is not completely appropriable in a single company. The results of such research are usually published in the open literature, where it is diffused far from its source. Thus, combustion research supported and performed at GM becomes of equal value to Ford, and even to some non-automotive industries. Thus, this research will be undersupported in any company relative to the more development related work. On the other hand, it is just such basic research which is at the heart of significant advances in efficiency or emission control. Similar arguments apply to development of an electric car or its equivalent. Thus, the government work should complement private industry by being more weighted toward the fundamental side.

5. R&D as a Function of Company Size

In the automotive case, we see an extreme example of how only the largest companies can afford R&D. GM, being the largest, also spends the most on R&D including engineering. Ford spends nearly as much, but a sharp cutoff after the Big Two. Although Chrysler does some engineering development, it has little or no true research activities, and American Motors is not a participant in R&D. Of perhaps equal importance, except for the support of the government, no research to speak of can go on in the small high technology engineering laboratories. Likewise, no university participation can be expected without government support.

6. Complementarity of Public and Private Sectors

We have noted that the primary government R&D concern is in the longer term, and that the automakers typically concentrate their attention and their funding on relatively close-in or short-term R&D. We have also noted the "jawboning" which is currently underway between Congress and the Administration, on the one side, with the automakers on the other, relative to improvement of gasoline mileage. These pressures are likely to further concentrate the automakers' attention on the period prior to 1985. In this same time frame, if the stratified charge engine should continue to show promise, the private sector is likely to have its R&D hands full in bringing this new development into production. By the same token, less attention is likely to be

...id to the longer term. Clearly, then, the roles of government and private industry are proving to be highly complementary to one another, and we develop this theme of highly interactive complementary roles for the private and public sectors in the next section.

7. Summary: The Federal Role in Automotive R&D

We thus find that a variety of factors dictate a substantial direct role for the federal government in automotive research complementary to the role of the private sector. These roles and responsibilities are:

a. Overall guidance of the long term national technical effort in automotive R&D.

b. Federal financial support and involvement in advancing the frontiers of automotive propulsion technology on a scale sufficient to assure the national goals in automotive transportation.

c. The creation of a cooperative R&D climate between government and private industry for the rapid advancement of automotive propulsion technology for the ultimate public interest.

We end this section with a gambler's note on the asymmetry between the options of full government participation in R&D and no government participation. If the government develops an R&D program in automotive R&D, but circumstances work out such that an accelerated program is not needed, and the private sector is adequate to the technical problems, the only loss is the financial and manpower investment made. If, on the other hand, the government does not inject itself onto the technical scene, and the private sector is inadequate to the task, then the consequences can reach national crisis proportions.

VII. Technical and Institutional Issues: A National R&D Center

In this section, we discuss some technical and institutional issues which emanate from the general federal roles spelled out in Section VI.

Technical Goals

Summarizing the general aims discussed throughout the paper, there are three interrelated general technical goals:

> The primary concern of federal automotive R&D policy is with the long term, post-1985, period. In this long term, the general goal of automotive R&D is to replace the petroleum based automotive fleet with one using more plentiful fuels. Resulting automotive propulsion systems will likely be composed of a mix of synthetic fuel burning heat engines and some form of the electricity using automobile.
>
> Fuel conservation is a major feature in both long and short term time periods. In the short term, the goal is to conserve petroleum based fuels to the maximum possible degree in order to limit the dependence on foreign oil, and to delay the depletion of domestic oil sources. In the longer term, conservation will be necessary in order to place as little stress as possible on the total energy demand, and especially on the demand for synthetic fuels. These goals will require the development of propulsion systems of the highest possible efficiency.
>
> In all aspects of the research program, environmental impacts must be studied and evaluated, and ultimate automotive systems must be optimized relative to pollution generation as well as energy consumption.

The terms "short term" and "long term," of course, have no sharp lines of demarkation, and a transition period characterized by complicated overlapping automotive developments is possible in which such requirements as a multi-fuel capability may be desirable. We reference some previous studies of automotive efficiency by including in Appendix B pertinent portions of the National Academy study on Alternative Power Sources, a study performed by the Eaton Corporation and an EPA study.

We have phrased the technical goals of the program in the rather narrow terms of automotive propulsion; however, there is a valid question as to how broadly to draw the mandate of the governmental program. In the detailed planning which should precede the initiation of the program, this question should be addressed directly. Two related areas which probably should be included in the program eventually are those materials and structural design aspects of vehicles which impinge on fuel consumption. Another candidate for eventual inclusion is propulsion systems of other forms of transportation. A good case can be made for including propulsion systems of buses, trucks, etc., because of their technically similar characteristics, and because they are also all based on petroleum-derived fuels. However, the point is a general one. Many aspects of the total transportation question are highly interrelated, and the question should be addressed whether the automotive R&D program should not in fact be a general transportation R&D program. In our view, however, although this may be an ultimate goal, the early program development should emphasize the automotive aspects.

For the sake of concreteness, we list below some examples of what in our view are the sorts of technical activity which are needed in the government program.

1. Alternate Fuels for Mobile Use
   Research on fuels should emphasize methods for achieving high volumetric and mass energy density, and should include systems studies on economic and other impacts of switching to alternate forms of fuel. Research must also include electrical energy and other storage, and electrochemical systems.

2. Combustion
   We have only a limited knowledge of the details of the combustion process (including pollutant formation) in both cyclic and heterogeneous combustion.

3. Heat Transfer
   In all heat engines, numerous problems of heat transfer arise both within the engine and its air environment. A better understanding of these phenomena could lead to improved engines.

4. Materials
   In many cases the practical implementation of theoretically desirable heat engine systems is limited by availability of suitable materials at a reasonable cost.

5. Vehicle Aerodynamics
   Any information that will result in reduced drag will obviously conserve transportation energy.

In view of the desirable level of private plus government research in a total national program, which we have placed at about $150 million annually, we believe an appropriate initial funding level for the federal program is $50 million per year with about half in-house and half in contracts. This would yield a national level of something more than $100 million per year, which is still well below the $150 million level. In subsequent years, efforts should be made to bring the total level to the optimum, but much of this increase should be in and by the private sector.

Institutional Issues: General

From the earlier discussion, it is clear that we view the complementary relationship between government and industry in automotive R&D to be crucial. This principle is implicit in our treatment in Section I of the automotive R&D problem as a national problem which possesses private sector and public sector aspects. It was also emphasized in Sections II and VI that the natural time span for industrial sponsored work is in the short term, and that the major government concern lies in the long term. These two thrusts must be closely tied together. We have also highlighted the problems which arise when the government deals with the automotive industry in an adversary mode insofar as the development of new technical approaches are concerned. The prospects are for increased government regulation and "jawboning" of the automotive industry on the subject of efficiency. In view of this liklihood, government-industry cooperation must occur at the technical level at all stages of regulatory and standards setting processes in order to prevent the sort of counter-productive results which we reviewed in Section III, and to ensure a flexible regulatory system which can respond to new technical possibilities.

A part of the government-industry interface is the matter of industrial incentives for innovation. To a large extent, if the overall technical program is a cooperative affair between government and industry, with an appropriate division of labor between industry and government, and if the planning of the program has included all the affected parties, then a major portion of the stimulation process will have been accomplished. In the proposals of this section, we discuss these aspects at some legth. Possibilities for additional, more direct actions by the government in terms of incentives for industry should receive more careful study than we have been able to give here.

Over and beyond the regulatory R&D aspects is the necessity for the government to provide technical leadership to the entire national effort, both public and private. Again, in order for this process to function, a spirit of technical cooperation at the working level in goal setting and in division of labor between public and private sectors is essential.

A related government responsibility is to open up the R&D system significantly. We have learned in this country how important the fast moving small high technology companies and the universities can be when the nation is faced with a major technological challenge. To date, these very important resources have not been tapped to help solve our automotive R&D problems to any significant extent, and one of the obvious aims of a government effort should be the stimulation of these groups to develop programs in automotive R&D. When this is done, of course, the total private sector complexity increases, and the task of insuring the technology transfer from area to area becomes more involved.

National Automotive R&D Center: A Proposal

We see the automotive question as posing two primary questions to the government. The first is whether to develop a major involvement in the area, and the second is the mode of that involvement. We believe that a positive decision on the first question requires a decision in the second to develop an in-house competence in automotive R&D.

There are two major reasons why a national automotive R&D center is required. The first is the need to serve as a base for the regulatory function. As we have said several times, the regulatory function cannot operate in a vacuum and must be based on a high quality in-house technical research competence. Advice of this sort cannot be bought on the outside because non-government regulatory advice is never entirely credible, and private sources are not always available in the form and quality required. There is thus no substitute for a dedicated in-house team possessing impeccable technical and scientific credentials to which the government can always turn for advice.

However, a high quality technical research organization has its own requirements for care and feeding, not the least of which is critical size. It is usually impossible to justify the expense of such an establishment purely in its role in the regulatory area, and, in fact, research teams which are restricted to this purely defensive technical role often prove technically sterile. Thus, if we can combine the regulatory support function with a function to operate more offensively in the development of new technical approaches to automotive propulsion, then the existence of an in-house R&D center is more fully justified.

The later justification for such a center follows naturally from our entire discussion of the long-term character of the automotive R&D problem, and with the need for the federal government to become involved in technical depth with the solutions in this area. In effect, we maintain that the automotive R&D problem is one of such magnitude and duration for the nation that the program must become institutionalized for the long pull in a way that only a dedicated laboratory center can ensure. Furthermore, we have emphasized the tendency of the private industrial R&D establishment to concentrate on short term product development and engineering. Providing facilities for carrying on the longer ranged research would be best accomplished by means of a Federal R&D Center.

We see no problem of conflict of goals between an in-house center and the private R&D establishment, because of the complementary roles played by the private R&D laboratories and by the Federal R&D Center. Mechanisms for increasing the effectiveness of the total system, however, are desired. Two main avenues exist for assisting this process. One is to enhance the interaction between the Federal R&D Center and the private sector by giving the Federal R&D Center contracting authority. Then the programs under active pursuit at the center will also be reflected in the private sector, and the results of the federally sponsored work will be disseminated more readily. Second, the R&D center should have associated with it a highly developed advisory panel system similar to those associated with the NASA laboratories. If the programs of the Federal R&D Center are planned as a result of extensive consultation with the private sector, then the govenrment's program becomes in consequence, a truly national effort. Also, the Federal R&D Center can be expected in the course of its work to develop a unique collection of experimental and testing facilities which can be made available in suitable ways to private research groups. Indeed, through this mechanism of sharing its facilities, the center should serve as an important point of interchange between the major portions of the automotive research community.

We have discussed the question of the federal role in automotive R&D with the Committee on Conservation of Energy and Other Material Resources of the Society of Automotive Engineers. They have unanimously agreed on the need for a government program in automotive R&D with emphasis on the longer ranged aspects of the problem, and also on the desirability for an in-house government laboratory. They, in fact, originally suggested to us the suitability of the old NACA model for automotive R&D support. In addition, they have recommended that the NASA-Lewis Laboratory serve as the nucleus for starting the Federal R&D Center. NASA-Lewis has a long history in combustion research, and its facilities and expertise in turbine research are outstanding. They are, in addition, already serving an important role within the AAPS Program in the automotive turbine area, and their location near Detroit is desirable. Furthermore, the NASA model for interacting with industry fits the desired automotive R&D approach. We concur that if the appropriate interagency arrangements can be made, that the NASA-Lewis group would be an excellent site for the new automotive effort. However, alternative candidates might also be evaluated.

The Need for Further Study

The first step in the inauguration of a substantial federal automotive R&D program is a major planning effort. We see the need for two separate studies to be carried on by two different groups, and to serve somewhat different purposes. The first study should be a study of the entire automotive transporation system performed in order to lay the groundwork for establishing the details and timing of the federal program. The study should assess the various time scales for innovation, the private sector financial and investment constraints, and the technical prospects for achieving various short and long-term goals in terms of specific accomplishments. We have not attempted to transgress with any detail into this area ourselves simply because of the magnitude of the technical assessments involved. The study should be aimed at the total national automotive scene so that a general division of labor can be worked out between the private and federal sectors. Because of the crucial role to be played by the private sector, all elements of the public and private technical automotive community should be involved.

The second study should focus on the broad technical and institutional aspects of the problem, and is viewed as general R&D policy guidance. We recommend that the second study be performed by the NAS-NAE individually or in some combination. We believe this study should address the various topics of this paper: automotive R&D as a necessary ingredient in the nation's energy conservation program; the broad institutional questions of how the technology is best generated and disseminated, and the roles to be played by the various actors in the process; more specifically, the desirability and role of a Federal R&D Center, and how it should operate; the general technical goals; and federal incentives to the private sector. The value of this study would consist in far more than its recommendations and its sorting out of the issues. In actuality, it would be the first step in exploring the new level of government-private sector cooperation in the area of automotive R&D which we have discussed at such length. The study should for this reason involve just those groups which should continue to function as part of the government-private sector team in guiding the generation of a national effort. The study should be sponsored on the government side by ERDA and include representation from NASA, FEA, DOT, CEQ (or EPA), and DOD. The private sector could best start with the SAE and its Energy Committee. In this connection, the sponsorship by NAS/NAE should not necessarily be considered as a permanent arrangement, but merely as a vehicle for gathering the appropriate parties together.

VIII. Summary Conclusions and Recommendations

1. The automotive sector is a crucial one for government action in dealing with the energy crisis, posing substantial government R&D issues. An expanded role for the government in automotive R&D will be necessary in order to provide the technical capability for replacing the current petroleum fueled automotive transportation by one based on more plentiful fuels, and for conserving all forms of fossil fuel through more efficient but clean propulsion systems.

2. An in-house research facility is proposed to provide direct long term government involvement and leadership in the technical program, and to serve as a base for government regulatory functions.

3. An essential characteristic of the total national R&D program is the interlocking of public and private roles. As a result, a high degree of public and private cooperation at the technical working level, and shared planning at the management level will be required.

4. An estimated total national budget on the order of $150 million per year will be required at steady state. Federal funding is recommended to start at $50 million split about evenly between in-house work and external contracts.

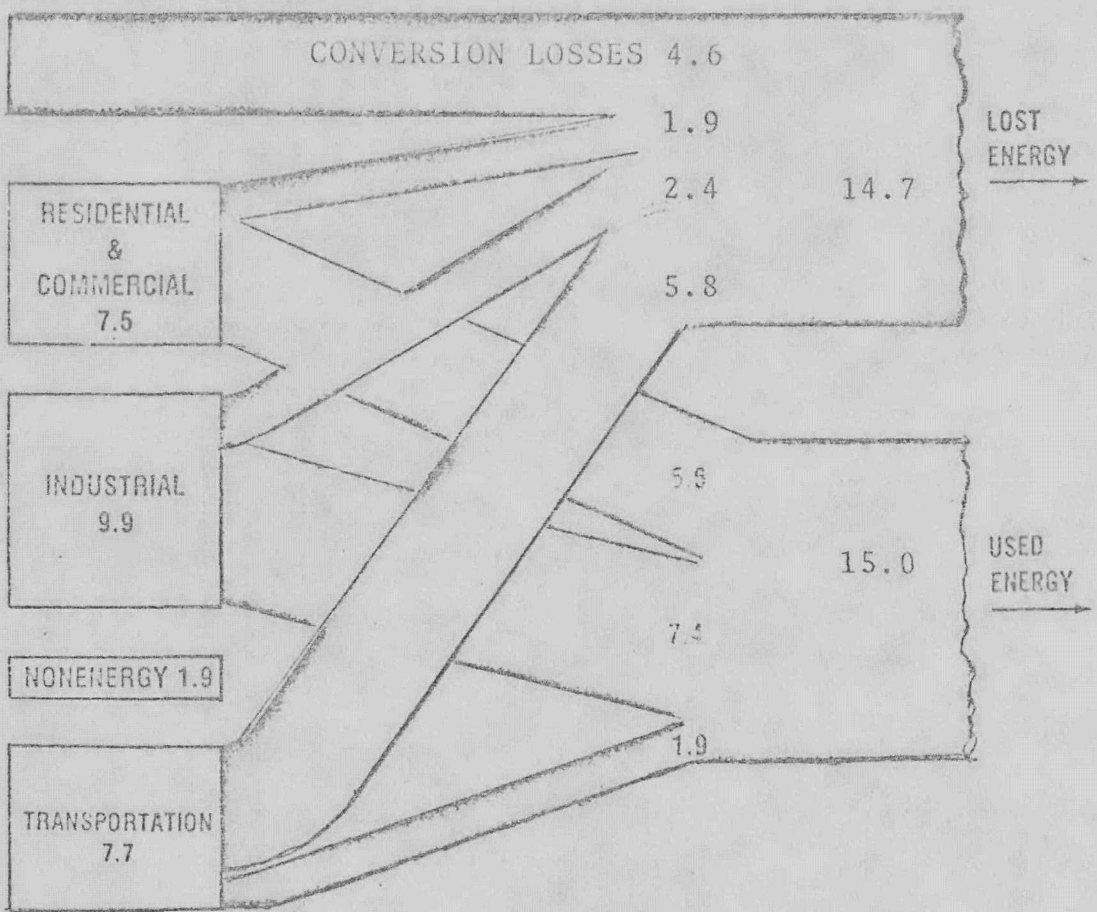
5. In order to initiate the program, two major studies are proposed. One should be a study of the total automotive technology system and should serve as a guide for detailed technical program planning. The second should be performed by NAE and/or NAS and address the broad technical and institutional questions explored in a preliminary way in this paper, and should serve as general R&D guidance for the total national program.

APPENDIX A

We include here some graphs and tables relating to gasoline consumption rates, etc., which are referred to in the text.

NATIONAL ENERGY PROJECT:

U. S. VS. LOSSES IN ENERGY 1970

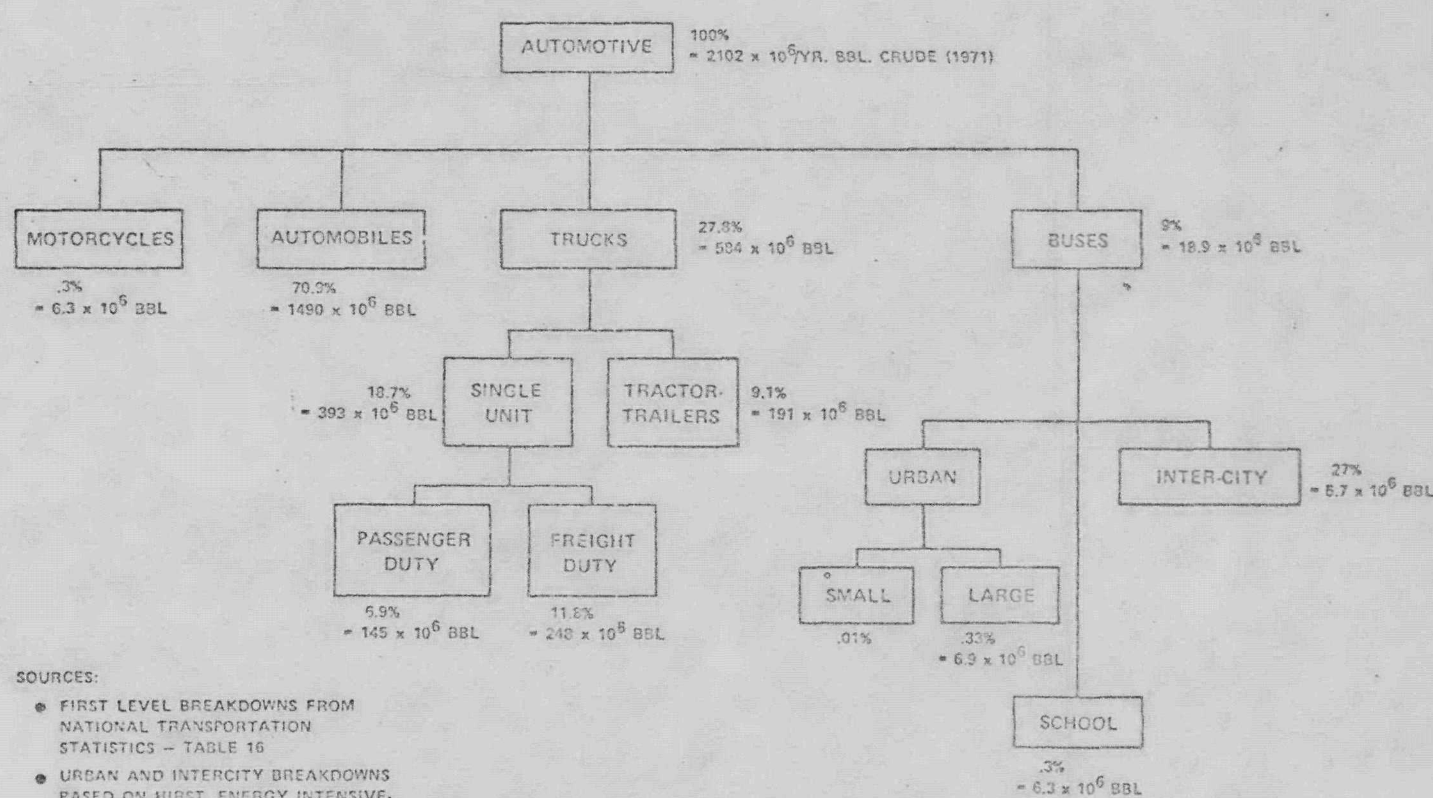


(UNITS: MILLION BBLS/DAY OIL EQUIVALENT)

"Understanding the "National Energy Dilemma," The Center for Strategic and International Studies, Georgetown University

FIGURE A-1

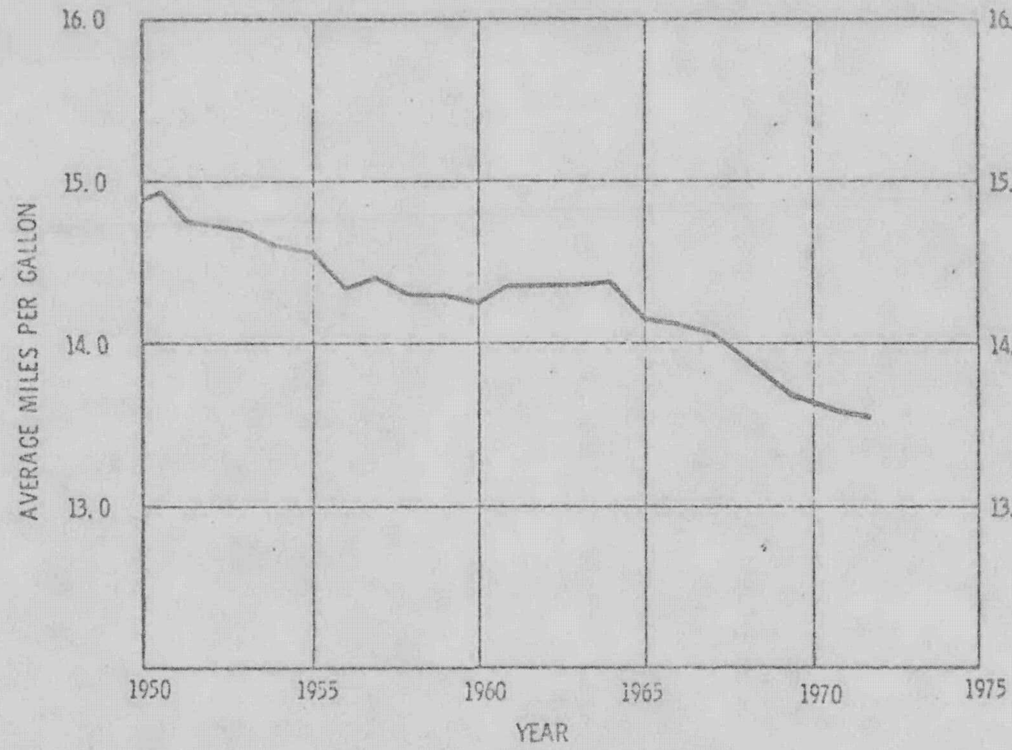
TRANSPORTATION FUEL USAGE



SOURCES:

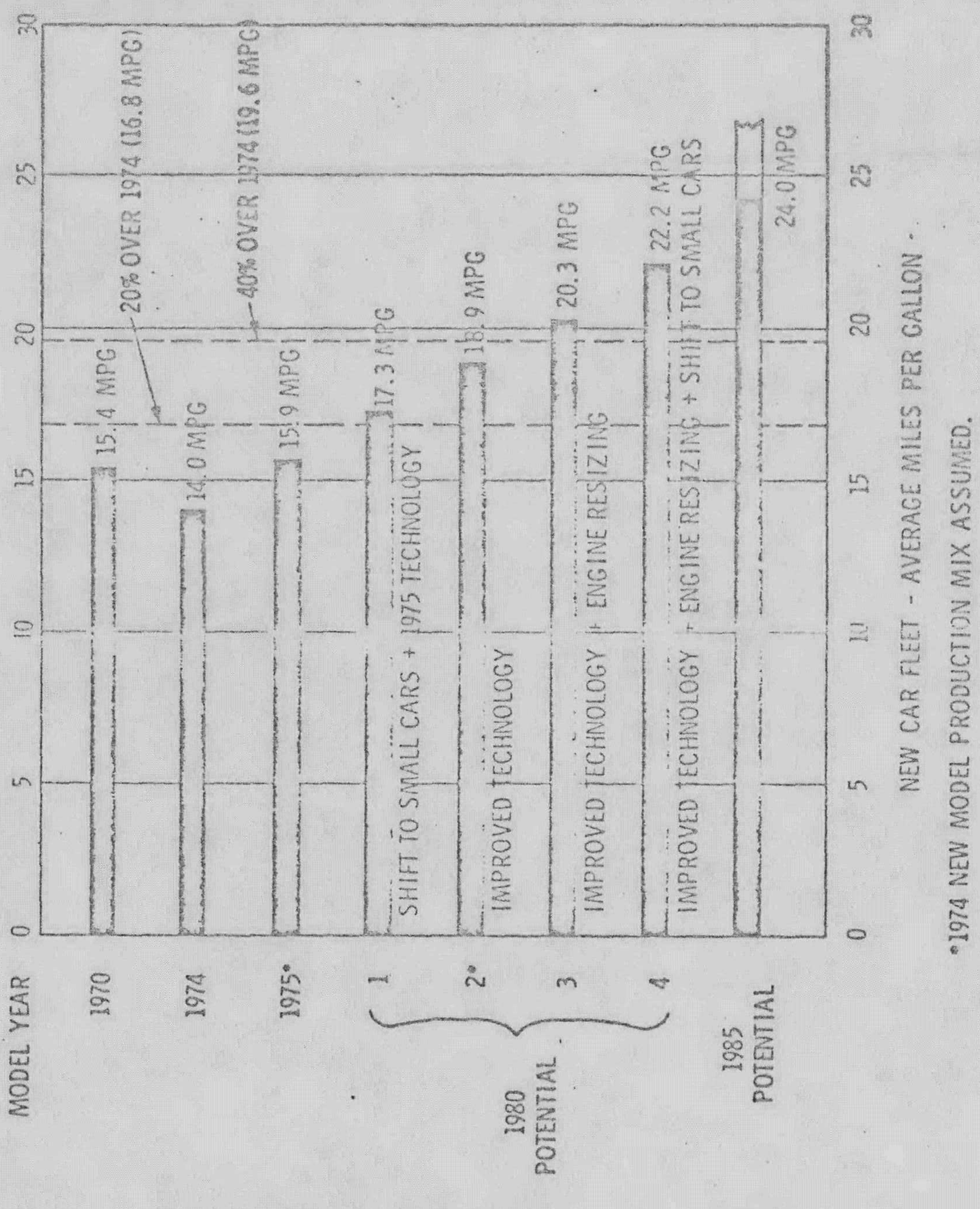
- FIRST LEVEL BREAKDOWNS FROM NATIONAL TRANSPORTATION STATISTICS – TABLE 16
- URBAN AND INTERCITY BREAKDOWNS BASED ON HIRST, ENERGY INTENSIVENESS OF PASSENGER & FREIGHT TRANSPORT MODES (1970)
- PASSENGER AND FREIGHT SINGLE UNITS BASED ON SURVEY OF PRIVATE TRIP MODES, NATIONAL PERSONAL TRANSPORTATION SURVEY (1970)

FIGURE A-2



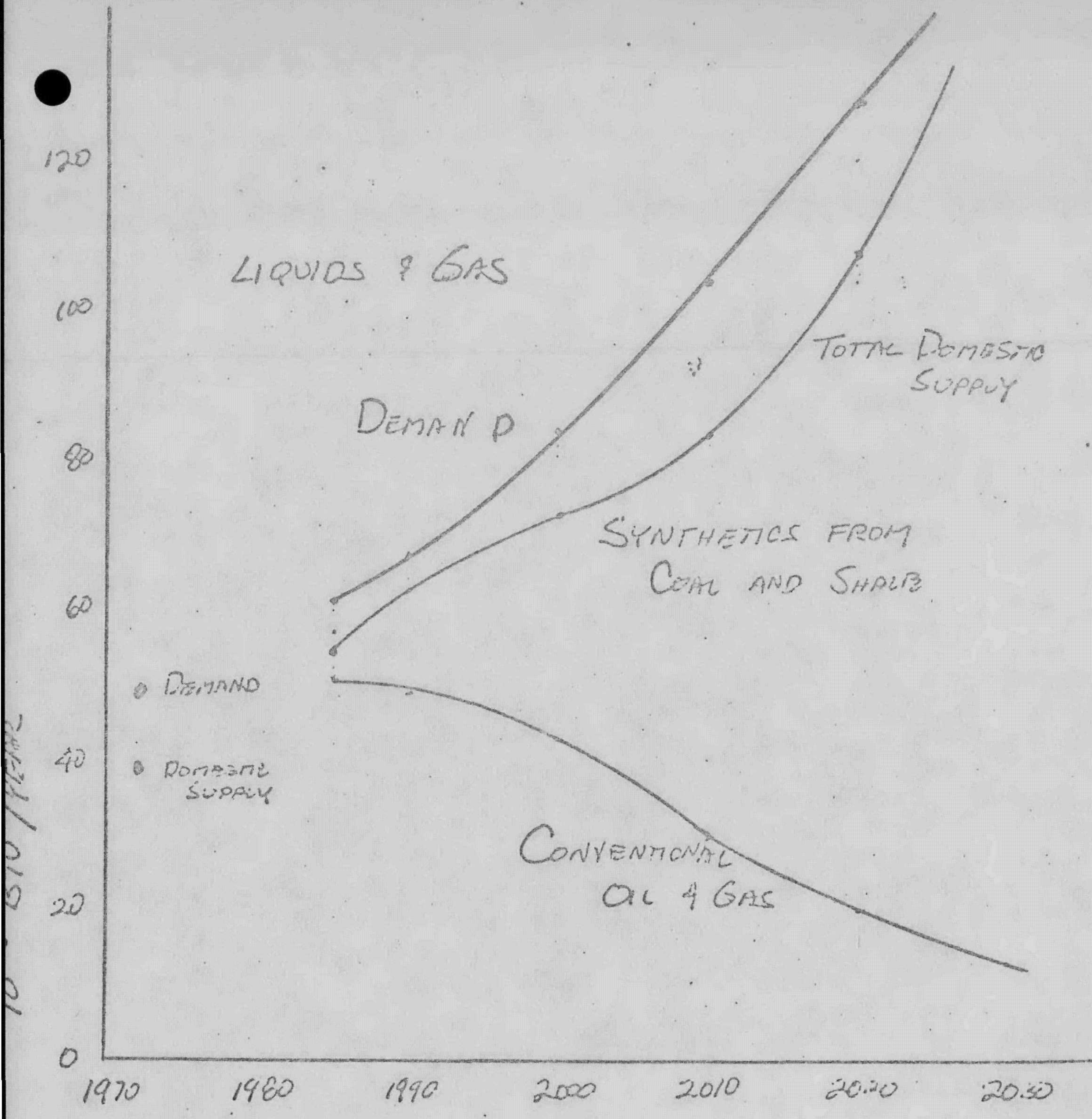
AVERAGE FUEL ECONOMY (MPG) OF U. S. PASSENGER CAR FLEET 1955-1972. DOT-EPA STUDY, "POTENTIAL FOR MOTOR VEHICLE FUEL ECONOMY IMPROVEMENT," OCTOBER 24, 1974.

FIGURE A-3



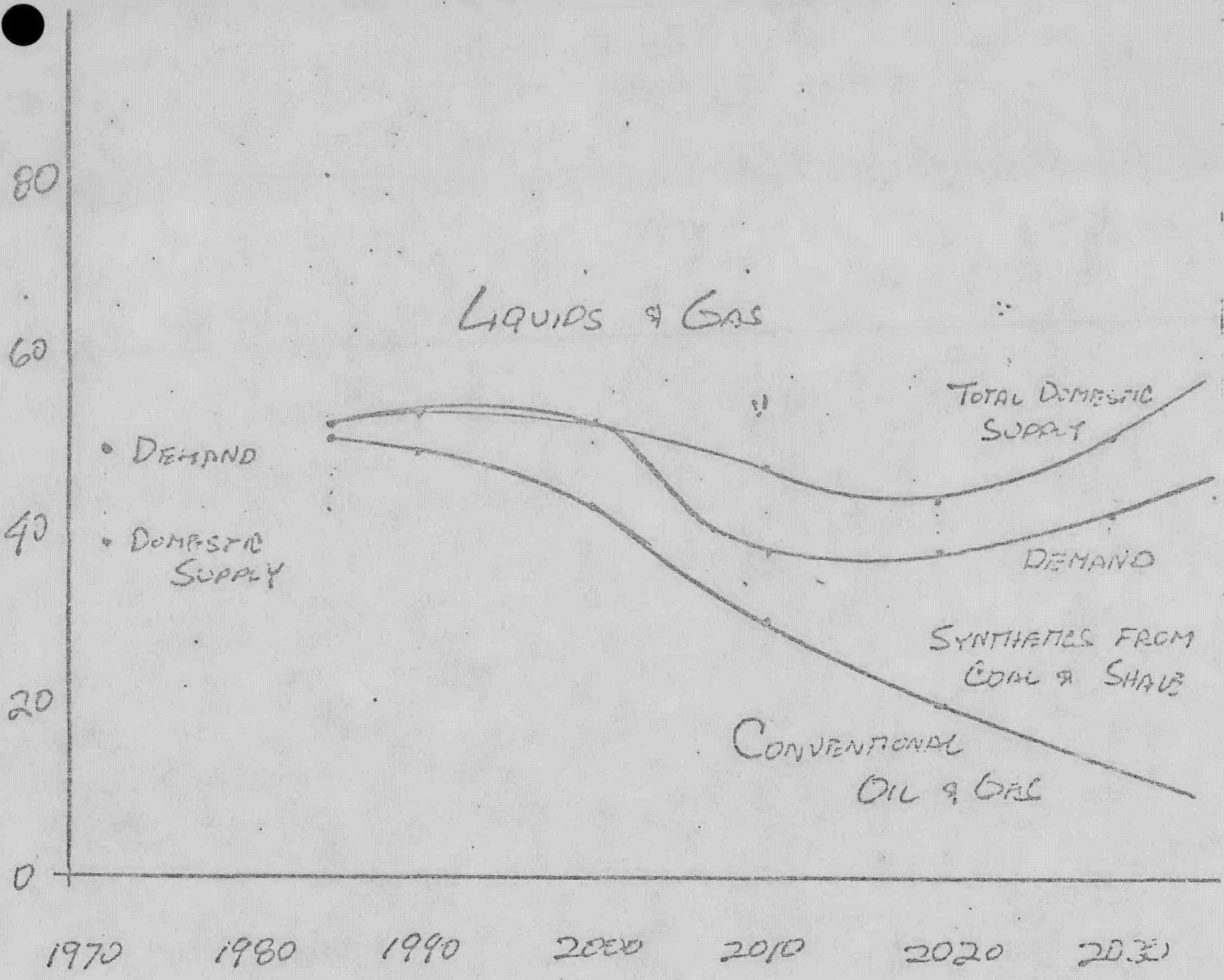
POTENTIAL FOR AUTOMOTIVE FUEL ECONOMY IMPROVEMENT. SUMMARY FINDINGS OF DOT-EPA STUDY, "POTENTIAL FOR MOTOR VEHICLE FUEL ECONOMY IMPROVEMENTS," OCTOBER 24, 1974.

FIGURE A-4



PROJECT INDEPENDENCE BLUEPRINT STUDY OF LONG-TERM LIQUIDS AND GAS DEMAND AND SUPPLY. BASE CASE. ESTIMATES MADE BY ENERGY RESEARCH INSTITUTE, OAK RIDGE, TENNESSEE.

FIGURE A-5



PROJECT INDEPENDENCE BLUEPRINT STUDY OF LONG-TERM LIQUIDS AND GAS SUPPLY AND DEMAND. CONSERVATION-WITH-SHIFT-TO-ELECTRIC-POWER CASE. ESTIMATES MADE BY ENERGY RESEARCH INSTITUTE, OAK RIDGE, TENNESSEE.

FIGURE A-6

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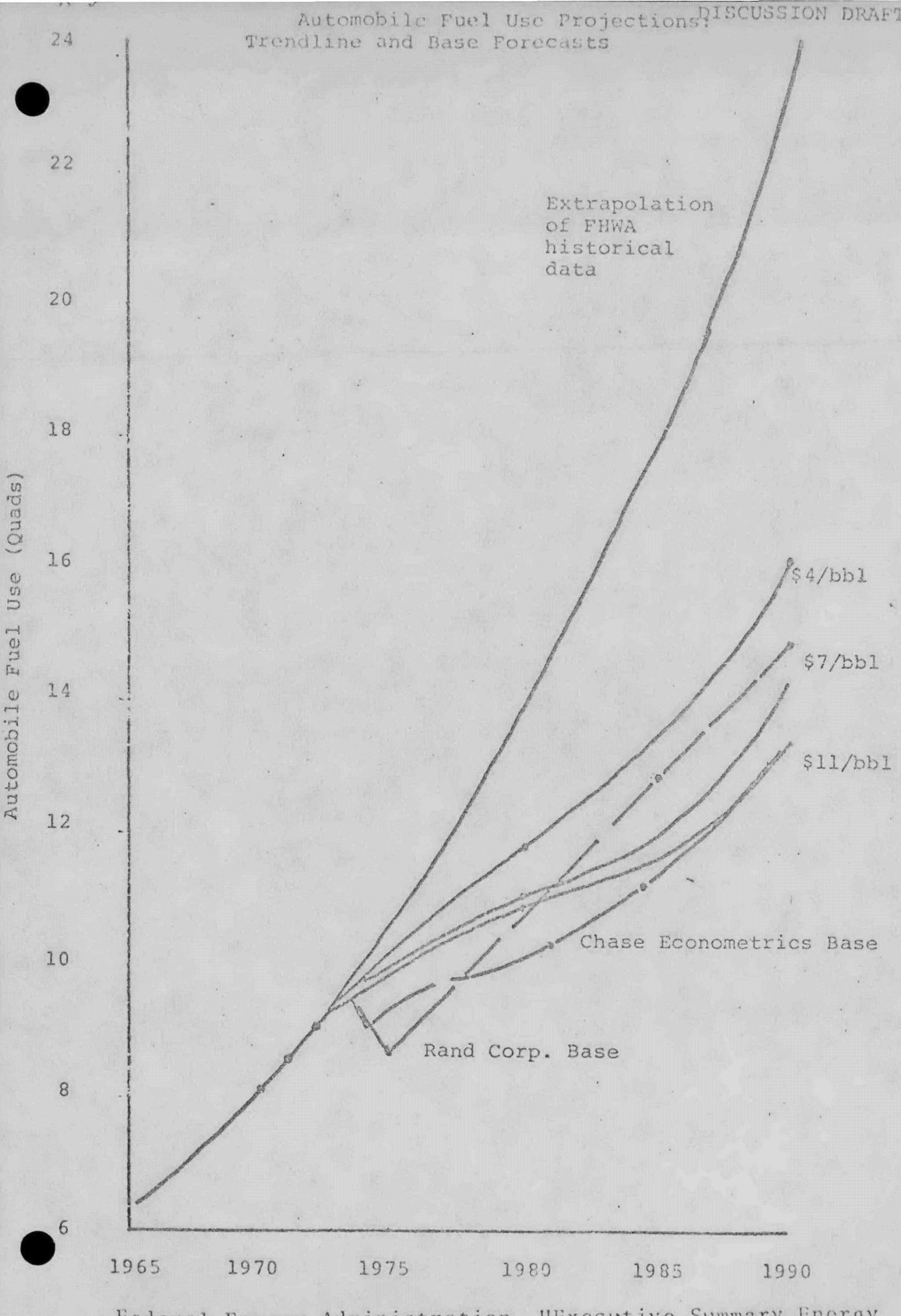
from
Original Document



Federal Energy Administration, "Executive Summary Energy Conservation: A White Paper"

FIGURE A-8

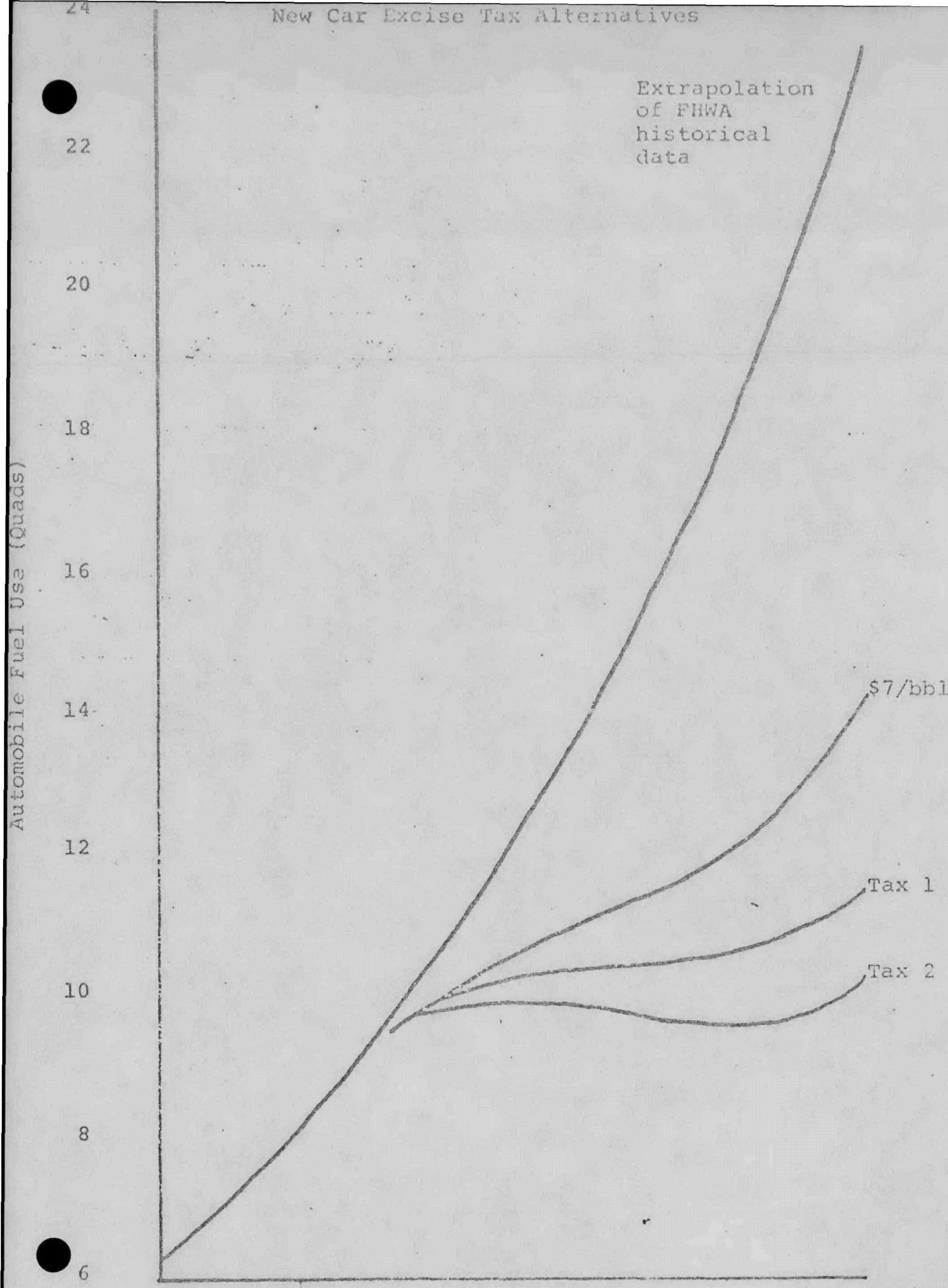
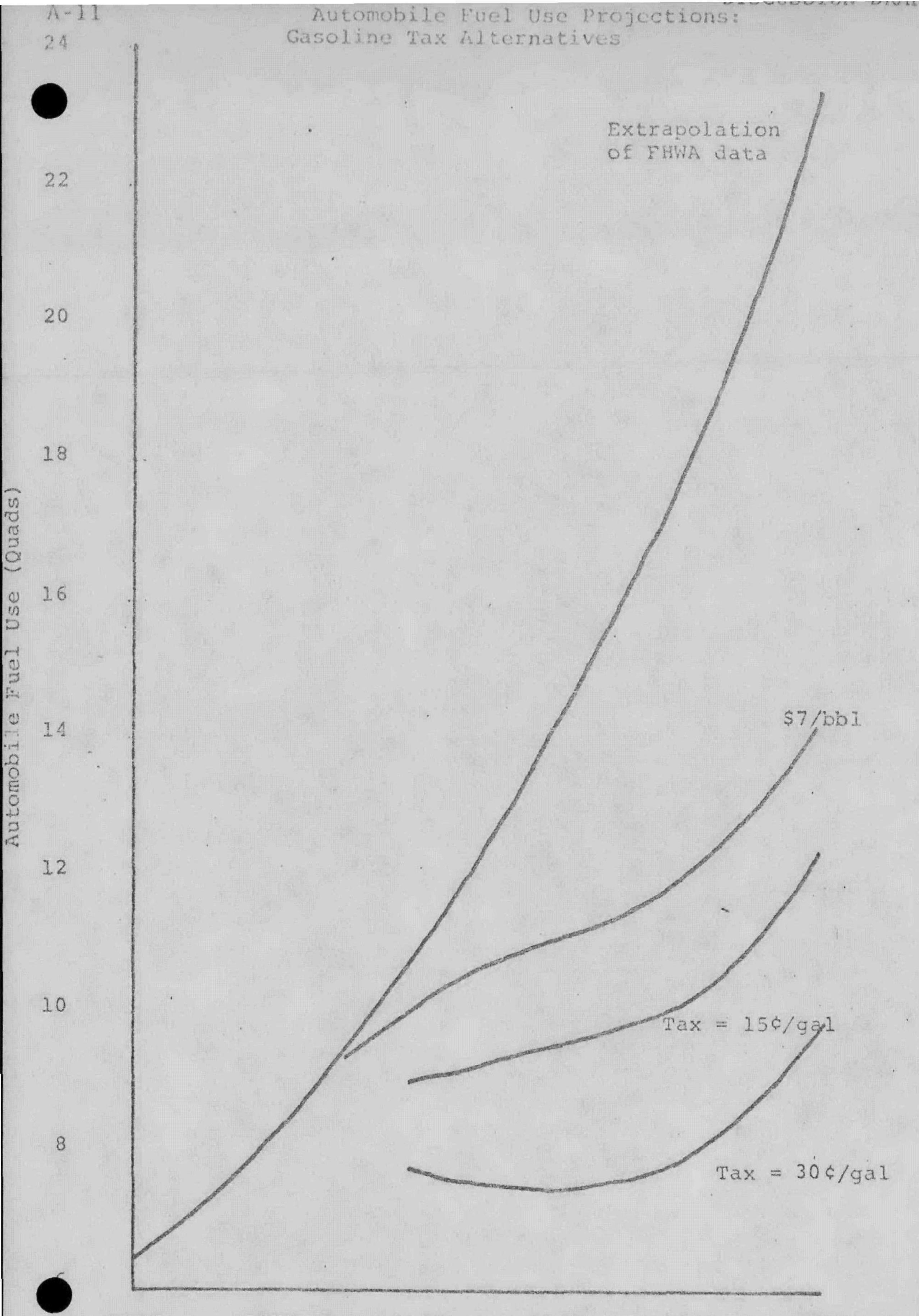

New Car Excise Tax Alternatives
Automobile Fuel Use (Quads)
24
22
20
18
16
14
12
10
8
6
1965
1970
1975
1980
1985
1990
Extrapolation of FHWA historical data
$7/bbl
Tax 1
Tax 2

FIGURE A-9



Federal Energy Administration, "Executive Summary Energy Conservation: A White Paper"

FIGURE A-10

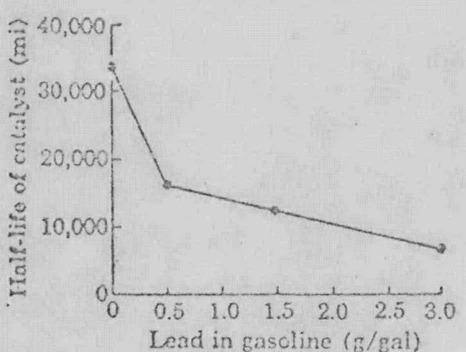


Figure 1. Effect of lead on catalyst life. From U.S. Senate, Subcommittee on Air and Water Pollution hearings, March 1970, ref. 2.

FIGURE A-11

APPENDIX B

We include here a review of alternative propulsion technical possibilities.

APPENDIX B

A number of reviews of alternate engines have been performed, with approximately the same general conclusions regarding the best bets for long-term optimization of efficiency and emission levels. Three of these reviews are summarized here. The first is by the NAS.

Their general summary is:

"Those candidates that appear to merit earliest consideration are as follows:

Diesel: Can be considered now for special applications such as taxis, police cars, light duty urban trucks and vans.

Advanced diesel: Earliest probable compromise solution for general car populations; fits many applications in present transportation systems. Can be considered for future transportation systems.

Advanced gas turbine: Suitable with little or no compromise to larger vehicles; some question about suitability in urban driving and in small cars; good fit to future energy system; can be considered for future transportation systems.

Advanced battery: Very good fit to future energy system.

Advanced fuel cells also fit this group as soon as it is clear that it is mostly engineering that is required for its development rather than a major technical and/or economic "breakthrough."

The present unsettled nature of the evolving socioeconomic situation regarding transportation and energy precludes a choice for one power plant at this time. It is logical to proceed in improving the characteristics of all likely engines, batteries, and fuel cells. By this means the most viable candidates will surface."

Thirteen different power plant options were studied, and the findings are displayed in Figure B-1.

Relative Status of Various Alternative Engines

	Diesel	Advanced Diesel	Gas Turbine	Advanced Gas Turbine	Battery	Advanced Battery	Rankine	Advanced Rankine	Stirling	Advanced Stirling	Advanced "Other"	Advanced Fuel Cell	Pre-Control Gasoline
Emissions	1975	1976?	1975	1976?	C.P.P.	C.P.P.	1976	1976	1976	1976	1976	1976	
Fuel Versatility	F	G	E	E	C.P.P.	C.P.P.	E	E	E	E	E	E	G-E
Fuel Consumption	2/3	3/4	1-2	3/4 - 1 1/2	3/4 - 1	3/4 - 1	1½-2	1 1/4	2/3	½-3/4	~3/4	½-3/4	1
Noise	F-G	G	E	E	E	E	E	E	E	E	E	E	?
Safety	E	E	E	E	F	G	G	G	E	E	E	G	E
Cost	2	1	2-3	1	> 5	2½-3	3	2½-3	1½-2	1	1½-2	10	1
Starting Ease	Ewde	Ewde	Ewde	Ewde	E	E	Ewde	Ewde	Ewde	Ewde	Ewde	Ewde	G
Response to Abuse and Neglect	E	E	G	E	F	?	F-G	F-G	P	E	E	?	E
Driveability	G	G	G-E	E	P-F	E	G	G	G	E	G-E	E	E
Serviceability	E	E	E	E	G	G	P-E	E	P-E	E	E	G	E
Design HP Versatility	F	E	F	F	F	E	F-G	G	E	E	E	E?	E
Control Ease	E	E	F	F	E($)	E($)	P	P	G	E	F-E	G?	E
Producibility	G	G	F	G	G	G	P	G	G	E	G-E	E	E
Size	2 1/4	3/4	1	1	-	1 1/2	1 1/2	1	3/4-1	3/4	1	3+	1
Weight	2-2½	3/4	3/4-1	½-3/4	-	1 1/2	1 3/4-3	1½-1½	1-1½	2/3	1-1½		
Integrability	F	E	E	E	P	E	P	P	G	G	G	E	E
Present Production Status	Ltd Prod	-4 yrs	Conc. Feas.	-4 years	Ltd Prod.	-4 yrs	-2 yrs	-4/-6 yrs	-2/-3 yrs	-5/-10 yrs	-5/-10 yrs	-15 yrs	Mass Prod.
Earliest Ltd. Prod.	Now	1980	1978	1982	Now	1980	1979	1981	1979	1981	1981	1992	Now
Earliest Mass Prod.	1976	1983	1984	1984	1976	1984	1983	1985	1983	1984	1984	1996	Now

P - Poor
F - Fair
G - Good
E - Excellent

C.P.P. - Central Power Plants
Ewde - Excellent, with delay
Yrs - Years to prototype
E($) - Excellent, but costly

FIGURE B-1

The EPA through its AAPS program has evaluated the same prospects with the following conclusions (Preliminary Program Planning, AAPS):

"The basic conclusions of the study were that the following engines should receive major consideration.

a. Dual chamber stratified charge engine

b. The lightweight Diesel

c. Stirling Engine

Current programs on the gas turbine should proceed; however, extensive work in this area should be predicated on the ability to realize an engine with high turbine inlet temperature for maximum performance which is constructed of noncritical materials such as ceramics.

Summary

With present knowledge it appears that the spark-ignition gasoline in its present form, but fitted with emission control devices, will remain the low cost power plant for automotive applications for the next 5 to 10 years. The reason being mainly current investment in tooling and the finite time necessary for the introduction of a new type of prime mover.

Concentrated development should be undertaken to introduce the dual chamber stratified charge engine which can use present tooling used for the Otto cycle engine. The only change required being a new cylinder head, dual carburetors and a third valve and necessary camshaft for the introduction of fuel and air into the prechamber. It should be possible to introduce such an engine into production in the late seventies, by which time the present gasoline engine with emission control equipment will be on the decline.

Concurrently, development of the diesel and Stirling engines should proceed without delay for introduction towards the end of the next decade.

These recommendations, at least as far as the stratified charge engine is concerned, generally agree with work done by Southwest Research Institute, Dr. Beno Sternlicht, and the Eaton Corporation."

The specific comments by engine type are reported in the following figure, Figure B-2.

Finally, the conclusions of a study performed by the Eaton Corporation is included as Figure B-3, which is self-explanatory.

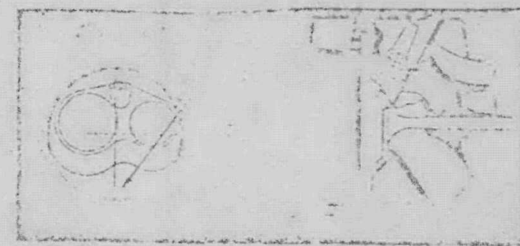
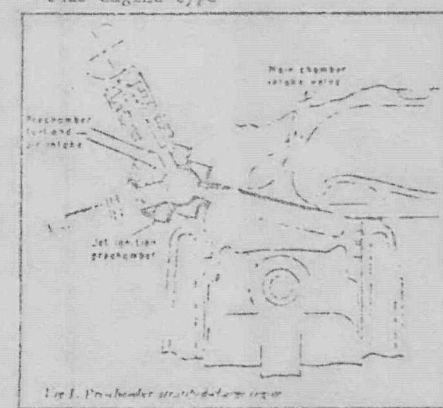
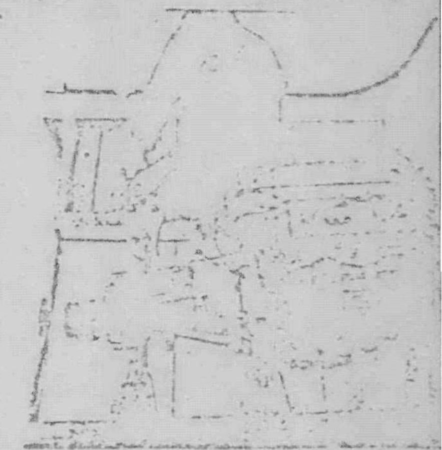
	Engine Candidate	Present Status	Potential	Action	Procedure	Time Span	Remarks
1a.	Present time Otto Cycle gasoline Engine	1976 Emission levels are beyond limits of current mass production technology. This confirmed by National Academy Science report to EPA. Some laboratory engines have met 1975 levels but not 1976. This not practical for mass production or 5 year life. Catalytic converters rely on (a) Platinum, (b) Palladium These two commodities are imported from abroad. (c) Chrome iron oxide and (d) spinels are in trial stage.	Emission control devices increase gasoline consumption which is already scarce. This engine will remain the power plant of the 1970's because of the time interval required to develop and introduce alternative ones.	Relax emission levels	Work on developing alternative power plants as soon as possible 	to 1978/80	1976 stringent emission level would not solve present pollution problem
1b.	Modified Spark Ignition Gasoline Engine	Prechamber stratified charge engine with fuel injection and part load throttling has shown definite promise in VW developments. Also Honda CIVIC engine. NO_x emissions reduced. Hydrocarbons can be handled by thermal oxydation in the exhaust.	Very promising. One manufacturer has already marketed such a car. Probably best suited for the smaller engines and economy cars. See "Diesel" below. Can be used with gaseous fuels as well as gasolines	Test and Evaluate current developments as soon as possible	No time should be lost in developing this engine type 	1974 - ?	Proven Concept
1c.	Rotary Engine (Wankel) NOTE: Listed as 1c only because it is in current production and not because of merit or potential.	Advantages on its small size and weight. This allows more room for addition of emission control devices on smaller cars. Has poor fuel economy Hydrocarbon emissions are higher but Nitrogen oxides lower. Responses to the same emission control devices as the gasoline engine. Can be made into stratified charge engine.	The Rotary Engine holds promise as a potential alternative to the current gasoline reciprocating engine and to the future stratified charge engine. Engine will not improve greatly over present development. Seals are still a problem. Other types of rotary engine other than the Wankel are currently under development in the U.K., Australia and Sweden.				

FIGURE B-2

Engine Candidate	Present Status	Potential	Action	Procedure	Time Span	Remarks
11. Diesel	EPA review and tests indicates the Diesel has the highest efficiency of any alternative power plant to date. Mercedes Benz Diesel engined cars have met the 1975 emission limits with present production models and have met the 1976 limits with laboratory engines. Ricardo & Co. with the Comet V prechamber head have done likewise. 30 to 450 plus IN^3 engines have operated in passenger cars, taxicabs, buses, pleasure boats etc., in Europe for 2 to 3 decades. No smoke or odor complaints have been made over these. Major overhaul periods of 250,000 miles are realised. NOTE: Vapor or liquified gas injection as a means of ignition must be developed otherwise the Diesel will die when liquid fuel supplies run out.	Excellent. Change over to Diesel would take less time than new alternative power plants including possibly the prechamber stratified charge engine as the automotive diesel exists now. Main criticism of Diesel is odor, smoke, weight, noise and cost. Nothing smells worse than a General Motors City Transport bus running on kerosene which has been accepted for years. Smoke can be eliminated. Weight can be controlled with the prechamber engine because maximum pressures are lower than a direct injection engine consequently design does not have to be so heavy. Cost. When the gasoline engine is costed taking into consideration all the emission controls and the complexity of stratified charge prechamber and fuel injection equipment the cost will be very similar to the gasoline engine. Noise is no longer a problem. Research on noise reduction is well advanced. MAN have built a "whisper" diesel. Rate of pressure rise and a robust block are the main criteria.	Why wait?	U.S. Auto manufacturers could start production of their European developed engines now.	1976?	U.S. Auto Manufacturers have a bias against this approach. Why?
2. Sterling	Very low emissions less than any other alternative. Fuel consumption equal to high compression gasoline engine without emission controls. Very low noise level. Multifuel capability closed cycle gives long service life. No lube oil consumption. Reliable starting. High pressure piston rod seal may be a problem. Engine is heavy needs aircraft design approach. Is currently in use on trial city busses. Is actively being developed by Ford and MAN in Germany. Manufacturing cost is high.	Good. Has fewer problems than a compound Diesel engine or hybrid power system. Retains I.C. engine technology and tooling.	Should pursue development.		1982?	



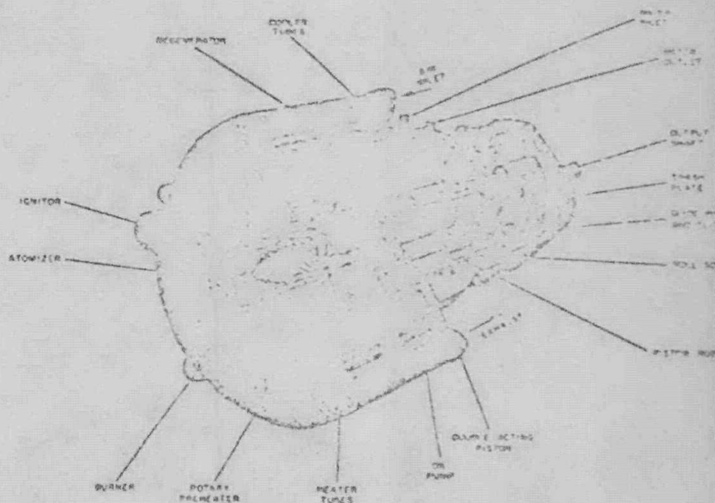


Fig. 3 Drawing of 200-HP Ford-Philips Automotive Engine

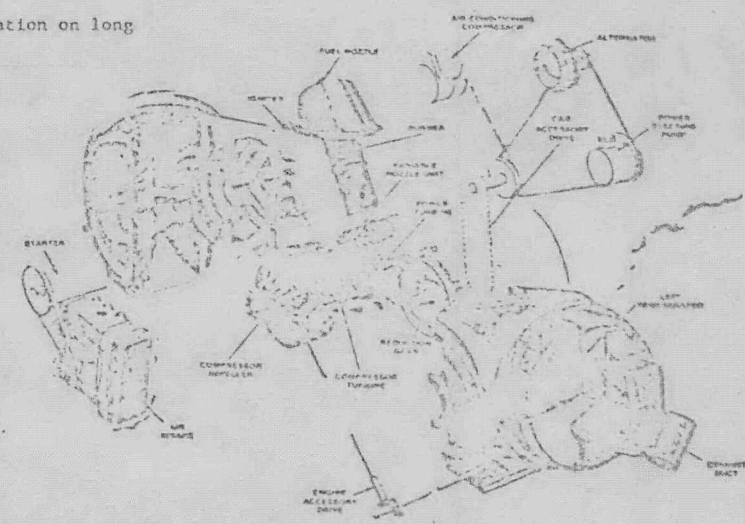
FIGURE B-2

Engine Candidate	Present Status	Potential	Action	Procedure	Time Span	Remarks
3. Battery Electric Vehicle	Is currently used in foreign countries for city and suburban delivery vans. Transfer pollution from vehicle to stack of power generating station. Using lead acid batteries range of 50 miles at 25 mph possible with acceleration from start to 30 mph in 12 seconds. Slow acceleration a safety hazard and not suitable for freeway traffic. Battery can be recharged from 110 Volt supply in 7 hours at off peak periods; that is, nighttime.	No breakthrough in battery development is foreseen in the near future. May have scope for city and suburban Van delivery or commuter use. Would have to be restricted for use off the freeways like bicycles, etc.				
4. Rankine Cycle Engine	Emissions no longer limiting factor. Problem areas: Higher fuel consumption; Improve expander efficiency operation of thermodynamic fluids at high peak cycle temperature; Lubrication in recip expanders; Freezing of water (if used); Large bulk difficult to fit under hood; Long response time from accelerator action to car response; Complexity involving relays, operating relays, etc.; Condenser size limiting; High thermal load on piston crown; High bearing load on wrist pin in recip expander; Condensation problems in cylinder on cold start up; High manufacturing cost; Increased weight over gasoline engine.	Low for passenger cars. May have some potential for long distance trucking but doubtful.				

Fig 8. Experimental 512 Series electric town car

FIGURE B-2

	Engine Candidate	Present Status	Potential	Action	Procedure	Time Span	Remarks
7.	Gas Turbine	The most advanced G.T. engine to date has these remaining problems: High NO_x; High first cost; Poor fuel economy, especially at part load. The G.T. automotive engine has been under development for two decades and the problems have not changed or been solved. In fact new ones have arisen namely, emissions and fuel economy. Other disadvantages: Poor acceleration; Variable turbine geometry to improve part load performance adds complexity and cost; Reduces reliability; Variable geometry also required for the combustor when the same remarks apply; To reduce NO_x combustor primary zone temperature has to be kept below 2000° F which appears impractical.	May find application on long haul trucks.				January 1974 Mechanical Engineering General Motors Corporation Technical Article
6a	Stored Energy	City buses using stored energy have been used for many years in the former Belgian Congo. The flywheels are speeded up at bus terminals using utility supplied electric power.	Proven concept for city transportation. Has limited value.				
6b.	Hybrid Systems	The hybrid engine electric utilizes a small fossil fuel powered engine onboard to charge batteries which in turn drive the vehicle. G.M. (1968) Stirling electric car used 14 lead acid batteries. 20 hp dc motor gave top speed of 60 mph, acceleration 0-30 in 8 1/2 seconds. Range on batteries alone 25 miles at 30 mph or 150 miles at 30 mph with charging system operating limited only by 5 gallon gas tank. Vehicle weight 3250 lb.	Advantage is battery acts as power ballast relieving the engine of the requirement to respond to rapid transient demands. The engine can operate at optimum condition for high efficiency. System introduces serious efficiency losses in conversion of energy from mechanical to electric, back to mechanical; control systems are complex and cost is very high. May have high potential as long-term approach!				From paper by E. M. Estes of General Motors April, 1972 given in London, England Journal of Automotive Engineering



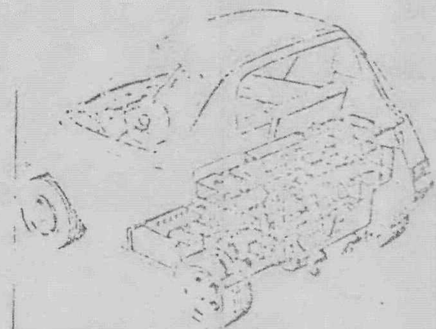


Fig 11. 512 Series urban car with hybrid gasoline-electric system

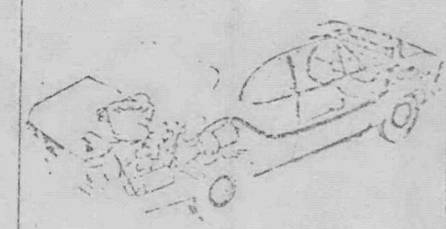


Fig 12 Series II Stirling electric hybrid

FIGURE B-2

SELECTION PARAMETERS AND COMPARISON OF PASSENGER CAR ENGINE TYPES*

	Wankel	Turbine	Stirling	Stratified Charge	Diesel
(1) Flexibility	Wankel engines tend to have lower torque at low speeds and a higher speed for their torque peak than reciprocating engines. This means that the rotary engine has reduced performance flexibility requiring more shifting or more sophisticated transmissions for equivalent performance.	Two-shaft turbines have a very favorable torque curve having in effect a built-in torque converter. Single shaft-engines which have recently come under serious consideration have an unfavorable torque curve.	The Stirling engine has a favorable torque curve providing substantial torque increase as speed falls.	The stratified charge engine can equal the flexibility of the piston engine, although it is difficult to achieve. It may not be achievable on all types of stratified charge engines.	Diesel engines generally operate over a lower speed range and require more gear [illegible] tios and shifting.
(2) Smoothness	A single rotor Wankel can be equal to or better than many 4-cylinder engines, while a two rotor Wankel is smoother than 4- or 6-cylinder engines. Most interest has been generated for two rotor Wankel engines with only little interest in three and four rotor engines and very little interest in single rotor engines.	As a continuous fluid flow rotary machine, the turbine is extremely smooth.	Stirling engines are also extremely smooth engines effectively completely balanced and have very minor cyclical variations in torque.	The stratified charge engine as a modification of the gasoline engine should have approximately equal smoothness.	The diesel is less smooth than the gas[illegible] engine due to its combustion characteris[illegible]
(3) Emissions	Untreated, the Wankel is a rather dirty engine with emissions of hydrocarbons as much as five times higher, carbon monoxide up to three times higher while oxides of nitrogen are up to 75% less. Derating a conventional engine to the same level of efficiency would be expected to result in similar emission levels. Conversely, as the Wankel's [illegible] are improved, oxides of nitrogen will tend to increase and hydrocarbons decrease. The Wankel has fewer exhaust ports and because of this [illegible] operates with a higher exhaust temperature which makes thermal reactors more applicable.	Turbine combustors can be built which have very low emissions, especially of hydrocarbons and carbon monoxide. There is some question as to whether they can meet the pending 1976 NO_x standard of 0.4 grams/mile.	The Stirling, based on bench tests, appears to have the lowest emissions of all known engines, well within 1976 requirements—achievable with little penalty in fuel consumption or cost.	Stratified charge engines have shown potential for low emissions. Honda has readily met the original 1975 standards with both small and large cars and has come close to 1976 standards with small cars. Other types of stratified charge engines, such as the Ford Proco have shown potential for relatively low emissions (but not yet as good as Honda).	Diesel engines have very low hydrocarbon [illegible] carbon monoxide emissions and can have [illegible] low oxides of nitrogen emissions but [illegible] not low enough to meet 1976 requirem[illegible] Diesel engines, however, also tend to pro[illegible] objectionable smoke and odor.
(4) Cost	Although the Wankel uses fewer parts and is lighter, even when built in high volume, it costs more than a piston engine. It will likely be more expensive for some time to come; however, with substantial product and manufacturing development effort, it could ultimately become cheaper to produce. (The cost is discussed in more depth in Section VIII.)	Turbine engines require the use of substantial amounts of expensive, difficult to fabricate superalloys and an expensive regenerator. Potentially possible, but requiring a great development effort, is a simpler turbine operating at higher pressure ratios and temperatures using lower cost ceramic materials. Such an engine could ultimately be cheaper than the piston engine. Single-shaft engines cost significantly less than two-shaft, but require more sophisticated and costly transmissions.	The Stirling appears to have a cost disadvantage due to the requirement for high temperature alloys in the heater head and to control problems. Recent developments indicate these control problems are not as formidable as once believed. At very tight emission standards, the piston engine could conceivably increase sufficiently in cost to make the Stirling competitive or possibly give it an advantage.	As there will probably be some loss in maximum power and some increase in complexity (prechamber 3rd valve or fuel injection), some increase in cost over present (1973) engines is likely. However, compared to dual catalysis, it would likely be substantially cheaper.	Because of the direct fuel injection system [illegible] 25% of engine cost) and because of [illegible] quirement for a more rugged structure [illegible] engines are substantially more costly.
(5) Noise	The elimination of mechanical moving parts, such as the valve gear, should reduce noise but data on the limited car (and snowmobile) models available show approximately equal noise levels.	Despite the image of turbine powered aircraft, the turbine engine is relatively easy to silence.	The Stirling engine has a very low noise level and is the quietest of any of the serious contenders.	Noise should be equivalent.	Diesel engines are generally much noisie[illegible]

*Extracted from "Automotive Engines for the 1980's – Eaton's Worldwide Analysis of Future Automotive Power Plants," by R. R. Richardson, Eaton Corporation, Cleveland, Ohio.

FIGURE B-3

SELECTION PARAMETERS AND COMPARISON OF PASSENGER CAR ENGINE TYPES (CONTINUED)

(6) Weight	Wankel engines weigh less, especially when only the basic engine structure is compared. When completely equipped with all accessories necessary for operation, there is a smaller relative advantage as these accessories are essentially equal or occasionally heavier. Wankel weight savings of 50% are often claimed. Realistic comparison shows much less. Comparison of the lightest experimental Wankel known with the lightest production piston engines indicates 12-16% weight savings on a pounds per horsepower basis. (These engines are not of equal horsepower.) Karl Ludvigsen in a recent article in *Road Test* magazine indicates an average weight savings of [illegible]% comparing several pairs of engines of equal performance. Significant reductions in average weight and size of piston engines are possible should this become a high design priority.	Turbine engines are substantially lighter than piston engines.	Recently developed double acting Stirling engines appear competitive in weight.	Due to some probable loss in maximum power, relative weight would slightly increase.	Unless the diesel were turbo-charged to a boost pressure and run at high speed it [illegible] be substantially heavier.
(7) Size	Wankel engines also have a size advantage usually somewhat greater than their weight advantage. Most of the comments on weight [illegible] here. Comparing the lightest and most compact engines shows size advantages in the range of 15-45% based on a "box" volume (max. length X max. height X max. width). Karl Ludvigsen's analysis indicated a 30% average advantage.	The basic turbine is also substantially smaller than the piston engine but the addition of a regenerator results in no net size advantage.	Stirling engines are somewhat larger than piston engines but studies show they can be installed with all accessories in engine compartments of both sub-compact and full size cars.	The same applies for size as for weight.	The same applies for size as for weight.
(8) Maintenance	The maintenance requirements of the Wankel are expected to be reasonably comparable to the piston engine. The Wankel has fewer but more complicated and expensive parts. It uses similar types of fuel, air cleaning, ignition, cooling, and exhaust systems. Wankels currently use a more complex emission control system requiring more maintenance. The Wankel can provide some savings through longer oil change periods. A recent survey indicates tune-up costs at dealers are approximately equal for Mazda and V8 engines. Fours and sixes cost less to tune up of course.	The turbine is basically a simple machine and, with freedom from vibration, should have lower maintenance.	Like the turbine, the Stirling should have relatively low maintenance requirements.	Stratified charge engines should require slightly more maintenance than uncontrolled engines—somewhat less maintenance than engines with dual catalyst.	Diesels have proven to have low maintenance requirements primarily due to the [illegible] design.

FIGURE B-3

SELECTION PARAMETERS AND COMPARISON OF
PASSENGER CAR ENGINE TYPES (CONTINUED)

9. Fuel consumption	Fuel consumption includes both quantity and quality of fuel. Wankel engines have substantially higher fuel consumption (30-40% higher for 25-30% fewer miles per gallon) than piston engines. At very low emission levels, this difference will probably be reduced but not eliminated. Improved seals will also help reduce, but not eliminate, this fuel consumption penalty as the combustion chamber appears inherently less favorable. In contrast to its higher use of fuel, the Wankel has a requirement for lower octane quality (low to mid 80's for Mazdas). The octane requirement will probably increase as seals are improved and as the engine is scaled up to larger displacement per rotor.	The turbine has higher fuel consumption, especially at light loads typical of much automobile operation. At very light emission standards, the fuel consumption increase of piston engines could result in the disadvantage of the turbine being eliminated. Development of materials allowing operation at higher temperature would help make the turbine competitive on fuel consumption. The turbine is capable of operating on a wide range of fuels, but specific designs require a limited range.	The Stirling has a fuel consumption potential lower than any other contender and will operate on the broadest range of fuels. Achievement of the very low fuel consumption may not be possible with a practical size radiator. Compromise would still leave the engine with lower fuel consumption than any engine but the diesel.	Probably a slight advantage in fuel consumption will be realized by practical stratified charge engines although development will be required. Burning of overall lean mixtures and reduced pumping losses both save fuel. Stratified charge engines can use a broader range of fuels.	The diesel is a very efficient engine and h[illegible] substantial fuel consumption advantage e[illegible]cially at light loads characteristic of passe[illegible] cars.
10. Durability	The durability of Wankel engines was initially very poor. The Mazdas have substantially better durability but are not yet up to typical U.S. standards. Combustion chamber surface materials and treatment together with seal materials having very long life have been developed but apparently not with acceptable cost and sealing characteristics.	Aircraft turbine engines have demonstrated much greater durability than piston engines. There is considerable doubt, however, whether this will be true for cars due to operation with very frequent wide fluctuations in load and operation with dirtier air. The addition of the regenerator required for reasonable part load fuel consumption may also reduce durability.	Developmental Stirling engines have shown extremely high durability—perhaps due to over-design. Some compromise to help reduce cost may be in order.	Based almost exclusively on current piston engine technology, the stratified charge engine's durability should be similar.	The diesel has also been proven to be a v[illegible] durable [illegible]
	Based on this somewhat superficial comparison, weighted for importance of parameters, the Wankel appears to have little, if any, net advantage. As the fuel consumption issue takes on more importance, the Wankel's competitive position will be more tenuous. If manufacturing cost breakthroughs are achieved, it may still find a substantial niche.	Overall, the turbine appears to have a significant potential net advantage and apparently warrants additional development effort.	On balance, the Stirling engine appears potentially the most attractive powerplant over the long range.	The stratified charge engine, on balance, is not as attractive as the Stirling, but because it is based largely on existing parts, it could be commercialized relatively rapidly with only slight disruption to the industry. It is only marginally attractive compared with current engines. It is quite attractive, however, compared to conventional engines with dual catalyst.	On balance, the diesel does not appear to [illegible] attractive alternate for passenger cars.

FIGURE B-3

OBSERVATIONS ON FEDERAL ENERGY RESEARCH AND DEVELOPMENT - DECEMBER 1974

Alvin M. Weinberg

and

Office of Energy Research and Development Staff

Federal Energy Administration

Much of our country's present stance in energy R&D is an embodiment of the recommendations presented in the Dixy Lee Ray report, "The Nation's Energy Future" (NEF).[1] Since that report appeared just one year ago, the Energy Research and Development Administration (ERDA)[2] has been established, and the Project Independence Blueprint (PIB)[3] has been completed. To what extent does the passage of a year change the priorities or the scale of energy research and development which was outlined in NEF? This memorandum recommends a few specific R&D programs and related institutional changes that ought to be undertaken in response to events that have occurred since November 1973.

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[1] A Report to President Richard M. Nixon, WASH-1281, U. S. Government Printing Office, Washington, D. C. (December 1, 1973).

[2] "Energy Reorganization Act of 1974", Public Law 93-438, 93rd Congress, H. R. 11510, Washington, D. C. (October 11, 1974).

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

- I. SCENARIO-PROOF REALITIES -

1974 has seen extensive use of econometric models in an attempt to foresee the energy future of the United States. We concede the impossibility of accurately predicting the future; nevertheless, for purposes of delineating a research and development policy, there are certain realities that are independent of our models and that must guide our general, and even specific, research planning. Of these, the most important realities are:

* The U. S. energy system currently depends primarily on oil and gas.
* Relative to our rate of use, U. S. oil and gas resources recoverable at reasonable cost are limited; it may no longer be possible to increase significantly either our recoverable reserves or production rates of oil and gas.
* The current rate of use of oil and gas requires that substitutes for them - such as synthetically produced replacement fuels or electricity - must ultimately be found, regardless of our success in reducing growth rates in the use of oil and gas.
* The U. S. has extensive resources of coal, oil shale, and - with breeder technology - uranium.
* Other potentially extensive energy resources - solar, geothermal, nuclear fusion - are tantalizing, but the technologies for using them are not presently understood well enough for us to rely on them.

- II. ENERGY RESEARCH POLICY AND PRIORITIES -

The realities of our energy system dictate this set of research priorities:

A. Develop advanced methods of recovery of oil and gas

The central research question revolves around the fraction of oil that can be recovered in both existing fields and fields yet to be developed. Industry is conducting experiments on advanced oil recovery and, in time, we expect that these measures will significantly increase our production of oil. The Government's participation in such activities has been minimal. We estimate that if joint government-industry efforts to develop advanced recovery technologies were launched, we could expand our recoverable oil resource base by 30-60 billion barrels 5-10 years sooner than will otherwise be possible. This should correspond to an increase in oil production of 1-3 million barrels per day. We therefore recommend that Government assume a much more active role in developing advanced recovery methods for oil and gas.

B. Develop technology to produce oil and gas from coal and oil shale

It seems inevitable that we shall need to extract coal from the ground and convert it into liquids and gases on a large scale, both to fill a predictable shortfall in oil and gas supply and to ensure our ability to use coal cleanly. If processes already developed were economical, we would now be deploying them commercially. Unfortunately, the estimated cost of clean synthetic fuels from coal remains high. Yet, as natural resources of oil and gas diminish, these higher costs for synthetic fuels may become acceptable. Thus, the present policy and program emphasis on development of advanced coal conversion technology makes sense. In addition, the federal government should support first-of-a-kind large scale coal hydrogentation plants based on current technology.

In sharp contrast to the present policy and relatively high level of funding for developing advanced coal conversion processes, are Federal activities for developing processes to extend our recoverable resource base of oil shale and to reduce the cost and environmental impact of oil production from shale. We recommend that increased emphasis be given to R&D on oil shale to support and complement oil-shale-land leasing policy. The Government should devote particular attention to developing in-situ recovery processes: this approach may prove to be very much less damaging to the environment than is the more conventional technique of mining and above-ground retorting.

C. Develop technologies that use energy efficiently

The benefits of developing energy supply technologies based on non-renewable resources disappear with exhaustion of the resource. In contrast, benefits from adopting more efficient ways to use energy are cumulative and everlasting.

Development and application of methods to convert and use energy efficiently may reduce fuel requirements as much as 26 mQ per year by 1990. More than one-half of the expected economy is in oil, primarily from the automotive sector. The second largest expected saving is in natural gas, largely from the industrial sector. We recommend careful study of these areas along with a commensurate increase in funding in subsequent years for R&D on promising concepts that are not being pursued expeditiously.

D. Develop non-fossil-based technologies, particularly electrochemical cells for autos

Closely related and of equal importance to the need for energy-efficient automobiles and efficient use of gas in industry is the need for developing automotive and industrial technologies that do not depend on oil and gas. A shift to electricity (or perhaps a synthetic fuel such as hydrogen) will take many years. For example, 30 to 40 years will be required to transform our automotive system; starting seriously now on making this transition seems prudent.

Here the single outstanding opportunity and difficulty is the development of high-performance batteries for automobiles and for power storage devices to be used by industry and the electrical utilities. For example, an efficient electricity storage device is essential if we are to rely in the future on solar and/or nuclear electric systems. There is no single technology with such high potential for ensuring the adequacy of our energy resource/supply/demand system and for creating a clean, quiet, cool environment for our cities. The payoff - particularly in the automotive application - is too long to expect adequate R&D funding from the private sector. The Government therefore must actively pursue this development, particularly of the non-fossil-based automobile.

The effort, both governmental and private, that is expended on developing storage devices is far too small; the Federal R&D program funding for FY-75 is about $7 million (0.3%). We would therefore recommend that development of electric cells, with appropriate performance for automotive application, be recognized as a matter of extremely high priority worthy of major support. This development should not be limited - either in funding or in the number of promising concepts for development.

E. Develop energy supply technologies - the breeder, fusion, solar, geothermal - independent of fossil fuel resources

1. Solar-electric

Our major thesis is that we must prepare for the ultimate depletion of our fossil fuels. This means developing alternative "inexhaustible" energy sources: fission breeders, fusion, solar energy (and its related sources), and geothermal. All of these should be pursued; however, it seems unlikely that geothermal will ever be a very large energy source, and there remain serious questions as to the scientific and technological feasibility of fusion. Thus, we are in a sense left with only two "sure things" - the fission breeder and electricity from solar energy. We must decide what the relative role of the breeder and solar electricity will be in our ultimate energy system.

With solar electricity, the issue is entirely one of practicability, not scientific feasibility. Estimates of the cost of electricity from solar energy vary widely. If the low estimates being made are valid, solar electricity may play a very important role; if the high estimates prove correct, solar energy will at best be a smallish thing, and the breeder will almost surely be the prime energy source for the society. Solar electricity thus becomes a major long-term issue which is not being addressed in a fully serious manner. We must know, say, by 1990 whether solar and/or its derivatives can be taken seriously as competitors of the breeder. In contrast to the Federal R&D programs on the breeder ($535 million in FY-75) and fusion ($175 million in FY-75), the solar-electric program in FY-75 is funded at $35 million. We therefore single out the solar-electric programs for expansion in the coming years.

2. Alternative breeders

Much discussion now surrounds the Liquid Metal Fast Breeder Reactor (LMFBR); the tenor of this discussion centers on whether or not to pursue the demonstration plants. But this analysis overlooks a prior question: should alternatives to the LMFBR be seriously considered; that is, should we plan to build 200-Mw reactor experiments for competing breeders, the Molten Salt Breeder Reactor (MSBR) and the Gas Cooled Fast Breeder Reactor (GCFBR)?

If indeed we are to prepare for the eventual depletion of our fossil fuel resources and if, as seems most likely for the coming decades, the breeder will be the basis of this age, then one can argue that we must pursue the breeder with at least the same sense of urgency that we attached to the non-breeders during the 1950's and 60's. In that period, the world developed perhaps 10 different reactor systems - to the point of building a fairly large-scale prototype of each. Present-day reactors emerged from this competition among reactor types. We believe the all-but-unilateral commitment to a single breeder type - the LMFBR - is a mistake because it does not allow us to judge among the different possibilities. The alternatives to the LMFBR - the Light Water Breeder Reactor (LWBR), GCFBR, and MSBR - ought to be elevated to a status where they have a chance of competing with the LMFBR rather than being viewed simply as back-up "insurance policies". This means a commitment to build 200-Mw GCFBR and MSBR reactors in the 1980's with the option of canceling the projects should serious technological obstacles be encountered. Only a direct comparison of competing breeder technologies can establish which is the best breeder for our energy future. This course is much bolder than the present one which is to maintain competitive breeders at a "technology" level before committing them to reactor experiments. This more conservative approach in fact probably will pre-empt the breeder decision and provide no alternative other than the LMFBR.

The previous discussion is entitled "alternative breeders," not "alternatives to the breeder." Thus, we are not raising the question of whether HTGR's or Th versions of the CANDU reactor can obviate the need for the breeder. The position we take here is simple: that an economical breeder, if it can be achieved, is clearly better than any of the alternative s. We should, therefore, seek to achieve the ultimate, quite apart from what we do with lesser, and hence temporary, solutions to the nuclear energy problem.

- III. ENVIRONMENTAL ISSUES -

As ERDA comes into existence, there should be established clearly identified groups of adequate size with assigned research responsibilities for the health and environmental effects of each of the major energy modalities. These groups should be in addition to the present groups that study environmental impacts of energy in the health and environmental agencies without specific reference to particular energy modalities.

Furthermore, we have two recommendations as to specific environmental questions to which R&D can contribute:

A. Establish environmental standards for energy-related pollutants

We would hope that the new ERDA organization will deal with this recurrent theme: establishment of scientifically-based environmental standards. This information is urgently needed for proper evaluation of our future energy technologies.

Within this broad framework of establishment of environmental standards, we recommend that several matters receive special emphasis. We highlight the following areas:

* Develop quick and inexpensive toxicity testing methods.
* Increase the supply of epidemiologists trained in non-medical fields (e.g., biology, chemistry, statistics).

* Complete baseline ecological studies for offshore oil prospecting areas.

* Increase efforts to understand the mechanisms of environmentally-induced pathogenic events at the molecular and cellular level.

B. Predict long-term climatological effects of energy production

From the many long-term environmental issues related to energy production, we include a topic of particular interest to the Office of Energy Research and Development: study of long-term climatological effects. That man's production of energy now is causing changes in the climate on a micro-scale seems to be beyond doubt. Are larger scale, irreversible climatological changes also occurring? These are very difficult problems that can hardly be answered unless more is learned about climatology. We should aim to learn enough about climatology over the next 10-15 years to be able to predict with some confidence at what stage man's production of energy will cause serious global effects on climate.

- IV. BUDGET ISSUES -

The basis for "The Nation's Energy Future" was President Nixon's request for a $10 billion, 5-year program which implied a commitment of about $2 billion annually. The Dixy Lee Ray report recommended an additional $1 billion for the FY-75 to FY-79 period for incremental support of environmental and basic research and manpower development. The current FY-75 plan calls for an expenditure of $1823 million for direct energy R&D and $216 million for support programs.

Is the nominal annual budget of $2 billion for energy R&D appropriate? The original commitment was rather arbitrary. Why wasn't it $3 billion per year or, for that matter, $1 billion? Granted that a budget always tends to be incremental and that $2 billion annually is an extrapolation of previous trends, we would argue that the current budget by no means represents a flat-out effort to do everything that can be done through R&D to help provide for our energy future. We would therefore propose re-examining the $2 billion budget with the intent of spending more where such expenditure appears to be appropriate.

We realize that this recommendation flies in the face of a commitment to cut rather than expand U. S. Government spending. However, we believe that the energy issue is of such crucial importance that it must be pursued as vigorously as possible: there are additional areas of energy R&D that could well use more money, and these should be funded even if this means more dollars for energy research and development.

- V. INSTITUTIONAL ISSUES -

Creation of ERDA has largely rationalized the governmental structure for dealing with energy R&D. However, there remain deficiencies in the structure of the institutions that actually conduct energy research and development.

A. <u>ERDA should create research institutes in solar, automotive, climatology, and coal science</u>

Many of the most important unanswered questions related to energy are long-range in impact, and will require prolonged and sustained effort. Such long-term R&D is best conducted in institutions that themselves have long-term identity and commitment.

We see four areas of energy R&D that particularly need this kind of institutional integrity: solar, automotive (especially the electric car), climatological, and coal science. Elements of a coal science institute exist to a limited degree in the Bureau of Mines laboratories, but these laboratories do not presently have the broad, in-depth, scientific strength in basic chemical, physical, and biological research that characterizes the existing Atomic Energy Commission laboratories. This coal science institute is essential if we are to make the best possible use of our coal resource in the decades ahead.

Each of these four research activities is long-range, and each is important. We therefore propose that ERDA establish government-sponsored, long-term institutes or laboratories for solar research, for developing high-performance electrochemical cells for automotive and other applications, for the climatological modeling necessary to predict the long-term impact of man's production of energy on climate, and for coal science. Presumably, these institutions can be formed largely by reshaping existing research centers.

B. ERDA must help create a scholarly tradition in energy analysis

One difficulty with the formulation of energy policy is that, in contrast to defense policy, we do not yet have a community of energy scholars, comparable to the community of defense scholars. Creation of such a scholarly tradition in energy analysis ought to be given substantial priority. One way of achieving this goal is to establish energy laboratories, at perhaps a dozen universities. The laboratories would have some similarity to the Interdisciplinary Development Laboratories (IDLs) in material science that flourished during the 1960's. The IDLs, on the whole, have had a salutary effect on material science in the United States. We would hope that energy laboratories would have impact on energy science comparable to that of the IDLs on material science.

C. ERDA must reintegrate fragmented research

Present practice (e.g., AEC, OCR) is to divide problems in Washington and parcel out the pieces to various laboratories and contractors. As a result, no laboratory gets enough of the action to deal in a fully coherent or, for that matter, responsible manner with an entire problem. Problems are born whole; the practice whereby the Washington bureaucracy splits them into small pieces with expectation of reintegrating the fragments in Washington is conceptually incorrect both in terms of responsibility and efficiency in research management. This is best seen if one contrasts the weapons programs of AEC which have always been integrated at the laboratories with, say, the LMFBR, which was integrated in Washington. Left alone, AEC-ERDA may continue this practice of splitting problems into sub-critical pieces. Though this procedure avoids hard decisions - since everyone gets a piece of the action - the resulting cost in terms of delay, confusion, coordination and duplication of effort in our energy research program is intolerable. Such practice must not be allowed to perpetuate itself and grow.

D. ERDA must define and take responsibility for energy-related basic research

Almost every physical, chemical, or biological process involves an energy transaction; it is therefore not easy to define what is and what is not "energy-related basic research". However, the definition could come from the institutional context in which the basic research is performed.

As a general principle, ERDA must be responsible for basic research relevant to energy - the question is how to establish this relevance. We believe this can be done if ERDA organizes its own energy research facilities so that basic and applied research are conducted side-by-side, and if ERDA supports research in institutions where there is the opportunity for vigorous interaction between the basic and applied research communities. For example, basic materials work in ERDA should be conducted by people who are first-rate basic scientists, but who are also aware of energy problems and who are sensitive to the possible connections between what they do and what the energy community needs. ERDA must create an "energy ambience" which helps focus basic energy R&D in appropriate directions.

Within ERDA's own structure, we believe that such research deserves a special position independent of any of the particular energy modalities. This is not to say that a given Assistant Administrator is enjoined from supporting basic research relevant to its own mission; but in general, basic energy research can be expected to relate to more than one Assistant Administrator, and can only be nurtured properly if it is given status within ERDA commensurate with its pervasive impact.

- VI. CONCLUSIONS -

This memorandum does not address all of the manifold issues surrounding the formulation of the Nation's energy research and development policy. Rather, we have identified a few extremely important energy research matters that will not command proper attention if left to the marketplace; yet, these matters are either missing, woefully underemphasized or, at the very least, not being considered in a fully serious way in the Government's energy research program. In doing this, we have ignored other crucial energy R&D topics (e.g., coal mining, stack-gas cleaning, uranium processing from low-grade resources, nuclear power park policy) that may also need some adjustment as the Nation's energy research and development program becomes better rationalized; but for the moment at least, we believe these topics are properly recognized and are being launched in good fashion.

We propose that the following list of recommendations be incorporated in an agenda for action by the Federal Research and Development Administration.

R&D on Energy Technology

A. The Government should assume a strong role in development of enhanced methods of oil recovery.

B. The Government should greatly step up its activities on developing *in-situ* methods of oil recovery from shale.

C. The Government should identify the development of high-performance electrochemical cells for automotive use as a major national goal and greatly increase Federal activities in that area of research.

D. The Government should continue to increase its research emphasis on solar-electric technology to prove its potential at the earliest possible time.

E. A commitment should be made to build 200-Mw experimental GCFBR and MSBR reactors for comparison with the LMFBR to ensure that the very best breeder technology can be adopted for supplying electricity in the 21st century.

Environmental Issues

A. Increased emphasis should be given to developing a scientifically sound basis for establishing environmental standards.

B. Increased emphasis should be given to the study of long-range climatological effects of energy production and use.

Institutional Questions

A. Specific institutes should be established for conducting energy research on solar energy; advanced automotive concepts (particularly electric); climatology; and coal science.

B. Energy laboratories should be established at universities.

C. The practice of fragmenting research by assigning pieces of a problem to many contractors and reintegrating the pieces by Washington program managers must be re-examined with a view to delegating central responsibility to groups away from Washington.

D. ERDA must create the institutional structures that will encourage its basic scientists to become aware of the relevance of their work to the needs of the national energy community.

PROSPECTUS

for

FEO OFFICE OF ENERGY RESEARCH AND DEVELOPMENT

Alvin M. Weinberg

The announcement of formation of the FEO Office of Energy Research and Development assigned to the Office five functions:

-- Formulate energy research and development policies and plans to implement them.

-- Ensure that research and development priorities are consistent with overall energy policy.

-- Assist the Administrator in evaluating new R&D programs.

-- Work with AEC, EPA, NSF, and Interior to ensure that R&D programs are coordinated and balanced throughout the Federal government.

-- Work with the OMB, CEQ, and other Executive Office agencies in presenting R&D alternatives to the President.

The Office of Energy Research and Development has been officially established since February 1; it is now appropriate to detail more specifically how the Office will operate in achieving these five aims.

I. Initial Program for OERD

It seems clear that OERD's short-term strategy will be dominated by Project Independence. This provides a central focus because it is important; it is definite; it carries thrust and momentum. However, the role of OERD in Project Independence requires definition since, on the whole, P. I. will depend more on existing technologies than on new technologies or R&D.

The primary responsibility for carrying out P. I. will be with the FEO/FEA Assistant Administrators for Resource Development (AARD) and for Economic Data Analysis and Strategic Planning (EDASP). However, other agencies, notably AEC and Interior, will have much to contribute; and this will require effective coordination. OERD will serve both to coordinate the research contributions of these agencies and to identify R&D elements in P. I. The newly established Interagency Energy R&D Committee will serve as a vehicle for transmitting FEO's position on P. I. to the agency R&D community.

There already are a number of studies on Project Independence, and OERD must be sensitively aware of these.

II. <u>Longer Range Programs for OERD</u>

The second major task of OERD will be to review "The Nation's Energy Future" (NEF) in view of the heavy emphasis on Project Independence. The most obvious change in NEF will be increased emphasis on short-term R&D: most notably, R&D that can affect oil production, conservation, and coal utilization within the next half-dozen years. Beyond this, the Synthetic Pioneer Program will have to be expanded.

However, it would be very wrong to allow Project Independence to pre-empt all our thinking on the overall energy R&D posture.

Our first impression is that the very long-range options are probably funded fairly comfortably; however, the mid-term options - alternative breeder, more extreme coal conversion techniques, more innovative technological approaches to saving energy - deserve additional emphasis.

One particular part of the NEF program that probably needs attention is conservation in industrial processes. This is where, in principle, a very large saving can be made; whether in practice this saving can be achieved depends on much more analysis and thought.

Finally, the environmental-energy balance needs deeper study. This will be conducted in cooperation with CEQ and EPA.

III. Mode of Operation of OERD

A. Relationship with Present FEO

Presently, FEO consists of a large group of people who are destined to become the FEA; and a much smaller group, mainly the Office of Energy Research and Development, which is destined to remain in the Executive Office of the President after FEA is established. The thrust and purpose of the FEO/FEA group is relatively short-range: to put out fires, to manage our current energy crisis, to proceed expeditiously with Project Independence. The thrust and purpose of the Office of Energy Research and Development is primarily long-range. However, there is an overlap which must be managed, since short-term decisions often pre-empt long-term policy.

Interactions between OERD and FEO demand the following:

1. Establish ties with the Administrator and Deputy Administrator.
2. Establish working arrangement with Assistant Administrator for Resource Development and with Assistant Administrator for Economic Data Analysis and Strategic Planning.
3. Carry out day-to-day tasks for FEO. Fortunately, the AARD has a large staff, of whom many have strong technical backgrounds. Many of the day-to-day R&D matters - i.e., most of item 3, properly should be handled by AARD.

The Office of Energy R&D's main ties with the Administrator and Deputy Administrator will be on matters of overall R&D policy. Our main day-to-day interaction with FEO will be with AARD and, to a lesser extent, with EDASP.

OERD should help where it can with the other functions of FEO. However, OERD must avoid becoming so caught up in the day-to-day workings of FEO as to make it impossible to carry out OERD's main thrust: to keep the entire energy research and development enterprise of the Government well focused.

B. Contacts with OMB

Much of the influence of OERD will depend upon establishing and maintaining a close relationship with OMB. All of the technical staff will be involved in these contacts. Two specific steps should be taken immediately in this connection:

1. Offer services to OMB for advice as required regarding detailed agency submissions relating to FY-75 apportionment.

2. Begin formulating plans for preparation of the FY-76 budget process.

C. Contacts with Other Agencies

As a means of bringing the Federal energy R&D picture into focus, an Interagency Energy R&D Committee has been formed. This Committee, which met for the first time February 26, has two primary functions:

1. Maintain a continuing overview of the country's plans for energy R&D, especially in view of the new circumstances imposed by Project Independence.

2. Formulate overall energy R&D strategy with respect to the FY-76 budget and beyond.

I view the Interagency R&D Committee as a key element in making OERD a useful instrument of government. It is through this committee that the Office of Energy Research and Development will bring the governmental R&D apparatus into step with the actions and policies of FEO, particularly Project Independence.

IV. Conclusion

The Office of Energy Research and Development is a new entity, and it is a responsibility of the staff to fashion it into an effective instrument of government. The Office consists largely of individuals of experience, many of whom have had responsibility for managing large R&D programs. This is proper since OERD will have to make serious and difficult decisions that will require mature judgment and background. I believe with hard work and a bit of luck there is every reason to expect the Office to be a successful and exciting venture.

March 1, 1974

STATEMENT OF DR. JOHN C. SAWHILL
DEPUTY ADMINISTRATOR, FEDERAL ENERGY OFFICE
BEFORE THE SUBCOMMITTEE ON ENERGY
COMMITTEE ON SCIENCE AND ASTRONAUTICS

HOUSE OF REPRESENTATIVES

FEBRUARY 7, 1974

Mr. Chairman and Members of the Committee.

I appreciate the opportunity to appear before you today to comment on the provisions of H.R. 11212, The "Geothermal Energy Research, Development and Commercial Demonstration Act of 1973." I would first like to review briefly our overall approach to energy policy and our organizational plans for carrying out this policy in order to provide an overall perspective for my specific comments on the bill.

Five-fold Approach to Energy Policy

Let me start by outlining the five-fold approach we are taking with respect to energy policy.

First, we must establish a central energy organization in the Federal Government. The creation of the Federal Energy Office is the first step toward bringing all energy policy activity under one roof. We hope that Congress will move quickly to provide a statutory base for the Federal Energy Administration. We need legislation to provide us with the capability to recruit and hire top-flight administrators and to let contracts with qualified performers so that we can build the organization needed both to run the short-term allocation program and to carry out the more important assignment of moving the country toward energy self-sufficiency. Beyond FEA and ERDA, we must press forward with the creation of a cabinet-level Department of Energy and Natural Resources to ultimately bring together all Federal energy-related responsibilities. Until these new organizations are created, the Federal Energy Office will provide leadership and coordination in energy matters.

Second, we must establish a permanent "conservation ethic" in this country. We have been too extravagent in our energy consumption patterns. With 6 percent of the world's population, we consume 35 percent of the world's energy. The recent embargo has forced us to reduce this consumption now, but even more important we must be sure that an attitude of conservation becomes a permanent part of our lives.

Over 30 percent of our energy is wasted in one way or another -- wasted in conversion from one form to another, wasted in transmission, and wasted in unnecessary usage. Over the long-term, conservation of energy will require investment in insulation of homes and offices, use of more efficient automobiles, development of mass transit, changes in methods of handling freight, and central heating plants for groups of buildings and towns.

Third, we must push forward in the development of our domestic energy resources through Project Independence.

This includes further development of oil and gas in Alaska and the outer continential shelf, greater utilization of coal, of which we have a supply unmatched by any other country in the world, further development of oil shale and nuclear power, and of particular concern to the subcommittee we must expand our efforts toward development of geothermal and solar power. Project Independence must be a two-pronged attack. In the short-run, we must both expand production and exploit untapped reserves of existing energy sources. Longer range solutions will be provided by the development of new and existing sources of energy.

Fourth, we must forge a new relationship between Government and industry in several key areas.

. The information we now have to work with is not adequate and its reliability cannot be checked. We must develop a permanent energy information system with a built-up auditing program on every aspect of the energy situation -- reserve refining operation, inventories and production costs -- so that we will be in a better position to assure the American people that our energy data is accurate and not subject to the change that it can be manipulated by industry.

. There must then be a new government role in the international activities of the oil industry.

. Finally, there must be a new partnership to assure the development, extraction and use of our domestic energy sources, including geothermal energy.

If we are to see the successful culmination of Project Independence, the Federal government must work hand-in-hand with American industry.

For the last five years, the President has provided for a continual expansion of our efforts in energy research and development. Federal funding increased almost 75 percent from $362 million in fiscal year 1970 to $672 million in fiscal year 1973 and was then raised to $1 billion for fiscal year 1974. Last June the President announced a commitment to an even more rapid acceleration of this effort through a $10 billion Federal program over the next five years, and he stressed that we would spend whatever additional sums were reasonably necessary.

On Wednesday, January 23, 1974, the President announced that in fiscal year 1975 -- the first year of the five year energy R&D program--total Federal commitment for direct energy research and development will be increased to $1.8 billion, almost double the level of a year ago. Included in this budget is $44.7 million for geothermal energy R&D. This figure represents a 310% increase over the FY 1974 level and is ten times the amount of Federal spending on geothermal R&D in FY 1973. It is only with the help of such accelerated research and development that we can achieve real self-sufficiency in energy.

Fifth, we must establish a framework of international cooperation among producing and consuming countries. The potential impact of energy supplies on the world economy is staggering and we must work together in developing energy resources and maintaining a healthy world economy in which energy exporting and energy importing nations prosper together. Greater cooperation must be initiated on research projects, on new ways to conserve energy and most important on establishing energy prices.

In this regard, I would like to point out in passing that for the past year the Bureau of International Scientific and Technological Affairs in the Department of State has had a special concern for promoting U.S. cooperation with other nations in the area of R&D on new or alternative forms of energy. Geothermal energy is one of the highest priority items on the cooperative R&D agenda, and several bi-lateral and multilateral agreements are now underway.

In the context of this overall policy, I will summarize the proposed Federal Energy R&D Organizational Structure because its impacts directly on the proposed bill.

Organization

. Federal Energy Office/Agency

The Federal Energy Office currently has broad policy and regulatory responsibilities for energy. It is now administering energy price and allocation programs, initiating energy conservation programs, working with the State Department on international aspects of energy, developing programs to increase energy supplies and working with OMB to coordinate energy R&D activities.

. <u>Federal Energy Administration</u>

The FEO programs designed to deal with the near and intermediate term problems (i.e. prior to 1985), will become the responsibilities of the Federal Energy Administration upon congressional approval. One of the major functions of this organization, as mentioned in the President's January 23, 1974, Message, will be to rapidly increase energy supplies. This is really the principle task of Project Independence. Within the FEA, the Office of Energy Resource Development will be aimed at this goal. This office will identify and develop means of overcoming problems and providing incentives for the:

- Development of Domestic Energy Sources
- Construction of Related Facilities (e.g., refineries, power plants, transmission systems, etc.)
- Transportation of Energy
- Conversion of Energy Sources to move Convenient Forms
- Utilization of Energy Sources
- Full Consideration of Environmental Values
- Elimination of Regulatory Problems

. Federal Energy Office

Energy policy is broad-based and reaches into all areas of government. For example, it encompasses building codes, environmental matters, international aspects, etc. And it is important to consider the impacts of energy policy on such diverse groups as farmers, poor people, and businessmen. Therefore, even after the formation of the FEA, there may still be the need in the Executive Office of the President for an FEO with responsibility providing coordination across the Government in matters of energy policy. This office will deal with a broad range of policy issues including those related to R&D. In particular, it will coordinate the energy related programs of EPA, NASA, DOT, DOD, NSF, DOC, DOI, etc.

. Energy Research and Development Administration

Also with Congressional approval, R&D programs to develop new technologies which would have an impact in the mid and longer term (beyond 1985) will be the responsibility of the Energy Research and Development Administration (ERDA). ERDA would include the research and development as well as the production functions of the Atomic Energy Commission, along with selected energy R&D functions of the Department of the Interior, the National Science Foundation, and the Environmental Protection Agency. Thus, the agency would bring all major energy R&D programs within the Federal government under one management structure.

. Department of Energy and Natural Resources

As the longer-run solution to the many interrelated problems in the energy and natural resources area, the President proposed the establishment of this new department. DENR would incorporate most of the responsibilities of the Department of the Interior; the activities of the Forest Service and certain water resource functions of the Department of Agriculture; the activities of the National Oceanic and Atmospheric Administration of the Department of Commerce; the water resource planning functions of the Corps of Engineers, the gas pipeline safety functions of the Department of Transportation, and the Water Resources Council. Drawn together, these responsibilities would form the basis of a modern department truly capable of providing a much needed balance between the wise utilization and careful conservation of our Nation's precious natural resources.

Once DENR is established, it should incorporate the functions of ERDA & FEA.

Near Term Use of Geothermal Energy

Naturally occurring geothermal steam is today generating many megawatt hours of electricity in the United States. And with proper incentives, geothermal energy could be used to generate substantially more electricity in the near future. The Geothermal Steam Act of 1970 is an example of how the Federal Government can stimulate private industry to develop this important resource.

We are encouraged by the results of the first bids received in the Federal geothermal leasing program. As you know, bids were received on 26,190 acres of know geothermal resource areas, with the total of the highest bids being $6,812,000. This expressed interest on the part of the private industry of this country in geothermal energy sources is indicative of the role geothermal energy could play in the near term in special regions of the country.

However, the leasing of Federal lands alone will not insure the development of an extensive geothermal power industry. Many barriers still remain, including those of an institutional as well as a technological nature, and further Federal incentives may be necessary to overcome these barriers. The Federal Energy Office will be evaluating the financial incentives or regulatory changes that may be needed to spur the rapid development of our geothermal resources. And we expect that, with Congressional approval, the Federal Energy Administration will apply the incentives selected in this evaluation in order to allow geothermal energy to make its fullest contribution to Project Independence.

Longer Term Potential of Geothermal Energy

Even though we expect geothermal energy to contribute in some measure to the domestic supply of energy in the 1970's, we recognize that the full potential of geothermal energy can only be reached if we develop the technologies to extract energy from the more common geothermal sources:

hot waters and dry hot rock formations, as well as from geopressured systems. We agree with the subcommittee that Federal financial assistance will be necessary to encourage the extensive exploration, research and development which will be required to bring these technologies to the point of commercial application. And as I have already noted, in the President's 1975 energy budget, $44.7 million were allotted for geothermal energy research and development. However, the thrust of this effort is somewhat different from that of the proposed bill and I will now discuss our views on H.R. 11212.

Comments on H.R. 11212.

. <u>Technological Aspects of Program</u>

The geothermal R&D agenda proposed by the Administration will include exploration and assessment of the various types of geothermal resources. Geopressured systems and hot rock formations will be included, but so will a variety of hydrothermal systems. Component technologies will be developed for the total spectrum of resource types and pilot facilities for several types will be planned and some construction will begin in FY 1975. Considerable attention will be paid to the environmental factors associated with geothermal energy development. Participation of the USGS, NSF, AEC labs, private industry and universities is expected.

This program was assembled with the cooperation of the many Federal agencies concerned with geothermal energy along with consultants from private industry and universities. We support it in preference to H.R. 11212.

. Adequacy of Proposed Funding Level

The funds provided by H.R. 11212 - $80M for 6 years - are less than twice the funds that will be needed in the first year alone of the Administration's program. We believe that the funding proposed by the Administration is more realistic and will result in more rapid solution of the problems currently preventing widespread utilization of geothermal energy.

. Length of Time for the Program

The production of electricity from hot dry rock will require the development of exploration, accessing and fracturing technology as well as suitable power generating equipment. To assemble a commercial power generating system which incorporates all these aspects could require a period in excess of 6 years - the time frame of H.R. 11212.

Power generating systems for the various resource types will have much common technology. We believe that by building plants to generate electricity from certain types of hydrothermal systems, many of the problems involved in utilizing geopressured and hot rock systems will be solved. Consequently, an integrated and comprehensive geothermal program, as proposed by the Administration, will provide for a greater utilization of geothermal energy in a shorter period of time. However, we must be prepared for an R&D effort that could extend beyond 6 years.

. Administrative Mechanism

In order to capitalize on the potential of geothermal energy, it will be desirable to have a centralized Federal organization, that provides support for geothermal energy within an overall energy context. We believe the Administration's proposed energy package, which includes FEA and ERDA would be the most suitable administrative mechanism for accelerating the development of geothermal energy.

Because of the variety of geothermal resources, encompassing immediately exploitable dry steam field as well as undiscovered hot rock formations, a federal program with continuity between the near term solutions and longer term results is essential. Certain types of geothermal resources can be expected to be used to meet a portion of the Nation's energy needs within the next 5-10 years, as I have discussed. The FEA, which has been proposed by the President to rapidly increase energy supplies, is preprepared to include geothermal energy among those sources of domestic energy supply which it will seek to develop. On the other hand, R&D on those geothermal sources which will be exploited in the longer term, would be carried out by ERDA, upon Congressional approval of the President's proposal to create such an agency. ERDA would include and expand on work presently being conducted at several AEC laboratories, as well as the development effort currently sponsored by the National Science Foundation. ERDA would thus consolidate much of the Federal R&D on geothermal energy and incorporate it into a management structure capable of effectively carrying out the multi-disciplinary program necessary to insure that geothermal energy will make a significant contribution to the Nation's energy future. Those aspects of geothermal R&D which remain in other Federal agencies (such as the U.S. geological survey) will be closely coordinated with the programs of ERDA. As I mentioned, such coordination will be part of the responsibilities of the FEO.

Concluding Remarks

In conclusion, I would like to say that we at the Federal Energy Office agree with the subcommittee's views that the Nation's critical energy problems require a national commitment to dedicate the necessary financial resources and enlist the cooperation of the private and public sectors to develop geothermal and other non-conventional energy sources. We have indicated the Administration's desire to be just that. Moreover, we have described the functions of our current Federal Energy Office and the plans to form new organizations with the capability to handle the near term and longer term energy problems of this country in a coordinated manner.

We are fully prepared to move ahead with these plans. However, we need the legislative tools proposed in the package by the President and we strongly urge your support and swift enactment of these bills to ensure, not only the rapid development of geothermal energy, but the general advance of energy technology towards meeting our national goal of energy self-sufficiency.

STATEMENT OF DR. JOHN C. SAWHILL
DEPUTY ADMINISTRATOR, FEDERAL ENERGY OFFICE
BEFORE THE SUBCOMMITTEE ON THE ENVIRONMENT
COMMITTEE ON INTERIOR AND INSULAR AFFAIRS

HOUSE OF REPRESENTATIVES

January 31, 1974

Mr. Chairman and Members of the Committee:

I appreciate the opportunity to appear before you today to address the important issues of the Nation's future energy research and development policy.

Few subjects are being discussed more extensively in the United States today than the energy situation. Although the analysis is not complete, the conclusions are clear: We must reduce energy demand and increase supply. These measures must be consistent with an acceptable environment, continued economic health, adequate national security, and tranquil foreign relations.

However, before I come to the details of our Energy R&D policy, I would like to review our overall approach to energy policy.

Five-fold Approach to Energy Policy

Let me start by outlining the five-fold approach we are taking with respect to energy policy.

First, we must establish a central energy organization in the Federal Government. The creation of the Federal Energy Office is the first step toward bringing all energy policy activity under one roof. We hope that Congress will move quickly to provide a statutory base for the Federal Energy Administration. We need legislation to provide us with the capability to recruit and hire top-flight administrators and to let contracts with qualified performers so that we can build the organization needed both to run the short-term allocation program and to carry out the more important assignment of moving the country toward energy self-sufficiency. Beyond FEA and ERDA, we must press forward with the creation of a cabinet-level Department of Energy and Natural Resources to ultimately bring together all Federal energy-related responsibilities. Until these new organizations are created, the Federal Energy Office will provide leadership and coordination in energy matters.

Second, we must establish a permanent "conservation ethic" in this country. We have been too extravagent in our energy consumption patterns. With 6 percent of the world's population, we consume 35 percent of the world's energy. The recent embargo has forced us to reduce this consumption now, but even more important we must be sure that an attitude of conservation becomes a permanent part of our lives.

Over 30 percent of our energy is wasted in one way or another -- wasted in conversion from one form to another, wasted in transmission, and wasted in unnecessary usage. Over the long-term, conservation of energy will require investment in insulation of homes and offices, use of more efficient automobiles, development of mass transit, changes in methods of handling freight, and central heating plants for groups of buildings and towns.

Third, we must push forward in the development of our domestic energy resources through Project Independence. This includes further development of oil and gas in Alaska and the outer continental shelf, greater utilization of coal, of which we have a supply unmatched by any other country in the world, further development of oil shale and nuclear power, and added efforts toward development of geothermal and solar power. Project Independence must be a two-pronged attack. In the short-run, we must both expand production and exploit untapped reserves of existing energy sources. Longer range solutions will be provided by the development of new and existing fuels.

Specifically, this program should include the following:

We must find ways to exploit our coal reserves more effectively. We have 1 trillion, 500 billion tons of identifiable coal reserves, or half of the non-Communist world's reserves, 425 billion tons of which are economically recoverable now. We must develop ways to utilize this abundant resource. We must develop techniques for mining surface coal that do not destroy the landscape. We must also develop ways to deep mine coal that protect the health and safety of miners.

We have talked for years about the production of oil from our oil shale. There are an estimated 1 trillion, 800 billion barrels of oil in the shale resources in the U.S., and just those reserves that we presently know are exploitable could satisfy our needs for oil for decades. We need an increased effort by both the Federal government and private industry to develop this potentially productive resource. I am especially encouraged by recent progress in the _in situ_ processes for extracting shale oil. This progress suggests that it may be possible to produce shale oil at less than the current cost of Persian Gulf crude. _In situ_ extraction should also have minimal impact on the environment and its development must be encouraged.

We also have to push forward in the development and utilitzation of nuclear power. The Administration will soon submit legislation to expedite the licensing and construction of nuclear powerplants which are an essential part of our program for achieving energy self-sufficiency. We should also develop a broader nuclear program which looks toward liquid metal and other breeder reactors. In addition, top priority must be given to assuring that nuclear powerplants are built and operated safely with acceptable environmental impact.

We have also talked for years about development of such relatively distant alternatives to fossil fuels as fusion, geothermal and solar energy. For the next decade these alternatives are still very much in the research and development stage of growth and they could not come into widespread use until after 1990. Although we have to invest in the development of these alternatives, our primary focus now must be on nearer term measures for expanding energy supplies.

Fourth, we must forge a new relationship between Government and industry in several key areas.

- The information we now have to work with is not adequate and its reliability cannot be checked. We must develop a permanent energy information system with a built-in auditing program on every aspect of the energy situation -- reserves, refining operation, inventories and production costs -- so that we will be in a better position to assure the American people that our energy data is accurate and not subject to the change that it can be manipulated by industry.

- There must then be a new government role in the international activities of the oil industry.

- Finally, there must be a new partnership to assure the development, extraction and use of our domestic energy sources. And, nowhere will the need for the combined efforts of industry and Government be greater than in energy research and development. If we are to see the successful culmination of Project Independence, the Federal government must work in partnership with American industry.

For the last five years, the President has provided for a continual expansion of our efforts in energy research and development. Federal funding increased almost 75 percent from $362 million in fiscal year 1970 to $672 million in fiscal year 1973 and was then raised to $1 billion for fiscal year 1974. Last June the President announced a commitment to an even more rapid acceleration of this effort through a $10 billion Federal program over the next five years, and he stressed that we would spend whatever additional sums were reasonably necessary.

On Wednesday, January 23, 1974, the President announced that in fiscal year 1975 -- the first year of the five year energy R&D program -- total Federal commitment for direct energy research and development will be increased to $1.8 billion, almost double the level of a year ago. It is only with the help of such an accelerated research and development program that we can achieve real self-sufficiency in energy.

Fifth, we must establish a framework of international cooperation among producing and consuming countries. The potential impact of energy supplies on the world economy is staggering and we must work together in developing energy resources and maintaining a healthy world economy in which energy exporting and energy importing nations prosper together. Greater cooperation must be initiated on research projects, new ways to conserve energy and most important establishing energy prices.

In the context of this policy, I would like to summarize the proposed Federal Energy R&D Organizational Structure. Then I will outline briefly our short and longer range Energy R&D goals.

Organization

Federal Energy Office/Agency

The Federal Energy Office currently has broad policy and regulatory responsibilities for energy. It is now administering energy price and allocation programs, initiating energy conservation programs, working with the State Department on international aspects of energy, developing programs to increase energy supplies and working with OMB to coordinate energy R&D activities.

Federal Energy Administration

The FEO programs designed to deal with the near and intermediate term problems (i.e. prior to 1985), will become the responsibilities of the Federal Energy Administration upon congressional approval. One of the major functions of this organization as mentioned in the President's January 23, 1974, Message will be to rapidly increase energy supplies. This is really the principle task of Project Independence. Within the FEA, the Office of Energy Resource Development will be aimed at this goal. This office will identify and develop means of overcoming problems and providing incentives for the:

- Development of Domestic Energy Sources
- Construction of Related Facilities (e.g., refineries, power plants, transmission systems, etc.)
- Transportation of Energy
- Conversion of Energy Sources to move Convenient Forms
- Utilization of Energy Sources
- Full Consideration of Environmental Values
- Elimination of Regulatory Problems

Federal Energy Office

Energy policy is broad-based and reaches into all areas of government. For example, it encompasses building codes, environmental matters, international aspects, etc. And it is important to consider the impacts of energy policy on such diverse groups as farmers, poor people, and businessmen. Therefore, even after the formation of the FEA, there may still be the need in the Executive Office of the President for an FEO with responsibility for providing coordination across the Government in matters of energy policy. This office will deal with a broad range of policy issues including those related to R&D. In particular, it will coordinate the energy related programs of EPA, NASA, DOT, DOD, NSF, DOC, DOI, etc.

Energy Research and Development Administration

Also with Congressional approval, R&D programs to develop new technologies which would have an impact in the mid and longer term (beyond 1985) will be the responsibility of the Energy Research and Development Administration (ERDA). ERDA would include the research and development as well as the production functions of the Atomic Energy Commission, along with selected energy R&D functions of the Department of the Interior, the National Science Foundation, and the Environmental Protection Agency. Thus, the agency would bring all major energy R&D programs within the Federal government under one management structure.

Department of Energy and Natural Resources

As the longer-run solution to the many interrelated problems in the energy and natural resources area, the President proposed the establishment of this new department. DENR would incorporate most of the responsibilities of the Department of the Interior; the activities of the Forest Service and certain water resource functions of the Department of Agriculture; the activities of the National Oceanic and Atmospheric Administration of the Department of Commerce; the water resource planning functions of the Corps of Engineers, the gas pipeline safety functions of the Department of

Transportation, and the Water Resources Council. Drawn together, these responsibilities would form the basis of a modern department truly capable of providing a much needed balance between the wise utilization and careful conservation of our Nation's precious natural resources.

Once DENR is established, it should incorporate the functions of ERDA & FEA.

Having outlined our overall approach to energy policy and described our organization, I will now outline the goals of our energy research and development policy.

We have tried to visualize our energy R&D policy in terms of what must be done in the relatively short range - say up to the mid 1980's; and what must be done in the long-term beyond the 1980's. The R&D strategies appropriate for dealing with the short-range are in general not the same as those appropriate for the long-range, and so I will discuss them separately.

Short Range R&D

In the short-range our primary shortage is oil and gas. Hence, our underlying strategy for dealing with the short-range is:

1. To encourage conservation measures, both by improved technology and by regulatory action.

2. To increase our domestic supply of gas and oil.

3. To substitute insofar as possible fuel resources which we possess in abundance, mainly coal and nuclear, for the oil and gas which is in short supply.

4. To meet the foregoing demands in an environmentally acceptable manner.

Research can make some contribution towards implementing these short-range strategies, but the real payoff from research will come in the next decade. Our progress towards self-sufficiency between now and 1980 will depend, for the most part, on our ability to implement existing technology rather than on the results of new research.

1. Conservation

In the short-run conservation measures will have to play a major role in closing the gap between demand and domestic production. We must reduce demand growth from the present rate of 4-1/2% to 3% or less. The AEC estimates that a crash conservation program could save as much as 7 million barrels of oil per day. Much of the expected 7 million barrels/day saving will come not from R&D per se but rather by implementing policies aimed at energy conservation. However, there is some R&D that should help reduce consumption of energy, particularly oil and gas. For example, better insulation of houses, more efficient automobile engines, and more efficient power cycles can save energy without causing economic or social dislocation. Thus, our research program must concentrate on these areas.

2. Increase domestic supply of gas and oil

To increase our domestic supply of gas and oil involves both the application of existing technology and the creation of new technology. Application of existing technology would include such techniques as secondary and tertiary recovery from existing oil fields and greatly expanded exploration for new oil and gas reservoirs, particularly on the Outer Continental Shelf.

The undiscovered oil and gas on Federal lands and beneath our Outer Continental Shelf can provide a significant portion of the energy necessary to make us self-sufficient. At the present time, we are working with the DOI to increase the acreage leased on the Outer Continental Shelf to 10 million acres beginning in 1975, more than tripling what had originally been planned. In later years, the amount of acreage to be leased will be based on market needs and on industry's record of performance in exploring and developing leases. In contracting for leases, we will also be working with DOI to insure that the proper competitive bidding procedures are followed and that environmental safeguards are observed.

An interagency program for monitoring the environmental aspects of the new leasing program is being set up. However, there will be no decision on leasing on the Outer Continental Shelf in the Atlantic and in the Gulf of Alaska until the Council on Environmental Quality completes its current environmental study of those areas.

In addition to the OCS program, we must move rapidly to exploit our resources in Alaska. It has long been clear that while an Alaskan oil pipeline was needed, it alone would not be enough. In addition to the huge oil reserves in the North Slope of Alaska, there are also gas reserves there of at least 26 trillion cubic feet -- enough to heat 10 million homes for 20 years. We are working with DOI on a study the President directed to determine the need for future Alaskan oil and gas pipeline capacity including the best routes should they prove necessary.

I would mention here also, the extraction of oil from shale. This can be done now; the main question is can it be done in an environmentally acceptable manner? We must give this matter extensive study. I would hope that even in the relatively short run, the results of our current research will enable us to extract significant amounts of oil from shale without doing serious damage to the environment.

3. <u>Substitute coal and nuclear energy for oil & gas</u>

This is a general strategy which will be appropriate both in the short-range and in the long-range. Here we can identify two separate approaches -- direct substitution and coal conversion.

a. <u>Direct substitution of coal for oil and gas in industrial and utility applications.</u> Substitution requires some R&D since the main problem in burning coal is control of undesirable effluents. We have a large program devoted to stack gas clean-up; there is every reason to expect this program to be successful, thus allowing us to substitute coal for a substantial amount of the oil and gas we now burn. Some experts have estimated that by 1985 we might save as much as 6 million barrels per day through direct substitution - 2 million barrels per day through direct replacement of oil under utility boilers, 1 million barrels per day in residential and commercial space heating (primarily through heat pumps) and 3 million barrels per day in industrial processes.

b. <u>Conversion of coal into liquids and gasses.</u> Techniques for liquifying and gasifying coal are fairly well known. However, in general these methods are expensive and will require further development before they become commercially feasible. If a crash program is started now, we might be able to replace as much as

3 million barrels per day of oil with synthetic fuels made from coal.

We thus visualize coal emerging as a very central element in our energy picture by 1985. There are some estimates that suggest that by then we shall have to mine as much as 1500 or even 1800 million tons of coal per year. This represents a tripling of our coal production - and to achieve this will require considerable research on better methods of extracting coal to insure that extraction methods are environmentally acceptable.

c. Expand the use of nuclear energy. This involves R&D on nuclear safety, waste disposal, siting of nuclear reactors, and thorium systems, as well as providing additional separative work capacity, and above all, assuring an adequate supply of U_3O_8. The latter requirement may require further work on mining and exploration. Siting is also an important element of our nuclear strategy since, in the absence of a rational siting policy for nuclear reactors, the nuclear option may be jeopardized. We urge Congress to give careful consideration to the energy facilities siting bill which we will be submitting in the near future.

4. Environmental considerations

In pursuing the foregoing aims, high priority must be given to establishing the scientific basis for environmental constraints, and, if possible, to reconciling them with practical considerations. However, we must recognize that establishing acceptable standards for low level insult is inherently difficult, and often impossible. Too much should not be expected from a crash program aimed at placing emission standards on a firm scientific footing.

Long Range R&D

Our long-range goal is first to eliminate, if possible, our dependence on foreign oil and gas; and second, to gradually transform the base of our energy system from the non-renewable fossil fuels to non-fossil fuels, mainly nuclear, geothermal, solar (and solar's children - hydro, wind, waves, ocean thermal gradients, and possibly biological sources). Since the long-range goals are necessarily uncertain, we believe that long-range R&D should retain as much flexibility as possible: we must not foreclose any of our options prematurely. What are the options?

1. Coal

Fortunately the country is well endowed with coal. The challenge is to learn how to transform our coal. The challenge is to learn how to transform our different types of coal through a variety of processes into acceptable gaseous and liquid fuels suitable as substitutes and replacements for dwindling supplies of petroleum and gas. Thus, low-Btu gas, which is probably marginal in the short-range looms with high priority in the long-range. And perfection of processes for coal hydrogenation leading to production of syncrude and syngas must be supported to the limit of scientific creativity.

2. Nuclear

Nuclear energy must be considered of most importance for the long-range primarily because it gives mankind an essentially inexhaustible energy source, one that is relatively independent of mineral resource costs. At the present time the breeder reactor is the only nuclear technology that can be counted upon today to achieve the nuclear promise. Thus, research and development of the LMFBR must be continued in a timely fashion and work on other breeder reactor concepts (light water breeder, gas cooled fast breeder, and molten salt breeder) must be supported and expanded to retain them as viable alternatives.

Controlled fusion energy is an exciting scientific field that has attracted and continues to attract some of the Nation's top scientific talents. Recent U.S. progress in duplicating and moving beyond the Soviet Union's success with Tokamak devices coupled with promising new concepts based on a maturing laser technology have stimulated new interest in and provide incentive for continued support of fusion research. However, practical fusion energy is only a hope until scientific and technical feasibility can be established.

3. Geothermal

Naturally occurring geothermal steam is today generating many kilowatt hours of electricity. The prospect of a very extensive resource of geothermal energy depends upon being able to recover, in a practical way, heat from dry hot rock lying deep below the earth's surface. Thus, the promise of geothermal energy must await results of research both on the extent of the geothermal resource and our ability to recover it.

4. Solar

The use of solar energy is attractive and there are many ideas for using solar energy directly for building and water heating that could be applied today if the problems of cost and public acceptance could be overcome. However, we cannot count on the sun as a major source of energy until there is much better evidence, hopefully to be provided by an expanded research effort, that solar energy can contribute to the large scale production of electricity and/or synthetic fuels.

5. Others

There are many other elements to be included, at small scale, in the long-range energy research plan (e.g., ocean gradients, winds, waves, wastes, topping cycles); with two possible exceptions they do not appear as important as the technologies of conservation, coal, nuclear, geothermal and solar. One exception is hydrogen or some other synthetic fuel; most likely its source will be improved electrolysis but thermal and biological methods of water decomposition deserve attention also. The other exception is improvement in electrical transmission - in particular the superconducting cable - possibly a key element in a world electrical energy system in the post fossil fuel era.

Let me close with the following general observation about energy R&D. It is the nature of R&D that the future is uncertain: we cannot guarantee that any of the long-range options, especially those for which scientific feasibility has yet to be demonstrated will indeed work. But we believe it is imperative that we mount a massive, serious effort at uncovering the possibilities - at determining as soon as we can which of the leads are promising, which are false. For in the very long run our own country as indeed the world's future depends on a flow of adequate energy. This can be had, we believe, only through the kind of R&D enterprise that our country is now committing itself to.

Conclusions

In conclusion, I would like to add that the approach toward R&D should be one of flexibility since it will not be possible to anticipate every success or failure in Project Independence or in ERDA's program. However, we have told you about our plans in general, the current organization and missions of the FEO and the FEA as well as our thinking on coordination with other agencies and with ERDA and DENR. We are fully prepared to move ahead with these plans. However, we need the legislative tools proposed in the package by the President and we strongly urge your support and swift enactment of these bills.

STATEMENT OF DR. JOHN C. SAWHILL
ADMINISTRATOR, FEDERAL ENERGY OFFICE
BEFORE THE SUBCOMMITTEE ON ENERGY
COMMITTEE ON SCIENCE AND ASTRONAUTICS

HOUSE OF REPRESENTATIVES

MAY 7, 1974

Mr. Chairman and Members of the Committee:

I am pleased to be here again today to discuss H.R. 14172, the proposed "Geothermal Energy Research, Development and Demonstration Act of 1974." On February 7, 1974, when I appeared before this Committee, we discussed H.R. 11212. Today we are discussing a modified version of the bill which reflects many of the suggestions I made on the earlier version.

Back in February, I outlined briefly the Administration's overall approach to energy policy and the role we hope geothermal energy will play. Before commenting on the legislation before us, I would like to update this broader view of the situation.

In the three months since early February, we have moved from an acute energy crisis affecting citizens directly through long gas lines to a situation in which for many individuals the energy problem appears to be solved. The lifting of the Arab oil embargo last month was the major contributing factor, but energy conservation by citizens throughout the country played a key role in reducing the supply-demand gap. We are pleased to be able to report an improved petroleum supply situation this month.

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Certainly it is a relief to everyone that the onerous gasoline lines have been eliminated and that motorists can buy the gasoline they need when they want to. The real question is whether individuals and industry will continue to conserve enough energy so that the continuing gap between available oil supplies and unrestrained demand will not lead to spot shortages again this summer. In addition, there is a question whether all of us, the Executive Agencies, the Congress and the general public will continue to make the difficult decisions about energy supply, consumption, and planning necessary to overcome the fundamental problems which allowed the Arab embargo to precipitate a domestic energy crisis.

Now that the FEO, has strengthened its organization and staff, and the immediate problems of allocations are behind us, we are devoting a major effort to developing detailed plans and actions for Project Independence. The President has directed us to prepare a comprehensive report outlining in depth the goals and objectives of Project Independence and the actions necessary to achieve these goals. We will prepare the report by late next Fall outlining the legislation needed to achieve energy self-sufficiency and the new relationship that must be forged between the government and private industry.

The Project Independence effort is centered within FEO, but it includes participants from all of the cognizant Federal agencies, as well as representatives from the private sector. It focuses on two separate but related activities -- an Early Action Program is aimed at removing the governmental and other potential roadblocks hampering the exploitation of existing technologies. The Project Independence Blueprint effort will analyze the many technical and policy options available and recommend a series of actions necessary to reduce the nation's vulnerability to supply cutoffs to tolerable levels. A whole range of supply and consumption options, together with the economic, environmental and other constraints on them, is now being evaluated. Our intent is to complete this work and make recommendations to the President in October.

We have included geothermal energy as one of the energy resources to be assessed in this Blueprint effort. A task force, chaired by Richard Green of the National Science Foundation, is now engaged in determining how much geothermal sources can contribute to the nation's energy economy over the next 15 years. Several different policy assumptions are being evaluated.

In parallel with our efforts on Project Independence, the Congress has been making progress toward enacting the reorganization legislation needed to carry it out. The Conference Committee report on the bill to establish FEA has been passed by the House and I hope it will be acted upon by the Senate within the next few days. The bill to establish ERDA has not progressed quite so far, but a marked-up version is now before the Senate Government Operations Committee and action is expected shortly. The Administration gives high priority to both of these bills and urges their swift enactment to provide the organization to advance the goals of Project Independence.

I would like now to address H.R. 14172 and the major points raised in your letter of April 10, 1974. As I mentioned at the outset, this revision reflects many of the suggestions I made in my previous testimony. The scope of the bill has been extended to include all geothermal resources, not just those farthest from commercial operation. Geothermal resource exploration and assessment, as well as general research and development projects, are now encompassed by the bill. The early termination date of the Act has been eliminated and the proposed level of funding has been dramatically increased to a level compatible with the President's FY 1975 budget requests.

As revised, the bill provides a major impetus to the nation's geothermal program by focusing on management of the effort, directing an R&D program to resolve technical problems, initiating a demonstration program, and providing loan guarantees. Although we strongly support the overall objective of the bill in moving the development of geothermal energy forward as expeditiously as possible, we have several reservations about the bill itself.

As you know, once ERDA is established it will be charged with the responsibility for overseeing the research and development of all new sources of energy including, geothermal energy. One question which should be addressed, therefore, is whether a new organization to oversee the geothermal R&D effort is needed in the interim period before ERDA becomes operational. Another question is what effect the enactment of H.R. 14172 will have on the overall energy R&D program to be administered by ERDA.

As I mentioned in my letter to the Chairman of February 8, 1974, the National Science Foundation has already been designated the lead agency for geothermal R&D and is actively fulfilling this role. The Atomic Energy Commission is also an active participant in geothermal R&D as are three separate entities within the Department of the Interior: the U. S. Geological Survey, the Bureau of Mines and the Bureau of Reclamation. In addition, the Bureau of Land Management is administering the geothermal leasing program. Geothermal R&D efforts are already underway in these agencies. The Administration has proposed a 1975 budget of $44.7 million for these geothermal R&D activities -- a figure which compares very favorably with the level of funding which would be provided by H.R. 14712. The geothermal R&D functions of NSF and AEC, of course, are scheduled to be transferred to ERDA.

At this point, one must ask the question whether in moving geothermal development ahead, during both the short run and the long run, it would be most effective to set up a Geothermal Energy Coordination and Management Project now and then transfer the function to ERDA? Or, would it be better to leave NSF as lead agency in the interim and allow the Administrator of ERDA maximum flexibility in establishing the most effective management organization?

Focusing on the short run, we are concerned that the Geothermal Energy Coordination and Management Project established by H.R. 14172 would add another layer to the existing structure and might serve to complicate the eventual transfer of on-going geothermal R&D projects to ERDA.

Turning to our long run objectives, it has always been our position that energy R&D programs including those related to geothermal energy, should be consolidated under one central management structure with sufficient flexibility to ensure that all the various sources of energy will make significant contributions to the nation's future energy needs. We believe that H.R. 14172, by establishing a specific set of tasks and goals as well as a separate organizational structure for a geothermal R&D project within ERDA, could interfere with the requisite degree of flexibility which will be needed if ERDA is to shape our overall energy R&D efforts effectively.

In addition to these general thoughts on the overall management structure, we would like to comment briefly on several specific provisions of H.R. 14172.

Sections 101 and 103 of the proposed bill would add another agency, NASA, to the list of agencies already involved in the managment of geothermal R&D. While it is important to make use of the best talent available within the Federal Government to carry out this program, I do not think it is necessary to give NASA a statutory role in geothermal energy. The existing agencies and ERDA would be able to transfer funds to agencies such as NASA for specific tasks. A statutory geothermal role for NASA would further complicate transferral of geothermal R&D programs to ERDA.

Section 101(b) of the proposed bill would require the Geothermal Energy Coordination and Management Project and eventually ERDA, acting through the U. S. Geological Survey, to survey and execute an inventory of geothermal resources. The responsibility for inventorying energy resource has long resided in the Department of the Interior and has been tied closely to that Department's leasing activities. Since Interior will remain responsible for leasing, ever after the enactment of the ERDA legislation, we believe the inventory and resource assessment programs should remain the responsibility of the Department of the Interior

Section 106(a) as well as several other sections of the proposed bill appear to treat oil, gas and helium as by-products of geothermal resources. If this is true, then the bill would expand the defintion of by-products contained in the Geothermal Steam Act of 1970. Such an expansion might create conflicts in administering leases under the Geothermal Act of 1970 and the Mineral Resources Act.

Section 106 would also mandate the establishment of a geothermal demonstration program. Clearly demonstration plants must be built and operated if this technology is to have a broad impact on the nation's energy supply. The question is really who should build the plants and when. At this time, it is not clear just when medium and large scale demonstration plants funded by the government would be appropriate. The approach used in the development of nuclear power has been for an industry group or individual firm to own and operate the demonstration facility with the government providing funds for the R&D and other extraordinary costs. By this arrangement the government avoids entering the utility or mineral extraction business and encourages more rapid commercialization, while at the same time providing both funding and technical support. This method is not the only one for demonstrating electric generating technologies but it is an important one which should be included in demonstration programs.

Title 2 of H.R. 14172 would establish a loan guarantee program to encourage the commercial production of geothermal energy. Loan guarantees, of course, are just one of many methdds for encouraging technological innovation and development in the geothermal area. Other techniques such as direct grants, tax breaks and government purchasing agreements may have a role to play as well.

Two complimentary efforts are now being addressed to understanding the most appropriate incentives for development of geothermal energy by private industry. In his January 23, 1974, energy message to Congress, the President directed the Federal Energy Office to establish an interagency working group to evaluate the financial, economic and regulatory changes that might be used to stimulate synthetic fuel production and other new energy sources. This study is now an integral part of FEO's Project Independence Blueprint effort. The results of this evaluation will obviously have broad application and will be included in the final Project Independence Blueprint report scheduled to be presented to the President in October.

The National Science Foundation has also identified economic incentives as one of several important areas it intends to focus on in its initial problem definition studies. These studies are designed to define the insititutional, legal and environmental problems surrounding the development of geothermal energy and to assess the resource and technical uncertainties which appear to be inhibiting development of geothermal energy by private industry.

Once the results of these two efforts are available, we will be in a better position to comment on the types of financial incentives which we best pursue in the geothermal area. We would hope that the results of these studies could be brought to bear before any one incentive is selected. Therefore, we feel that the establishment of a loan guarantee program at this time might be premature.

In summary, the Federal Energy Office concurs with the objective of moving ahead as rapidly as possible to bring geothermal energy into widespread commercial use. An active geothermal R&D program spearheaded by the National Science Foundation with assistance from the AEC and with the Department of the Interior is already underway.

We believe that the long range goal of promoting the discovery and utilization of new sources of energy, including geothermal energy, lies in establishing ERDA and FEA. Our reservations about H.R. 14172 suggest that it might be more prudent to move ahead with the organization of the two agencies as soon as possible rather than to set up new machinery in the interim.

This concludes our testimony. I would be pleased to respond to any questions you may have.

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STATEMENT OF WILLIAM E. SIMON
ADMINISTRATOR, FEDERAL ENERGY OFFICE
BEFORE THE SENATE
APPROPRIATIONS SUBCOMMITTEE ON INTERIOR AND RELATED AGENCIES
MARCH 20, 1974

Mr. Chairman and members of the Committee: I am pleased to have the opportunity to discuss with you some significant aspects of the energy situation before discussing our budget request. My comments fall into five major categories:

1. The short-term situation,
2. How this situation arose,
3. A five-fold approach to energy policy aimed at dealing with our long-term and short-term problems,
4. The organization of the Federal Energy Office, and
5. An overview of the FEO budget.

THE SHORT-TERM SITUATION

Today, I want to discuss some of the short-term problems caused by the oil embargo but first I would like to remind you what the prophets of doom were saying last November. It was widely stated that the embargo would result in power blackouts, freezing homes, galloping inflation and large-scale loss of jobs; in short, a massive dislocation of this country's economy. This has not happened. We made a conscious decision to preserve jobs and keep our homes warm at the expense of having as much gasoline as we would like. It is true, for example, that there has been some loss of jobs in the automobile industry and in those sectors of the leisure and recreation industries that are heavily dependent on the automobile, but this is not massive industrial dislocation. We are not freezing in our homes and there have been no power blackouts. Our policy has worked. The price we are paying is the inconvenience of queuing for gasoline but, let me stress, this is an inconvenience, not a disaster. In December at our request the refineries began to increase the proportion of heating oil produced per barrel of crude. Now they are switching back and producing more gasoline.

Let me now address the immediate short-term outlook for fuel supplies in more detail. Our current estimate for the first quarter of this year is that the Arab embargo will reduce supplies of both crude oil and product by 2.7 million barrels a day, or about 14 percent below anticipated demand. In developing such estimates, the worst, yet most realistic, assumptions have been used. We assumed unconstrained demand, and did not take into account price elasticity or embargo leakages or large inventory drawdowns. The important thing to realize is that we are managing a shortage, rather than forecasting, and we therefore prepared for the worst. These estimates were based on imports of 4.9 million barrels per day from non-embargoed sources -- which is what we have been averaging over the last four weeks. We are now revising our forecasts for the second and third quarters of 1974 and these estimates should be completed within a few days.

Because of our efforts to increase supplies of middle distillates as well as the response of the American people to our conservation program and the mild winter, there has been no shortage of home heating oil. In turn, our relatively large stocks of distillates provide us with great flexibility in dealing with the changing shortages of the spring and summer. Moreover, major conservation efforts continue to be essential by both business and other consumers particularly in the consumption of gasoline and residual fuel. Also essential is the continuation of our oil-to-coal switching program for utilities. Our attention is now focussed on increasing the supplies of gasoline, aviation jet fuel, and residual fuel oils to prepare for the expected summer demand increases.

The short-term strategy of FEO has been to allocate our fuel resources as equitably and effectively as we can, and to respond decisively to exceptions not covered by our regulations as they arise. The 1974 Economic Report stresses the Administration's determination to manage the energy shortage so as to keep loss of jobs and production to a minimum. To do this, it will be essential to provide or permit incentives to maximize imports, domestic exploration and production, as well as providing rapid fuel shifts to key industries.

Our main concern is still to minimize impacts on industrial output and the employment situation. The past months have shown that reductions of 15 to 20% in total fuel consumption can be achieved without severe economic dislocations. We are continuing the development of conservation and allocation policies to deal with shortages of these magnitudes. What has not been determined are the longer term effects of this level of shortage on the general economy.

HOW THIS SITUATION AROSE

To fully understand how our present situation may be resolved, it is important to understand how we arrived where we are.

At some risk of exaggeration, the energy crisis with which we are now confronted is a result of mistaken policies of the Federal, state and local governments over many years. For a long time we have been sacrificing the long-run interests of our Nation to secure short-run objectives such as unrealistically low prices, wasteful patterns of consumption, and the too-rapid application of environmental controls and restrictions. Now, unfortunately, we are paying for these policies. Over the last 15 years, the rate of growth of energy production has decreased continuously while the rate of growth of demand has increased continuously. Thus, the gap, which has been met by imports, has been widening at an ever-increasing rate. Over the last three years, demand has grown by over 5 percent per year while domestic production has increased only about 3 percent per year.

As a result, domestic sources, which provided 95 percent of United States energy in 1960, provided only 83 percent in 1973. More significantly, the percentage of petroleum imported doubled over the same period.

Natural Gas: In his April 18 Energy Message, the President called for the deregulation of new natural gas dedicated to interstate markets. Following this Message, legislation was introduced which would exempt new natural gas from Federal Power Commission regulation. This legislation would permit prices of new gas to seek competitive levels. This would stimulate exploration and development of domestic natural gas resources and, over time, allow the market to reallocate supplies of gas to the most efficient and highest priority uses. Unfortunately, this legislation has not been acted upon by Congress.

It seems to me that there is little choice at a national level between no natural gas outside the gas-producing states at 25¢ per thousand cubic feet and adequate supplies everywhere priced between 65 and 80 cents per thousand cubic feet.

Coal: As in the case of natural gas the net effect of our policies toward coal, our Nation's most abundant fuel, has been to discourage production. To meet air quality standards, the utilities, the principal consumers of coal in this country, have been switching to oil, thus exacerbating the oil shortages that our country now faces. Government policies have made it more expensive to mine and have discouraged production. If Congress passes unnecessarily restrictive strip-mining environmental legislation, they will also discourage coal produced at the surface.

Coal has been the long-suffering step-child of the energy industry. Yet, if Project Independence is to have a chance of succeeding, coal production must be expanded sharply, at least 60 percent by 1980. In both coal mining and distribution, we have to give the coal industry what it has sorely lacked for many years; a set of firm, fair, yet workable ground rules on which it can plan and act over the long-term. It needs, above all else, to know with certainty what public policy will be regarding surface mining so that the industry can recover the investment it must make. The entire coal gasification and liquefaction efforts hinge on this, as does the future of coal as a powerplant fuel.

Oil: At a time when we should have been intensifying our exploration efforts to find more oil, we have, instead, reduced the depletion allowance, imposed especially stringent price controls on the industry, withdrawn leases for environmental reasons, delayed construction of the Alaskan pipeline, and have set back and delayed development of our offshore and Arctic reserves. We have also allowed our domestic refinery capacity to fall behind demand.

Domestic exploration has been declining since 1956, with a corresponding decline in discoveries. As a result, withdrawals from proved reserves of oil have outnumbered additions in six of the last ten years. Total domestic petroleum reserves at the end of 1971 amounted to slightly over 45 billion barrels, including an estimated 9.6 billion barrels on the North Slope. Because of the continued reserve decline in the lower 48 states, the ratio of crude oil reserves to production has fallen to a critically low level.

Until 1967, U.S. domestic fields could have supplied all U.S. petroleum requirements. Since 1967, imports to the U.S. which bridged the gap between domestic supply and demand, have risen to six million barrels per day just prior to the embargo. This dependence on foreign imports has been brought about by two converging trends: (1) the increased use of oil to offset shortages of other energy sources, especially natural gas and nuclear power, and (2) the greater profitability of foreign investment which has encouraged industry capital to flow overseas at the expense of domestic exploration, development, and refining.

In the past, onshore reserves were adequate to meet projected petroleum requirements. However, recent drilling efforts have not resulted in significant onshore discoveries. The most favorable geologic provinces have already been developed. In the late 1940's only 30 wildcat wells were needed to locate a significant new field; the number of wells required nearly doubled by 1960 and this trend has continued since then.

In other words, the cost of discovering and producing domestic oil is inexorably increasing. The best and most accessible fields have been exploited. Secondary and tertiary recovery techniques must be used which are increasingly costly. There has been a substantial and, to some extent, avoidable delay in efforts to develop our off-shore oil and gas resources. The acreage currently under lease on the Outer Continental Shelf is three percent of the total area under Federal control. The primary reason for this has been a delay in leasing prompted by a lack of urgency, bureaucratic sluggishness, and litigation by environmental interests. Potential Outer Continental Shelf ultimate recoverable resources total over 150 billion barrels of oil and over 350 trillion cubic feet of natural gas. Yet, since 1954, when Outer Continental Shelf leasing began, leases have been awarded on less than three percent of the potentially productive OCS lands.

The President's April 18 Energy Message called for tripling the annual acreage leased on the Outer Continental Shelf by 1979, beginning with expanded lease sales in 1974 in the Gulf of Mexico. It also called for studies of the environmental impact of oil and gas production in the Atlantic Outer Continental Shelf and in the Gulf of Alaska. Recently the Department of the Interior has launched an even larger leasing program which will offer ten million acres per year, starting in 1975, more than tripling what had been planned.

Nuclear Power: The United States has also failed to build nuclear powerplants for many of the same reasons that it has failed to build refineries. The Manhattan Project first demonstrated the feasibility of atomic power as a source of energy in 1942. Yet, thirty years later, nuclear power provides approximately one percent of U.S. energy needs. Ironically, this is about the same percentage provided by woodburning. There is necessarily a long period of development before any entirely new technology can be widely applied. However, the conversion to nuclear power has also been delayed by difficulties in obtaining licenses and site approvals and uncertainties about the environmental effects of nuclear power-plants and their safety. It takes eight to ten years to build a nuclear powerplant in the United States. It takes half that time in Europe and Japan and the difference is due to these delays.

Because we have not built nuclear powerplants as rapidly as had originally been planned, we have had to rely, instead, on fossil fuels to generate much of our additional need for electric power. And, because we have discouraged the burning of coal in many parts of our country, we have had to rely most heavily on residual and, in some instances, No. 2 fuel oil. This has been a major reason why, in recent years, our demand for oil has outgrown supply.

Conclusions: As a result of our policies toward gas, coal, oil and nuclear power, we have become increasingly dependent on imported oil and, in particular, oil from the Middle East. Many oil producing countries are beginning to worry about depletion of their reserves. Also, these countries are enacting laws and orders restricting output. In addition, the foreign exchange holdings of some Middle Eastern countries have been growing and are expected to continue to grow at a rate faster than they can be spent. Moreover many oil producers fear that these foreign exchange reserves will continue to depreciate in value while oil in the ground is increasing in value. Therefore, even after the boycott is lifted, there is a possibility that countries may defer production because prices and profits will be even greater in the future than they are now.

FIVE-FOLD APPROACH TO PROBLEMS

We have developed a five-fold approach to energy policy to deal with the present crisis and to implement the necessary programs to achieve long run energy goals.

First, we must establish a central energy organization in the Federal Government. The creation of the Federal Energy Office is the first step toward bringing all energy policy and implementation under one roof. We still need legislation to provide us with the capability to recruit and hire top-flight administrators and to let contracts to qualified consultants so that we can build the organization needed both to run the short-term allocation program and to carry out the more important assignment of moving the country toward energy self-sufficiency. Beyond FEA and ERDA, we must press forward with the creation of a cabinet-level Department of Energy and Natural Resources to ultimately bring together all Federal energy-related responsibilities. Until these new organizations are created, the Federal Energy Office will provide leadership and coordination in energy matters.

Second, we must establish a permanent "conservation ethic" in this country. We have been too extravagent in our energy consumption patterns. With 6 percent of the world's population, we consume 35 percent of the world's energy. The recent embargo has forced us to reduce this consumption now, but even more important we must be sure that an attitude of conservation becomes a permanent part of our lives.

Over 30 percent of our energy is wasted in one way or another -- wasted in unnecessary usage. Over the long-term, conservation of energy will require investment in insulation of homes and offices, use of more efficient automobiles, development of mass transit, changes in methods of handling freight, and central heating plants for groups of buildings and towns.

Third, we must accelerate the development of our massive untapped domestic energy resources through Project Independence. With almost half the free world's known coal reserves, we have enough coal to meet our total energy needs for centuries. We must therefore rapidly move ahead with coal gasification and liquefaction development in order to use this coal economically and in an environmentally acceptable way. We have the equivalent of 1.8 trillion barrels of oil locked in our massive oil shale reserves in Colorado, Wyoming, and Utah, enough to last more than a century. We must therefore press ahead with development of suitable processes to extract this oil. The in situ process is very attractive from an environmental viewpoint. It bears repeating that less than 3 percent of the OCS has been leased in the twenty-odd years since the program was originated. We can no longer afford to allow these critical resources to lie underdeveloped, or underutilized.

We also have to push forward in the development and utilization of nuclear power by expediting the licensing and construction of nuclear powerplants which are an essential part of our program for achieving energy self-sufficiency. We should also develop a broader nuclear program which looks toward liquid metal and other breeder reactors. In addition, top priority must be given to assuring that nuclear powerplants are built and operated safely with acceptable environmental impact.

We have also talked for years about development of such relatively distant alternatives to fossil fuels as fusion, geothermal and solar energy. For the next decade these alternatives are still very much in the research and development stage of growth and they could not come into widespread use until after 1990. Although we have to invest in the development of these alternatives, our primary focus now must be on nearer term measures for expanding energy supplies.

Fourth, we must forge a new relationship between government and industry in several key areas.

The information we now have to work with is not adequate and its reliability cannot be checked. We must develop a permanent energy information system with a built-in auditing program on every aspect of the energy situation -- reserves, refining operation, inventories and production costs -- so that we will be in a better position to assure the American people that our energy data is accurate and not subject to the charge that it can be manipulated by industry.

There must then be a new government role in the international activities of the oil industry.

Finally, there must be a new partnership to assure the development, extraction and use of our domestic energy sources. And, nowhere will the need for the combined efforts of industry and government be greater than in energy research and development. If we are to see the successful culmination of Project Independence, the Federal government must work in partnership with American industry.

Fifth, we must forge a new structure of international cooperation within the world community, between producing and consuming nations. The international implications of the energy crisis are profound because of the obvious economic and national security ramifications. Most industrialized nations are now competing for limited supplies in a market with dramatically escalating prices.

Like it or not, America and a majority of the other members of the world community face a critical challenge that, if left untended, could undercut existing economic and national security relationships. The first step in this direction has been taken at the recent Washington Energy Conference where we established a coordinating committee among consuming nations to lay the framework for considering various aspects of international energy problems. We are considering the possibility of a meeting of consuming and producing nations at a future date.

ORGANIZATION OF FEDERAL ENERGY PROGRAM

To develop a unified policy approach to long and short term energy problems a permanent organizational framework must be created. The Federal Energy Office currently has broad policy and regulatory responsibilities for energy. It is now administering energy price and allocation programs, initiating energy conservation programs, formulating the blueprints for the program to achieve energy self-sufficiency, working with the State Department on international aspects of energy, and working to coordinate energy R&D activities.

Federal Energy Administration: The FEO programs designed to deal with both near and long-term problems will become the responsibilities of the Federal Energy Administration upon congressional approval. One of the major functions of this organization as mentioned in the President's January 23, 1974, Message will be to rapidly increase energy supplies in both the long-term and the short-term as well as coordinating Energy Research and Development.

The general organization of the Federal Energy Administration will follow that of the present Federal Energy Office. This is shown in outline on the Chart 1 (attached). The major divisions of FEO are:

• Policy, Planning and Regulation, responsible for developing policy and program alternatives; developing and promulgating energy allocation regulations; developing, promulgating and administering energy resource pricing regulations; and conducting agency policy and program evaluation.

• Economic and Data Analysis and Strategic Planning, responsible for collecting, evaluating, compiling, analyzing and publishing data on energy requirements, production, and resources, and analyzing economic impact of energy resources and energy programs.

• Operations and Compliance, responsible for implementing and administering energy allocation programs; maintaining relations with state and local governments, industry and the public with respect to energy allocation; and managing the agency's regional and field allocation offices.

• Energy Conservation and Environment, responsible for developing and administering energy conservation programs; conducting and supporting energy conservation studies; coordinating and evaluating Federal agencies' energy conservation programs; and reviewing and evaluating the impact of energy activities on the environment and of environmental programs on energy supply and demand.

• Energy Resource Development, responsible for identifying and developing means for overcoming constraints that hold up building and operation of energy facilities, such as construction, regulatory and materials and labor shortages; developing incentives for increasing domestic energy production; and coordinating FEA's energy resource strategy with R&D programs being pursued by the Energy R&D Administration (ERDA).

• International Policy and Programs, responsible for maintaining current understanding of the international and national security aspects of energy resource management; developing and monitoring international energy resource management programs; and coordinating within FEA and with other government agencies with respect to international energy resource policy.

• Policy Analysis, responsible for participating in the development of energy policies, and providing liaison with other Federal agencies on economic policies.

Federal Energy Office: Energy policy is broad-based and reaches into all areas of government. For example, it encompasses building codes, environmental matters, international aspects, etc. And it is important to consider the impacts of energy policy on such diverse groups as farmers, the poor, and businessmen. Therefore, even after the formation of the FEA, there may still be the need in the Executive Office of the President for an FEO with responsibility for providing coordination across the government in matters of energy policy.

This office would deal with a broad range of policy issues including those related to R&D. In particular, it would coordinate the energy-related programs of EPA, NASA, DOT, DOD, NSF, DOC, DOI, and other agencies as necessary.

Energy Research and Development Administration: Also with Congressional approval, R&D programs to develop new technologies which have an impact in the mid and longer term (beyond 1985) will be the responsibility of the Energy Research and Development Administration (ERDA). ERDA would include the research and development as well as the production functions of the Atomic Energy Commission, along with selected energy R&D functions of the Department of the Interior, the National Science Foundation, and the Environmental Protection Agency. Thus, the agency would bring all major energy R&D programs within the Federal government under one management structure. This is what is needed to start with, but we all recognize that in the long-term, an organization that coordinates all energy and natural resource policies must be formed.

Department of Energy and Natural Resources: The President proposed the establishment of this new department as the longer-run solution to the many interrelated problems in the energy and natural resources area. DENR would incorporate most of the responsibilities of the Department of the Interior; the activities of the Forest Service and certain water resource functions of the Department of Agriculture; the activities of the National Oceanic and Atmospheric Administration of the Department of Commerce; the water resource planning functions of the Corps of Engineers, the gas pipeline safety functions of the Department of Transportation, and the Water Resources Council. Drawn together, these responsibilities would form the basis of a modern department truly capable of providing a much needed balance between the wise utilization and careful conservation of our Nation's precious natural resources.

Once DENR is established, it should incorporate the functions of both ERDA and FEA. Then and only then will we have an organization that can provide an integrated overview of the development and use of all energy and natural resources.

BUDGET OVERVIEW

I would now like to present an overview of our Fiscal 1975 budget request. First, however, a statement of our current financial and manpower resources:

Fiscal Year 1974 Resources: Present resources for the current fiscal year total $55.4 million and are provided from the following sources:

FY 74	Thousands of Dollars
Interior Department FY74 Base	$ 3,260
Interior Department FY74 Supplemental Energy Appropriation	42,262
Cost of Living Council	557
FEO Supplemental Appropriation	9,360
	$55,439*

* Includes $10 million contingency funds to be made available to the states upon passage of S.2589 or similar legislation establishing the Federal Energy Administration.

We have also requested for your consideration a supplemental increase of $18 million to cover the printing of gas ration coupons for one quarter and their storage as well as an investigative staff which Internal Revenue Service will hire and train for the Federal Energy Office.

The FY 1974 resources constitute an amalgamation of offices charged with energy responsibilities. The Federal Energy Office functions as an umbrella for these programs until substantive legislation is approved.

As of March 7, these various organizations and the FEO headquarters office in Washington had a staff of 2,482 including some 1,364 employees detailed temporarily from other Federal agencies.

Fiscal Year 1975 Budget Request: The FY75 budget request for energy programs is being submitted to the Congress through two appropriations committees -- the Subcommittee on Department of the Interior and Related Agencies, and the Treasury-Postal Service-General Government Appropriation Subcommittee.

We have requested $19 million from the Treasury-Postal Service Subcommittee for 1040 permanent positions and to provide for necessary support expenses. This budget is an annualization of our FY74 budget of $9.4 million supplemental appropriation which covers approximately six months of operations. The Department of the Interior is submitting within its FY75 budget request to the Interior Appropriations Subcommittee a request for $99.3 million for energy operations within their respective organization components. Thus, the total resources being requested for energy programs for FY75 is $118.3 million. This combined funding provides for 3367 positions and necessary support expenses.

Chart 2 (attached) summarizes the budget request by organizational component in Interior and bridges the energy programs under the FEO organization.

For the most part, the budget request covers an annualized or full-year cost of these programs at the fiscal year 1974 level. We may well need to request additional resources for increases in these programs after passage of the authorizing legislation for the Federal Energy Agency.

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This completes my prepared remarks. I will be very happy to answer any questions the committee may have.

Attachments

E-74-104

CHART 1

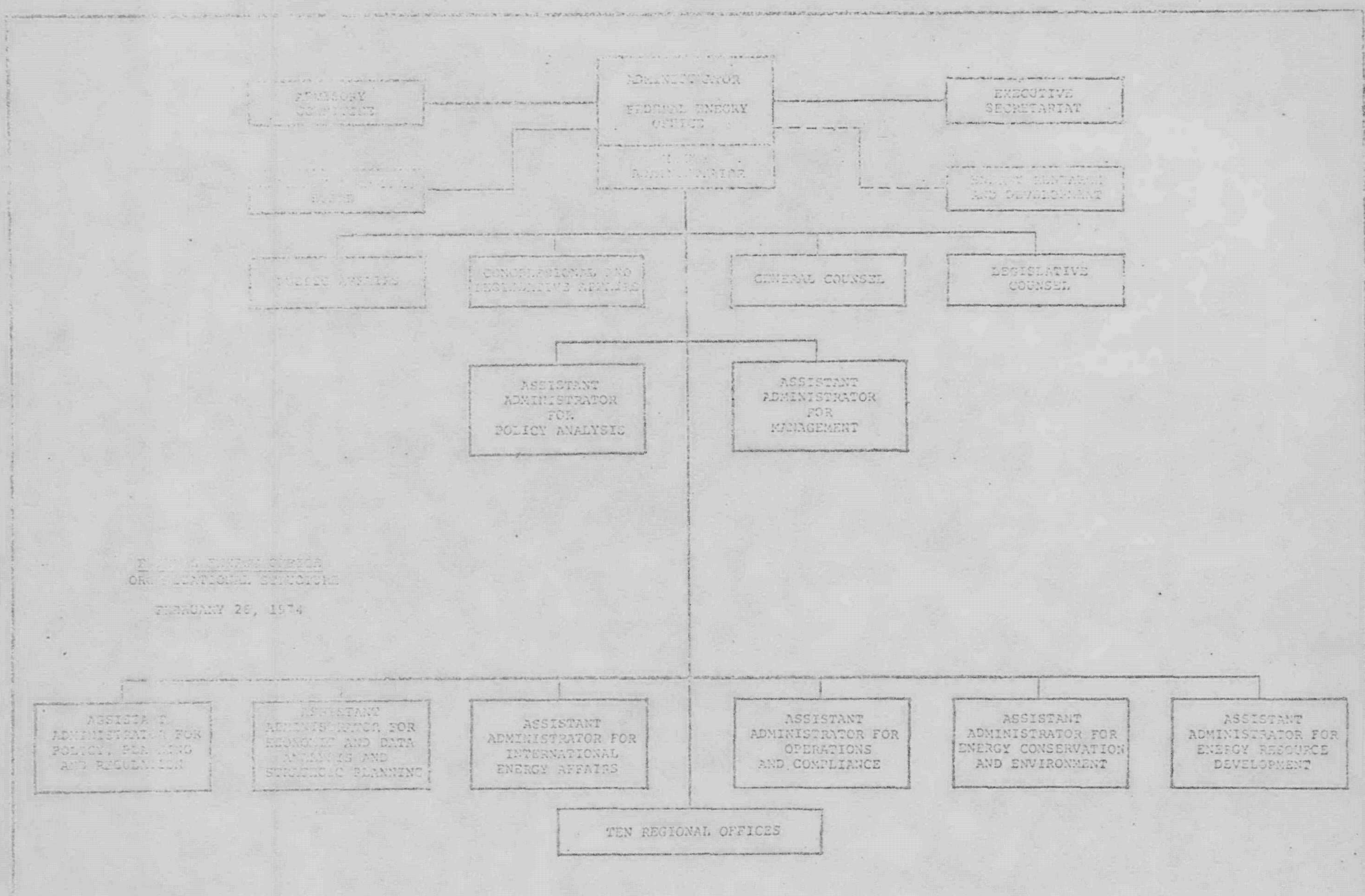
ADMINISTRATOR
FEDERAL ENERGY OFFICE
ADVISORY COMMITTEE
EXECUTIVE SECRETARIAT
GENERAL COUNSEL
LEGISLATIVE COUNSEL
ASSISTANT ADMINISTRATOR FOR POLICY ANALYSIS
ASSISTANT ADMINISTRATOR FOR MANAGEMENT
FEBRUARY 26, 1974
ASSISTANT ADMINISTRATOR FOR INTERNATIONAL ENERGY AFFAIRS
ASSISTANT ADMINISTRATOR FOR OPERATIONS AND COMPLIANCE
ASSISTANT ADMINISTRATOR FOR ENERGY CONSERVATION AND ENVIRONMENT
ASSISTANT ADMINISTRATOR FOR ENERGY RESOURCE DEVELOPMENT
TEN REGIONAL OFFICES

CHART 2

Fiscal Year 1975 Budget Overview
of Federal Energy Programs
(in thousands of dollars)

	As reported to the Treasury-Postal Service-General Government Appropriations Subcommittee		As reported to the Interior Appropriations Subcommittee											
			Fuel Allocation, Oil and Gas Programs						Energy Conservation and Analysis					
	Federal Energy Office		Petroleum Allocation Program		Coordination of Oil and Gas Activities		Office of the Solicitor		Office of Energy Conservation		Office of Energy Data and Analysis		Total 1975 Energy [illegible]	
Federal Energy Activities	Positions	Amount	Positions	Amount	Positions	Amount	Positions	Amount	Positions	Amount	Positions	Amount	Positions	[illegible]
Administration	197	$ 6,663	-	-	-	-	-	-	-	-	-		197	$ 6,[illegible]
Economic and data analysis	40	598	-	-	-	-	-	-	-	-	90	$ 5,000	130	5,5[illegible]
Policy planning and regulation	70	3,026	-	-	-	-	-	-	-	-	-		70	3,0[illegible]
Operations and compliance	633	6,698	2017	$67,200 1/	-	-	60	1,300	-	-	-		2,710	75,[illegible]
International policy and programs	50	1,653	-	-	-	-	-	-	-	-	-		50	1,653
Energy conservation and environment	9	133	-	-	-	-	-	-	42	$ 22,900 2/	-		51	23,0[illegible]
Energy resource development	41	229	-	-	118	$ 2,900	-	-	-	-	-		159	3,[illegible]
TOTAL 1975 budget request	1040	$19,000	2017	$67,200 1/	118	$ 2,900	60	$ 1,300	42	$22,900 2/	90	$ 5,000	3,367	$[illegible]
Average positions	914		2035				60		128				3,137	

1/ Includes contingency funding of $10 million for State and Federal energy shortage programs.

2/ Includes $12.9 million in 1975 budget amendment.

FEO Budget and Financial Management

February 26, 1974

TESTIMONY OF THE HONORABLE WILLIAM E. SIMON
ADMINISTRATOR OF THE FEDERAL ENERGY OFFICE
BEFORE THE
COMMITTEE ON GOVERNMENT OPERATIONS
Tuesday, February 26, 1974

Mr. Chairman, Members of the Committee

I appreciate the opportunity to appear before you today to present the Administration's views on S. 2744 and S. 2135. S. 2744 is a bill which creates an Energy & Research Development Administration and an independent Nuclear Energy Commission. S. 2135 would create a cabinet level Department of Energy and Natural Resources. Prior to getting into the specifics of bills, I would like to outline very briefly our approach to energy policy.

Five-fold Approach to Energy Policy

Let me start by outlining the five-fold approach we are taking with respect to energy policy.

First, we must establish a central energy organization in the Federal Government. The creation of the Federal Energy Office is the first step toward bringing all energy policy activity under one roof. We hope that Congress will move quickly to provide a statutory base for the Federal Energy Administration and to create an Energy and Research Development Administration. We need legislation to provide us with the capability to recruit and hire top-flight administrators so that we can build the organization needed both to run the short-term allocation program and to carry out the more important assignment of moving the country toward energy self-sufficiency. Beyond FEA and ERDA, we must press forward with the creation of a cabinet-level Department of Energy and Natural Resources to ultimately bring together all Federal energy-related responsibilities. Until these new organizations are created, the Federal Energy Office will provide leadership and coordination in energy matters.

Second, we must establish a permanent "conservation ethic" in this country. We have been too extravagent in our energy consumption patterns. With six percent of the world's population, we consume 35 percent of the world's energy. The recent embargo has forced us to reduce this consumption now, but even more important we must be sure that an attitude of conservation becomes a permanent part of our lives.

Over 30 percent of our energy is wasted in one way or another -- wasted in conversion from one form to another, wasted in transmission, and wasted in unnecessary usage. Over the long-term, conservation of energy will require investment in insulation of homes and offices, use of more efficient automobiles, development of mass transit, changes in methods of handling freight, and central heating plants for groups of buildings and towns.

Third, we must push forward in the development of our domestic energy resources through Project Independence. This includes further development of oil and gas in Alaska and the outer Continental Shelf, increased secondary and tertiary recovery, greater utilization of coal, of which we have a supply unmatched by any other country in the world, further development of oil shale and nuclear power, and added efforts toward development of geothermal and solar power. Project

Independence must be a two-pronged attack. In the short-run, we must both expand production and exploit untapped reserves of existing energy sources. Longer range solutions will be provided by the development of new and existing fuels. These long-range solutions can be brought about through an increased R&D effort which we must undertake now.

Specifically, this program should include the following:

We must find ways to exploit our coal reserves more effectively. We have 1 trillion, 500 billion tons of identifiable coal reserves, or half of the non-Communist world's reserves, 425 billion tons of which are economically recoverable now. We must develop techniques for mining surface coal that do not destroy the landscape. We must also develop ways to deep mine coal that protect the health and safety of miners.

We have talked for years about the production of oil from our oil shale. There are an estimated 1 trillion, 800 billion barrels of oil in the shale resources in the U.S. This amounts to about 47 times our present known oil reserves. We need an increased effort by both the Federal Government and private industry to develop this potentially productive resource. I am especially encouraged by recent progress in the <u>in situ</u> processes for extracting shale oil. This progress suggests that it may be possible to produce shale oil at less than the current cost of Persian Gulf crude. <u>In situ</u> extraction should also have minimal impact on the environment and its development must be encouraged.

We also have to push forward in the development and utilization of nuclear power. We should develop a broader nuclear program which looks toward liquid metal and other breeder reactors. In addition, top priority must be given to assuring that nuclear powerplants are built and operated safely with acceptable environmental impact.

We have also talked for years about development of such relatively distant alternatives to fossil fuels as fusion, geothermal and solar energy. For the next decade these alternatives are still very much in the research and development stage of growth, and they could not come into widespread use until after 1990. Although we have to invest in the development of these alternatives, our primary focus now must be on nearer term measures for expanding energy supplies.

Fourth, we must forge a new relationship between Government and industry in several key areas.

o The information we now have to work with is not adequate, and its reliability cannot be checked. We must develop a permanent energy information system with a built-in auditing program on every aspect of the energy situation -- reserves, refining operation, inventories and production costs -- so that we will be in a better position to assure the American people that our energy data is accurate and not subject to the charge that it can be manipulated by industry.

o There must also be a new partnership to assure the development, extraction and efficient use of our domestic energy sources. And, nowhere will the need for the combined efforts of industry and Government be greater than in energy research and development. If we are to see the successful culmination of Project Independence, the Federal government must work in partnership with American industry.

Fifth, we must establish a framework of international cooperation among producing and consuming countries. The potential impact of energy shortages on the world economy is staggering, and we must work together in developing energy resources and maintaining a healthy world economy in which energy exporting and energy importing nations prosper together. Greater cooperation must be initiated on research projects and new ways to conserve energy.

In the context of this policy, I would like to discuss FEA and ERDA. Before examining FEA and ERDA it must be understood that neither of these organizations can be considered by themsevles but must be related to the total energy responsibility. In addition, energy R&D and Energy Resource Development is integrally related to the management of all our Natural Resources.

For several years, it has been clear that a new Federal organization is needed to coordinate both energy and natural resources. In March, 1971, the President submitted to the Congress a proposal for a Department of Natural Resources to solve this problem. The current energy situation has heightened the need for such an organization. We still firmly believe that such a major cabinet department is the most effective organization structure for the government in integrating and managing its energy and natural resource responsibilities, and in its ultimate form would contain both ERDA and FEA.

We have always recognized that such a major departmental reorganization involves the concerns of a great many interests and would require careful Congressional scrutiny and perhaps some change before it could be enacted.

One of the least understood dimensions of the Federal role in facing up to our national energy problems is what we have called "energy resource development." The great bulk of responsibility for assuring that we have supplies of energy to meet our demands lies with the private sector. It is our assessment however, that there are a great many ways in which the Federal Government, working with the private sector, can encourage and help it to expand energy production. This may involve cutting governmental red-tape, eliminating or simplifying constraints which tend to curtail production, strengthening economic incentives for production, expediting Federal or State and local decisions, and a variety of other actions. The Federal Energy Administration would serve this role within the framework of the total National energy policy which it would be instrumental in developing. This kind of energy resource development uses available technology and can pay off over the next several years, particularly in the 1974-80 time frame. It is estimated that upwards of 750 billion of private and public investment over the next decade will be made. With this in mind, the respective roles of FEA and ERDA can be made clear.

The FEA will be the principal organization within the Federal Government for energy policy and implementation to meet the energy crisis. Its key responsibilities will be:

- Facilitate implementation of the President's program to develop the potential for energy self-sufficiency.
- Develop and implement programs for dealing with energy shortages, such as fuel allocations and rationing.
- Develop and implement voluntary and mandatory energy conservation programs and promote efficiencies in the use of energy resources.
- Develop and promulgate energy price regulations.
- Develop and recommend policies on import and export of energy resources.
- Collect, evaluate, assemble and analyze energy information on reserves, production and demand and related economic data.
- Work with industry, state and local governments and the general public on energy resource management.

And while we look forward to the passage of S. 2135 which would provide for the Department of Energy and Natural Resources, we strongly urge the establishment of FEA now to give us the proper statutory base to carry out these programs.

ERDA

The above brings me to a discussion of S. 2744 which would create an Energy Research and Development Administration which would include the research and development as well as the production functions of the Atomic Energy Commission together with energy R&D functions of the Department of the Interior, the National Science Foundation and the Environmental Protection Agency. Thus the agency would bring all major energy R&D programs within the Federal government under one management structure. The legislation would also create an independent Nuclear Energy Commission to carry out the AEC's licensing and regulatory functions.

For the last five years, the President has provided for a continual expansion of our efforts in energy research and development. Federal funding increased almost 75 percent from $362 million in fiscal year 1970 to $672 million in fiscal year 1973 and was then raised to $1 billion for fiscal year 1974. Last June the President announced a commitment to an even more rapid acceleration of this effort through a $10 billion Federal program over the next five years, and he stressed that we would spend whatever additional sums were reasonably necessary.

On January 23, 1974, the President announced that in fiscal year 1975 -- the first year of the five year energy R&D program -- total Federal commitment for direct energy research and development will be increased to $1.8 billion, almost double the level of a year ago. It is only with the help of such an accelerated research and development program that we can achieve real self-sufficiency in energy.

We believe the time has come to address the full spectrum of our nation's energy resource and utilization technologies in a single R&D agency; ERDA will build on the existing AEC research, laboratory, and contractor capabilities and fossil fuel R&D from Interior in achieving new balance between nuclear and non-nuclear research. ERDA will become the base for carrying out an integrated R&D strategy capable of accommodating future changes in R&D work in such areas as energy conservation, environmental impact, and health and safety considerations; it will conduct a program which ranges from the practical applications of technology to pure research.

The passage of the legislation will provide us with the management tools we need. In addition the Congress must enact additional legislation in order to enable us to reach our goal of self-sufficiency in energy.

We must also use the scientific resources available to meet our short-range objectives. Therefore, we have tried to visualize our energy policy in terms of what must be done in the relatively short-range -- say up to 1980, and what must be done in the long-term, beyond 1980. The strategies appropriate for dealing with the short-range are in general not the same as those appropriate for the long-range, and so I will discuss them separately.

In the short-range our primary shortage is oil and gas. Hence, our underlying strategy for dealing with the short-range is:

1. To encourage conservation measures by improved technology.

2. To increase our domestic supply of oil and gas through such processes as oil shale development and other means.

3. To substitute insofar as possible fuel resources which we possess in abundance, mainly coal and nuclear, for oil and gas which is in short supply.

4. To meet the foregoing demands in an environmentally acceptably manner.

Research can make some contribution towards implementing these short-range strategies, but the more significant payoff from research will come in the next decade. Our progress towards self-sufficiency between now and 1980 will depend, for the most part, on our ability to implement available technology rather than on the results of new research. Therefore, though EDRA will play a significant role, FEA will bear the major brunt of these short-range programs.

Our long-range goal is first to eliminate, if possible, our dependence on foreign oil and gas; and second, to gradually transform the base of our energy system from the non-renewable fossil fuels to non-fuels, mainly nuclear, geothermal, solar waves, ocean thermal gradients, and possibly biological sources. We believe that long-range R&D should retain as much flexibility as possible: we must not foreclose any of our options prematurely. What are the options?

1. Coal.

Fortunately coal is our most abundant resource. The challenge is to learn how to transform our different types of coal through a variety of processes such as gasification and liquefication into clean gaseous and liquid fuels suitable as substitutes and replacements for dwindling supplies of oil and gas. Thus, low-BTU gas, which is probably marginal in the short-range, looms with high priority in the long-range. And perfection of processes for coal hydrogenation leading to production of syncrude and syngas must be supported.

2. Oil Shale.

The "oil bearing rock" known as oil shale is also an abundant and virtually untapped domestic energy resource. Research and development must provide us with the advanced technology which will enable us to efficiently utilize oil shale to the maximum extent while at the same time minimizing, or eliminating, surface disruptions and water utilization. We must also further develop the processes whereby the shale oil, or kerogen, is transformed into the full equivalent of other oil, while at the same time preserving its clean burning attributes. We know that oil shale deposits in the Green River Formation in Colorado, Wyoming and Utah, alone, underlie some 11,000 square miles. These deposits contain more than 600 billion barrels of kerogen in place in rock assaying more than 25 gallons per ton and in deposits of at least ten feet thick. In some places, these deposits reach thicknesses of 2,000 feet. Clearly here is a great challenge for our future research and development activity.

3. Nuclear.

Nuclear energy must be considered of most importance for the long-range primarily because it gives mankind an essentially inexhaustible energy source. At the present time the breeder reactor is the nuclear technology that has the most potential. Thus, research and development of the Liquid Metal Fast Breeder Reactor must be continued in a timely fashion and work on other breeder reactor concepts (light water breeder gas cooled fast breeder, and molten salt breeder) must be supported and expanded to retain them as viable alternatives.

Controlled fusion energy is an exciting scientific field that has attracted and continues to attract some of the nation's top scientific talents. Recent U. S. progress in duplicating and moving beyond the Soviet Union's success with Tokamak devices (control of fusion by thermo-nuclear devices), coupled with promising new concepts based on a maturing laser technology have stimulated new interest in and provide incentive for continued support of fusion research. However, practical fusion energy is only a hope until scientific and technical feasibility can be established.

4. Geothermal.

Naturally occurring geothermal steam is today generating many kilowatt hours of electricity primarily in the West. The prospect of a very extensive resource of geothermal energy depends greatly upon being able to recover, in a practical way, heat from hot brine and dry hot rock lying deep below the earth's surface. Thus, the future of geothermal energy must await the results of research both on the extent of the geothermal resource and our ability to recover it.

5. Solar.

The use of solar energy is attractive, and there are many ideas for using solar energy directly for building and water hearing that could be applied today if the problems of cost and public acceptance could be overcome. However, we cannot count on the sun as a major source of usable energy until there is much better evidence, hopefully to be provided by an expanded research effort, that solar energy can contribute to the large scale production of electricity and/or synthetic fuels.

6. Others.

There are many other elements to be included, at small scale, in the long-range energy research plan (for example, ocean gradients, winds, waves, wastes, topping cycles). A further energy resource is hydrogen. Thermal and biological methods of water decomposition deserve attention also. Improvements in electrical transmission -- in particular the superconducting cable -- is possibly a key element in a world electrical energy system in the post fossil fuel era.

Let me make the following general observation about energy R&D. It is the nature of R&D that the future is uncertain: we cannot guarantee that any of the long-range options, especially those for which scientific feasibility has yet to be demonstrated will indeed work. But we believe it is imperative that we mount a massive, perservering effort at exploring the possibilities -- at determining as soon as we can which of the leads are promising, which are false. For in the very long run our own country as indeed the world's future depends on a flow of adequate energy. This can be had, we believe, only through the kind of R&D enterprise to which our counqry with the help of Congress is now committing itself.

DENR.

This brings me to a discussion of S. 2135, a bill which would establish the DENR. As you are aware, the President proposed the establishment of this new Department in his June 20, 1973 message to the Congress, expanding his previous Department of Natural Resources proposal. The new department would incorporate most of the responsibilities of the Department of the Interior, the activities of the Forest Service and certain water resource functions of the Department of Agriculture, the activities of the National Oceanic and Atmospheric Administration of the Department of Commerce, the water resource planning functions of the Corps of Engineers, the gas pipeline safety functions of the Department of Transportation, and the Water Resources Council. Drawn together, these responsibilities would form the basis of a modern department truly capable of providing a much needed balance between the wise utilization and careful conservation of our nation's precious natural resources.

Once DENR is established, it should incorporate the functions of ERDA and FEA. Therefore, it would bring into being in one agency most of our energy related programs. But most importantly, it would allow our government to manage our total energy resources under one department which will enable us to prevent many of the problems we are currently facing. Many of these problems have arisen because we have not adequately managed and conserved our total energy resources. No one agency has been able to relate one energy resource to another or more importantly to the total needs of the American people.

I cannot stress too strongly the need for a DENR just as soon as Congress can provide it. The present Executive Branch structure must be updated by the Congress to conform to our present and future energy needs. The President acted on his own to establish the Federal Energy Office on an interim basis to deal with the emergency. If the Congress will now give us the first steps toward this reorganization which have already proceeded part way through the Congress, the Federal Energy Administration and the Energy Research and Development Agency, this will give us the organization with which we can move ahead now. But, as I have indicated, the Congress will not have fully dealt with the requirement of revamping our government for energy and related responsibilities until it provides a new Federal department initially requested three years ago by the Administration.

In conclusion, I want to reemphasize our organizational needs.

I know, first hand, that we do, in fact, have an energy emergency. It is nothing less. I also know that pointing fingers at each other, between States and the Federal Government, between Congress and the Executive Branch, within Congress and within the Executive Branch, between nations, and at the energy industry, is not going to add one iota to the solutions which must be forthcoming.

Furthermore, I know that there is only one way to proceed. The nation needs to start, not tomorrow, but now, with a permanent governmental organization which has the authority and responsibility to do all that is necessary to guarantee the people of this nation that they and their children's children will have adequate energy supplies.

The House of Representatives has already passed H.R. 11510 to create an ERDA organization. I urge similar action in the Senate, just as I urge the House to complete, without delay, its action on the FEA bill.

As the ultimate organizational solution, I urge the Congress to take prompt and positive action to create the Department of Energy and Natural Resources.

This concludes my statement. I will be pleased to respond to any questions you might have.

TESTIMONY BEFORE SENATE COMMERCE AND INTERIOR COMMITTEES

HEARINGS ON S. 2650 AND H. R. 11864

APRIL 5, 1974

ALVIN M. WEINBERG

I am appearing before you in general support of the intent of S. 2650 and H.R. 11864 (as amended), which is to proceed with national prototype demonstration projects for solar heating and cooling in houses. However, as you know, the Administration is opposed to the bills for the reason that they are in the province of the proposed Energy Research and Development Administration (ERDA), and should await the establishment of that agency. Currently, the National Science Foundation (NSF) has the lead agency role for solar energy, and we are requesting a total budget in solar energy of $50 million in Fiscal Year 1975.

There is by now general agreement that one of the ultimate "answers" to the problem of developing adequate and nonpolluting energy resources in the United States is to harness solar radiation. The tantalizing technical point is that roughly an average of 150 watts of energy impinge on each square yard of the United States; thus the total energy requirement for the United States in 1970 could, in principle, have been obtained (at 10 percent efficiency) from solar radiation on a mere 50,000 square miles which is only about 3 percent of our total farm land.

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A second fundamental point which makes solar energy potentially so attractive is that it is practically non-polluting, and forever renewable. Thus, provided technical feasibility of particular systems can be established and, provided these systems show some promise of economic practicability, solar power must be given serious consideration for the long term.

It is also generally agreed that the technology is presently sufficiently in hand for solar heating of houses and other buildings for prototype development and possibly larger scale demonstrations to proceed. Also, the prospects for combined heating and cooling solar systems seem not too far behind those for solar heating. It is estimated[1] that ultimately 35 percent of the total thermal energy of buildings in the United States can be developed cost effectively through solar energy, with savings of roughly 30 mQ (1 mQ = 10^{15}BTU) per year in 2020. A number of investigations have been made of current engineering feasibility, and these indicate that depending upon the geographical location, solar heating may sometimes be economically competitive with gas and oil when appropriate economies of scale are assumed.

However, left entirely to the private sector, solar heating and cooling may be very slow to develop because of

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1 Report of the Committee on Aeronautical and Space Sciences, U. S. Senate, "Solar Heating and Cooling Demonstration Act of 1974", March 13, 1974, pp. 36, 66, 77, 102.

constraints due to building codes, lack of building design criteria, lack of knowledge of production economies, lack of public familiarity with such systems, architectural problems, and general inexperience. Thus, a federal program to hasten the adoption of widespread solar thermal systems in buildings and housing will inaugurate a highly desirable long-term trend to use solar energy for space conditioning to the extent practicable. The current National Science Foundation program is designed to overcome the aforementioned barriers to more widespread use of solar energy.

Turning to a comparison between the two bills before you, I note that HR. 11864 permits the incorporation of the solar energy demonstration program under ERDA, while S. 2650 does not. A case might be made that the time is ripe now to give a strong boost to solar energy without encumbering it with the predictable organizational growing pains of a new ERDA. However, the creation of what will amount to a special mini-agency to administer the solar energy demonstrations, which S. 2650 appears to do, would create a very undesirable situation for the new ERDA just because the very idea of ERDA is to provide unified leadership to the national energy effort. Thus, a timely incorporation of any energy demonstration project under ERDA would be highly desirable both in order to enhance the development of a coherent national energy posture, and in order that the demonstration project itself would be appropriately connected into other energy-related R&D which ERDA will manage.

I note that H.R. 11864 allows for considerably more administrative flexibility in developing the prototype-demonstration projects as the program proceeds. For example, the matter of an orderly development using prototypes before demonstrations, is specifically spelled out in H.R. 11864, and the size and number of demonstrations is left to the particular circumstances. Also, the time specified for development of design criteria for solar heating in S. 2650 may not be enough. It is my opinion that in general, as any energy program proceeds, it may turn out, for technical or other reasons, to be desirable to tailor a series of prototype and demonstration projects to prove out several competing approaches at various times and at various levels of effort. H.R. 11864 again allows for such flexibility, whereas S. 2650 does not. H.R. 11864 also allows for greater flexibility in funds.

The major weaknesses of H. R. 11864 are that no clear-cut program responsibility has been established, and the success of the total program will depend upon agency cooperation. Second, the National Science Foundation programs in solar energy are not incorporated formally within the bill. This in our view would be a mistake in light of the experience the National Science Foundation has had in their solar heating programs, and in view of their general research programs in a wide variety of solar energy projects. Some of these projects are directly related to the solar heating and cooling problem such as research on collectors and storage systems, evaluation of specific heating-cooling systems, etc., while others are more long range, like research on direct conversion devices. In fact, the National Science Foundation has been a "lead agency" for solar energy research, and I see no reason to change this role of NSF.

You have asked me to comment on incentives for the private sector to pick up the results of the governmental demonstrations. This is a crucial matter, and concerns such economic incentives as tax write-offs., government leverage on market development through GSA and DOD, work with the State and local building code agencies, etc., which are beyond the strict purview of my office. I am sympathetic to the plea of Dr. I. A. Jones[2] of TRW in testimony regarding one of these bills that the housing infra-structure be involved as early as possible in the demonstration phase of the program. Others[3] have

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2 Jones, I. A., Testimony before the Subcommittee on Housing, Committee on Banking, Housing and Urban Affairs, March 21, 1974.

3 Study of Committee on Public Engineering Policy (COPEP), "Priorities for Research Applicable to National Needs," 1973.

commented in a different connection on the necessity for a "technology delivery system" when transferring technology from the federal R&D sector to the private sector, and the Energy Policy Project of the Ford Foundation is currently funding a major study on the institutional problems of the commercial application of new solar conversion systems. A draft report of this latter study is now available from the Energy Policy Project.

Drawing on the general experience with Operation Breakthrough and the opinions of the sources quoted above, it will clearly be necessary to develop a sophisticated understanding of the various elements in the private sector which will have to participate in a successful commercial development of solar heating and cooling. It may be necessary to couple all these elements together skillfully with a variety of federal incentives as a part of any proposed demonstration program in order to ensure a successful result. As only one example among many, if it should turn out that the first costs of solar energy are high relatively to conventional heating-cooling systems, but that total lifetime costs are lower, then financing schemes which would appear to the consumer as utility-type costs might be a desirable element of the technology delivery system. Of course, a part of the incentives picture is an estimate of the cost effectiveness of solar heating-cooling relative to other energy alternatives. Clearly, incentive schemes in which the federal role may be large in the early stages would have to show an orderly phase-out in favor of the private sector in later stages.

In addition to the Department of Housing and Urban Development, the Office of Energy Conservation of FEO has also given much thought to the matter of federal incentives in the private housing sector, and you might like to hear from them both directly on this point.

In summary, I fully support the goal of both pieces of legislation: A strong push for using solar energy soon. However, I view the organizational arrangements as awkward, and I believe that the National Science Foundation currently has the authority to accomplish many of the objectives of this bill.

-FEO-

Final

STATEMENT OF ALVIN M. WEINBERG
DIRECTOR
OFFICE OF ENERGY RESEARCH AND DEVELOPMENT
FEDERAL ENERGY OFFICE
BEFORE THE JOINT COMMITTEE ON ATOMIC ENERGY
MAY 7, 1974

I am delighted to participate with you in your deliberations regarding the Solar Energy Bill, S. 2819. I understand that Senator Humphrey has a second Solar Energy Bill, S. 3234, which is not formally before you, but which represents his later thinking on the subject. With your permission, I will address my remarks primarily to the later bill. As I understand it, the only significant change between the two is that S. 3234 will transfer the solar energy office from the AEC into the newly established ERDA when that organization is established. In my opinion, the change is a desirable one. We also understand from Mr. Norman Klug of the Joint Committee staff that you would like to have my general opinions regarding the future and potential of solar energy, and what the Federal government role should be. I will be delighted to share my opinions with you.

Perhaps, I should begin by explaining the function of my office. We are a very small office of fourteen professionals reporting to Mr. Sawhill. Our function is to oversee the entire Federal energy research and development program, to coordinate the program - the research between the various agencies, and to provide advice to Mr. Sawhill regarding research issues in energy.

We also work very closely with the Office of Management and Budget on energy R&D matters. As you know, Project Independence is the major concern of the FEO currently, and my office is responsible for coordinating the input to Project Independence for research and development.

I believe the general facts regarding the very high potential for solar energy have been established. The total solar radiation on the planet is an extremely large quantity compared to the total human energy needs. I have estimated, for example, that one could obtain the total energy requirement for the entire U.S. in 1970 at only 10% efficiency from the solar radiation on a mere 50,000 square miles, which is only about 3% of our total farm land. Put another way, about 150 watts of energy on an average impinge on each square yard of the U. S. In addition, of course, this energy comes in a natural unpolluting form with very few secondary drawbacks to safety, health, etc. These basic facts have tantalized many people to try to make actual use of this natural resource, especially in the past few years as the pressure on our other energy resources has become apparent.

However, the technical and practical drawbacks to large scale electrical production from the sun are large. The main problem is that this energy comes in a very diffuse and unconcentrated form. Although the sun itself is very hot and solar radiation could theoretically be captured at high temperatures, practical considerations make it a low temperature form of energy. Generally speaking, engineers desire energy in as compact a form as possible, and they usually desire it at as high temperature as possible, at least up to the temperatures where material limitations become important. Thus, solar energy installations tend to be large and bulky, they may require extensive use of land, and they often require technologies which are not yet available. These technologies tend to be unavailable for the reason I have just mentioned, namely that solar energy represents a different trend from natural engineering developments.

The one big exception, of course, has been the use of solar energy in the space program. This is one high technology area par excellence where a major effort has been expended to develop power from solar energy sources. As you can imagine, however, the solar energy technologies developed within the space program are not usually directly transferable to the commercial field because of cost considerations.

In my own opinion, the ultimate choice before us so far as solar energy is concerned, comes down to a tradeoff between nuclear power and solar power. Nuclear power is in a sense a culmination of the technical trends toward extremely high temperatures and extremely high energy density, whereas solar power is just the opposite. Both are, of course, for practical purposes, infinite so far as total resource is concerned. As in many cases of this sort, I believe it is likely that the Nation will develop some type of equilibrium between these two modailities (and for that matter for the fossil fuel option also) which reflect some kind of overall averaging of the economic, environmental, and convenience factors, which is difficult for us to predict accurately at this time.

Let me elaborate on my own views as to the trade-off between solar electricity and nuclear electricity. The capital cost of a nuclear powered system is now estimated to be around $500/Kw. Solar electricity by direct collection and conversion to steam probably will cost considerably more than this, perhaps as much as $1,000/Kw to $3,000/Kw. So large a difference probably will not be compensated by the smaller operating costs of the solar system. I have, therefore, always felt that unless society decides to turn away from nuclear energy for reasons connected with the potential hazards of radioactivity, nuclear would win over solar for the long run.

However, I must make a caveat here. Future developments may lead to solar energy considerably cheaper than my estimate; and some of solar's children, like winds or ocean thermal gradients, may prove to be quite cheap eventually.

For these reasons, I believe the Nation should support a vigorous program in research on solar energy. Much of this program should be in physical research exploring the various scientific and engineering possibilities, some of it should be in studies to explore the various types of tradeoffs which compare solar energy to other forms, and some of it should be of incentives to the private sector to bring practical commercial systems into actual use as fast as possible when feasibility has been demonstrated. The planned Administration programs demonstrate that the personal views I have just outlined are also reflected in the official position of the Administration. In addition to the general comments I have just given regarding overall solar R&D, I believe we are now close to practicality in one area of solar energy, namely the solar heating of houses. In fact, combined solar heating and cooling houses also seems to be a near term practical possibility, although some development work is still required for the cooling system. You are, of course, aware of bills in the Senate and the House relative to Federal demonstration programs in this area. I have testified in general support of the intent of those bills. In short, I believe the Federal government should pursue a very vigorous program to bring feasible systems as fast as possible into the commercial sphere.

Turning now to where the Federal programs in solar energy reside, as you will understand from the previous comments regarding my office, the role of my office in energy R&D is overall coordination and planning. We do not fund any research programs directly ourselves. Likewise, the FEO itself is not directly involved in solar energy R&D. At this time, the NSF has been given the lead role in solar energy. The major NSF activities are in the RANN Division, and I believe Dr. Eggers will be testifying to you on that program tomorrow. In addition, substantial efforts are underway in both the AEC and in NASA. You have just heard from the AEC, and I believe you will hear from NASA tomorrow.

As you will hear tomorrow, the NSF program very broadly covers the general scientific potential of energy from solar radiation. Their program extends from very basic research on some of the more distant applications of solar energy to the demonstration of feasibility of solar heating in school buildings. You will also hear that they are funding three very important studies at this point which are expected to give crucial information on the details of commercial practicability of solar heating. With the completion of these studies, I believe it will be possible to make some important decisions about how the government can help develop incentives in the private sector for the solar heating of buildings. In my office, we will be watching these developments very carefully so that the appropriate government mission agencies, such as HUD, are involved as the NSF research and development stage is phased out.

The most important factor to my mind so far as solar energy is concerned, and indeed, so far as the entire energy R&D picture is concerned, is the reorganization of the Federal R&D effort in energy which is embodied in the establishment of the Energy Research and Development Administration. There seems to be every reason to believe that ERDA will be a reality within the next few weeks. In the current form of ERDA, solar R&D would be under a separate Administrator for solar, geothermal, and advanced systems. In the ERDA bill, the work in the National Science Foundation on solar heating and cooling will be transferred into ERDA. I fully expect the eventual ERDA program in solar energy to develop in such a way that the total Federal programs for energy will represent an appropriate balance between basic research, applied research, engineering development, and system demonstrations.

Given the attention which solar energy will surely receive under its Assistant Administrator in ERDA, the central position which ERDA will have in the total energy R&D picture, and in particular, its lead role in the development of solar energy, I believe the general intent of S. 3234 will be achieved. Further, it is my opinion that it would be a mistake at this time to set up a special office within ERDA with its own budget, and with its own independent position. On the contrary, I believe it is most important to develop a coordinated thrust for the whole energy R&D program with no special and external position and priority imposed on any of the particular energy aspects or modalities. In my opinion, the Congress will have ample opportunity to review the relative priorities of the various modalities as they are developed by the Administration through ERDA in the future without the establishment of such a special office for solar energy.

As to the matter of the budget for solar R&D, I note that in 1975, there is relatively little difference between the proposed Administration budget in solar energy and the budget proposed in S. 3234. Since the budget for the later years has not yet been specified by the Administration and is still being studied, I cannot comment on how that might differ from the authorization proposed in S. 3234. Again, after ERDA has been established, and has submitted its FY 1976 budget to you, there will be ample opportunity for Congressional review of the solar energy portion.

In summary, I wholeheartedly endorse the general intent of the solar energy bill for 1974 which is to give a strong push to research in all the aspects of solar energy. I do not believe, however, that the establishment of a special office for solar energy either within the agency or within the eventual ERDA would have a beneficial effect upon either the orderly development of overall energy R&D posture for the Nation, or even for the portion of R&D devoted to solar energy itself.

Representative Holifield. The next witness is Mr. David Cope, Federal Energy Administration.

Dr. Cope, will you please proceed.

STATEMENT OF DAVID COPE, ENERGY RESEARCH AND DEVELOPMENT OFFICE, FEDERAL ENERGY ADMINISTRATION (ACCOMPANIED BY: WALTER HIBBARD, DIRECTOR OF ENERGY RESEARCH AND DEVELOPMENT, FEA, AND VINCENT MC KELVEY, DIRECTOR OF THE UNITED STATES GEOLOGICAL SURVEY.)

Mr. Cope. Thank you, sir.

Mr. Chairman and Members of the committee, my name is David F. Cope. I am at the Energy Research and Development Office of the Federal Energy Administration.

Accompaning me on my right is Dr. Walter Hibbard who is Deputy Director of the Energy R&D Office. On my left is Dr. Vincent McKelvey, Director of the U.S. Geological Survey.

We are pleased to have been invited to testify before this committee.

I am here today to testify to the committee on the adequacy of uranium resources to meet the rapidly growing nuclear energy program and the importance of a sound import policy in relation to assuring that these resources will be available when needed.

Part of the basic near-term strategy of FEA's Project Independence program is to make greater use of our more abundant domestic resources, such as coal and nuclear energy to meet our future energy needs.

This pre-supposes the availability of adequate domestic supplies of these fuels to permit this substitution.

Estimates on domestic coal resources have been developed over a long period of time by a variety of independent sources leading to a fairly high degree of confidence in our knowledge of the extent of these reserves. However, we cannot say the same for urnaium.

~~I~~ We believe that in any ordering of priorities for the near future assuring the availability of uranium supply is of utmost importance. FEA, therefore, considers it necessary that we determine the extent of our uranium resources and that we do it promptly.

Representative Holifield. What are you doing in that field to determine that?

Mr. Cope. We are in the process now of working with other Government agencies, particularly the AEC, the U.S. Geological Survey, the Bureau of Mines and industry, ~~to try~~ to determine what they are doing to map out a program, We will to determine that the program is adequate, and do ~~and~~ then ~~to~~ follow up ~~and see~~ what is necessary to see that the program is implemented.

Representative Holifield. You are really depending on your information then from these sources? You are not doing it independently, you are merely receiving it and evaluating it.

Mr. Cope. That is correct. At the present time we are receiving it and evaluating it. We are trying to get information independently from various sources.

Representative Holifield. What luck are you having?

Mr. Cope. We are having very good luck in getting information. I think the information that we have assures us that there are some programs under way. ~~As to~~ whether these programs are adequate, ~~we~~ still need to do further work to determine ~~on them~~.

Representative Holifield. Programs under way for what?

Mr. Cope. Exploration, mapping and trying to lay out and delineate what uranium resources are available.

Representative Holifield. From what source areas?

Mr. Cope. You mean agency source areas?

Representative Holifield. I mean what source areas are the energy sources, are you talking about coal, oil, gas, nuclear?

Mr. Cope. In ~~my~~ this particular case I am talking about nuclear. ~~The~~ Other parts of the Federal Energy Administration are looking at oil, gas, coal resources, oil shale and all sorts of energy resources.

Representative Holifield. Then you only have to do with the nuclear field.

Mr. Cope. That is all I am speaking to here, yes, sir, Mr. Chairman.

Representative Holifield. Are you the overseer for all of the sources of fuel?

Mr. Cope. My ~~particular~~ primary area of responsibility and interest is nuclear but in the energy research and development ~~area~~ program we have ~~some~~ cognizance and ~~some~~ input into the other energy areas. Perhaps Dr. Hibbard would like to speak to that.

Representative Holifield. Would you speak to it on the basis of saying how many people you have assigned to nuclear, how many people you have assigned to coal, oil and gas?

Mr. Hibbard. We have a small office, Mr. Chairman. We have a specialist in each of these areas. We have a specialist in nuclear, Dr. Cope. We have a specialist in oil and gas, a specialist in coal, a specialist in oil shale.

So, our total office is only 10 people.

Representative Holifield. Of course, you know I am the author of the Federal Energy Agency Act.

Mr. Hibbard. Yes, sir.

Representative Holifield. We did place a section in that Act authorizing you to get that information.

Mr. Cope. Mr. Chairman, there are other parts of FEA looking into this rather extensively. I guess we are not ~~qualified~~ prepared to speak on this aspect of it today. ~~we are not fully informed on what the other sections are doing.~~

Representative Holifield. You said you were in charge of the energy area.

Mr. Cope. We are in the energy R&D area.

Representative Holifield. What other people would be getting figures on fuel resources that you would not be cognizant of?

Mr. Cope. The people in the Project Independence Blueprint program specifically. Although we have people in our group who are following that rather closely, I don't know that any of us in this meeting here today are following it.

Representative Holifield. I want to follow that up because I am just wondering if you coordinated your information gathering sources and somewhere there must be either one man or two men who are getting these statistics that we ask you to get.

Now, are you the one who is responsible for getting all the statistics or part of it?

Mr. Cope. No, sir, we are not the ones responsible. I am responsible for it in the nuclear area.

Representative Holifield. Who is in the other area?

Mr. Cope. I am sorry, I can't tell you who has that responsibility. We can provide that information, sir.

Representative Holifield. I would hope so. I think it would be of vital interest to us to know if you are looking at the nuclear end of it, its relation to the fossil end of it, because unless you put the two together we don't have the total figure and it is meaningless.

Mr. Cope. Mr. Chairman, we are looking at that and we are looking at that in our group. I just don't happen to know the name of the individual in FEA who is responsible for gathering this information. There are a number of committees. These committees are looking at different aspects of the energy program. They have crosscut committees and ~~various~~ inputs. But we are looking at it and we are coordinating within the agency.

Representative Holifield. Is Mr. Sawhill or one of his deputies coordinating this energy which comes from similar sources and is for the same purpose as far as independent use, kilowatts?

Mr. Cope. That is correct, and that is one of the main tasks that is being undertaking under Mr. Sawhill.

Representative Holifield. That who would be taking?

Mr. Cope. The Federal Energy Administration. There are several deputy administrators involved. I think Mr. ~~Zellner~~ in particular is involved in ~~that.~~ Many people in the Federal Energy Administration are involved in various aspects of it. ~~It is just a complicated situation --~~

Representative Hosmer. Who will coordinate all of this so that somebody knows what is going on?

Mr. Hibbard. May I answer that?

Under Mr. Sawhill who is the Administrator there is an assistant administrator for resource development who is [illegible]

the ~~broad~~ resources ~~in the~~ development.

Also under Mr. Sawhill there is assistant administrator Eric ~~Sossner~~ Zausner. He is responsible for the Project Independence Blueprint which is being developed relative to the proposal for the ~~long-range~~ energy policy for the country.

Representative Holifield. What is he interested in?

Mr. Hibbard. He is an assistant administrator.

Representative Holifield. What phase of the energy development is he interested in?

Mr. Hibbard. He is interested specifically in looking at the various modalities from the standpoint of supply, comparing them to the projected demands, and coming up with a plan and a policy which hopefully will have the supply and the demand in balance.

Representative Hosmer. Let us take a test here and see how well everything gets around. Yesterday I read an interesting press release that originated in your Department, Dr. Hibbard, that somebody wants to dig holes 30,000 feet deep every 20 miles throughout the country to inventory the energy resources and other resources that might be available and there are quite a lot of unknowns about that.

Do you know about that?

Mr. Hibbard. I knew about that, yes.

Representative Hosmer. Did you know about that, Dr. Cope?

Mr. Cope. I did not.

Representative Hosmer. Dr. McKelvey, did you know about that?

Mr. McKelvey. Yes, I did, sir.

Representative Hosmer. Well, that is two out of three.

Representative Holifield. I am a little bit surprised very frankly at your lack of knowledge, Dr. Cope, of some of these things that are certainly vital. We are very much interested in nuclear of course, but we are also interested in coal and oil. We are interested in the overall industry.

Maybe we should have somebody else come up -- you know, one of the things that we find out about the agencies is that sometimes they are so compartmentalized that it is difficult for us to know whom to talk to to get the overall information that we need.

Mr. Cope. Mr. Chairman, if I may I would like to respond to that.

Representative Holifield. Yes, you may.

Mr. Cope. If I indicated that I was not knowledgeable that is not correct because in our office, the energy R&D office, all of these inputs come into us, we do review them and we try to place in balance what the various alternatives are.

I think, sir, where I was unable to answer your question was what one person in the Federal Energy Administration had the specific responsibility for looking at the oil and gas, and other ~~thing~~. fossil energy supplies.

In the Federal Energy Administration there are a number of studies going on. We ~~They~~ are still in the process of trying to develop the Project Independence Blueprint. ~~There is a vast amount of material that is going around through the agency which we are trying to keep up with.~~

Representative Holifield. I want to be fair to you. Perhaps our invitation to you indicated that we only wanted you to testify on the nuclear part.

Mr. Cope. We certainly expected that was the case.

Representative Holifield. All right, proceed.

Mr. Cope. Virtually every portrayal of the nation's energy future, whether short or long-term, pictures a rapid expansion in nuclear energy as one of several means for meeting the nation's energy requirements.

The AEC's most recent estimate on nuclear power growth projects as one of its medium range cases a nuclear electric generating capacity of about 250,000 megawatts electrical (Mwe) by 1985 and 1,090,000 Mwe by the year 2000.

FEA as part of its Project Independendence Blueprint will consider various energy options and several different cases for each of these options, including the roll of nuclear.

We are now in the midst of analyzing these energy

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options and therefore, I cannot comment on these projections at this time. I will instead discuss the uranium requirements associated with the AEC estimate.

To achieve the above level of generating capacity, AEC estimates that the cumulative uranium requirements will be about 400,000 tons of uranium oxide by 1985 and about 2,200,000 tons of uranium oxide by 2000.

However, the 30 to 40 year lifetime requirements for these same reactors will be approximately 1.5 million tons and 5.0 million tons respectively of U_3O_8.

Representative Holifield. For each reactor?

Mr. Cope. That would be for the total nuclear capacity in those respective years. In other words, 1985, the lifetime requirement for all reactors would be roughly one-and-a-half million tons and then the five million tons for the year 2000.

The viability of the nuclear option is dependent upon our ability to meet these anticipated demands for uranium. This ability in turn, depends upon the existence of commercially recoverable reserves and mining and milling capacity.

A comparison of the AEC estimates of projected reserves with anticipated uranium demands suggests that unless exploration to identify richer reserves proceeds at a more rapid pace, we may be forced by the year 2000 to use low-grade uranium of 60 parts per million (ppm) or less.

In principle this may not greatly increase the cost of nuclear electric power because of the relatively small components of the total generating cost represented by the cost of uranium ore.

However, the economic cost could be much greater than now estimated and the mining of these low grade ores might impose serious and even unacceptable environmental and social penalties.

Representative Holifield. That makes it more urgent than ever that we get to the liquid metal fast breeder.

Mr. Cope. I certainly think so.

Thus, extensive mapping and exploration are required to locate and characterize the richer deposits so that we may assess our ability to supply the rapidly increasing amounts or uranium which will be needed in the period 1985 and beyond.

In the uranium mining business, exploration and eventual development of a mining operation requires long lead times and there needs to be strong incentives for a company to invest in such an operation.

We are troubled by the fact that, for a variety of reasons, the market has not responded forcefully to the vast prospective increase in uranium demands.

. . . .

delineate the location, concentration and character of our domestic reserves and the capacity to convert these reserves into above-ground uranium at a rate and cost consistent with the projected expansion of nuclear power.

FEA believes that the matter of uranium availability is of greater urgency than is generally recognized at present. We support the efforts of the AEC, USGS, Bureau of Mines and industry in the development of new programs in this area and the strengthening of existing ones.

Among our specific recommendations are:

(a) The determination of the availability of domestic resources which can be developed on a schedule and at a price which will meet the present and projected fuel needs of the nuclear electric generating industry.

(b) The development of new and improved techniques for deep uranium exploration and development.

(c) The development of new techniques for the recovery of low-grade ore.

(d) The development of environmentally acceptable criteria and techniques for mining uranium ore and, in particular, the low-grade ores which require massive excavations.

(e) The determination of the cost and practicality of extracting uranium from sea water.

(f) The development of government policies and incentives to encourage the exploration and production of domestic uranium resources consistent with the long-term objective of providing uranium fuel for the nuclear industry at acceptable economic and evnironmental costs.

Representative Holifield. Dr. Cope, why didn't you have, with those alphabetical indentations, anything about the liquid metal fast breeder? You go into the whole field here of low-grade ores which you and I both know are very expensive, you go into deep mining techniques, and even to getting uranium from sea water. But you don't say a word about the liquid metal fast breeder reactor.

Mr. Cope. Mr. Chairman, ~~the way we~~ approached this problem ~~b this~~ was directed specifically at resources, it was not an attempt to either address or avoid addressing the breeder.

We considered that this is ~~something that is~~ a separate problem although strongly related. There was no intent either deliberately or otherwise to leave that out.

Representative Holifield. I see so much of this going on in the AEC from thetop level on down, a lack of any kind of enthusiasm or urgency for doing the one thing which would make unnecessary low-grade ore, deep and expensive ore, the extraction of uranium from sea water which of course in itself would be a massive research and development technology, it would [illegible] dollars.

You know, the President said that the liquid metal fast breeder reactor was of the highest priority.

Mr. Cope. That is correct.

Representative Holifield. This committee accepted that. The utility industry accepted that. The manufacturing industry accepted that. All of us accepted that.

Yet, I find it passing strange that you don't have anything in there. You talk about massive excavation and all that for low-grade ores but you don't say anything about getting on with something that we believe is technically possible and which has the highest priority and which is lacking now for some three years without any action on it.

Mr. Cope. Mr. Chairman, this could have well been said. In our analysis of the uranium resource ~~problem~~ situation, if we assume that the breeder comes in on the projected schedule that the AEC now has and that we will have a commercially ~~an~~ available breeder along about 1988 or early 1990's we think there still will be ~~the~~ a problem with the availability of uranium resources notwithstanding the breeder.

I ~~think~~ that is the reason we didn't bring it into this particular session.

Representative Hosmer. I think what Mr. Holifield is getting at, and I want to get at, too, is that out at the [illegible]town AEC parking lot we think there are a lot of bumper stickers out there saying, "Impeach LMFBR."

Mr. Cope. As I say, there was no attempt on our part to exclude the breeder.

Representative Holifield. Again, I find it passing strange that you did not have an item in there, an explanatory item in regard to the LMFBR and its potential impact on the nuclear energy structure throughout, because from the amount of information we have in this committee, which has been laboriously and at great expense developed over the past 12 or 14 years, we believe that this is the most important thing for us to be going at in research and development so far as the nuclear field is concerned.

We would know how to make the water reactors. We know the whole technique of them. We are building and operating them at more than competitive levels with fossil fuels with their present high prices, coal and oil

We also have known about the shortage of uranium ore. We have known it for a long time. This is why almost 12 years ago we started on research. I think it is back farther than that when we started with EBR-I. Twenty years ago we started with the EBR-I to try to find out if the utilization of plutonium and development of the liquid metal fast breeder technology could be done.

We finally, after spending, let us say, a billion dollars [illegible] model, the first demonstration model. This was not just this committee. This was all of the utility industry, the manufacturing industry, the President and the Congress, because this committee got these research and development funds approved by the Congress in both Houses, the Senate and the House.

I would think that you might want to add a chapter to your testimony and send it in if you feel the way I feel about this.

Mr. Cope. Mr. Chairman, I can certainly speak personally on this. This is on two points. In our evaluation of the Project Independence exercises, which if you use a cutoff date of about 1985, it does not appear that the breeder will come in in time to affect that program per se.

But the second point ---

Representative Holifield. I am not disagreeing with you. I might extend it to 1995 at the rate AEC is going.

Mr. Cope. On the second point, certainly the sooner the breeder comes in then the less serious will be our uranium resource problem.

Representative Holifield. That is right, but you do not say anything about that. Yet you worked in Milton Shaw's department for many years, you have been in the AEC for 20 years. So, you must be knowledgeable on that.

Mr. Cope. [illegible], sir.

Representative Holifield. I invite you to tell the whole

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story on nuclear energy in your testimony if you are going to testify on that point.

Mr. Cope: Thank you.

Chairman Price. I ask unanimous consent that he be able to revise and extend his remarks.

Representative Holifield. Is there objection?

Representative Hosmer. No objection.

Representative Holifield. Hearing no objection, the request will be granted.

Mr. Cope. Relation to Uranium Import Policy.

We recognize that the above program goes beyond the scope of these hearings. However, we believe that this background is important to place our uranium import policy in proper perspective with respect to the overall program or uranium supply.

Foreign policy with respect to importation of uranium is an essential ingredient to the viability of the nuclear segment of our energy supply and requirements picture.

Uncertainty on what the policy is or should be is in itself a problem and a firm and clear enunciation of policy, whatever it may be, is preferable to no policy.

FEA has not yet fully evaluated the pros and cons of this issue to suggest what the policy should be. However, as we [illegible] that insufficient exploration work is being undertaken to determine what the U.S. assured uranium reserves really are; that there needs to be significantly increased exploration efforts by industry and government to correct the situation; that for various reasons the present market forces are not providing the incentive for industry to move ahead at an acceptable pace, and that a long-term stable market is an essential ingredient to providing the incentives for industry to proceed on its own to develop the needed uranium reserves.

There are many forms which these incentives could take, but the following are several which have been suggested to FEA:

(a) Tax incentives for utilities to enter into long-term ore commitment contracts with the terms being more favorable for domestic ore commitments.

(b) Government stockpiling, or guaranteed price.

(c) Requiring as a condition to licensing a nuclear plant that the licensee have an assured uranium supply to meet the plant's anticipated needs for some number of years in the future, for example, ten to thirty years.

Representative Holifield. All the recommendations are desirable. Some of the testimony is that nobody is able to get such an assurance right now.

Mr. Cope. I recognize that.

Representative Holifield. If that recommendation were [illegible] required fuel over the lifetime of the plant.

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Mr. Cope. Unless it was done in a gradual fashion ~~by~~ a policy that would say you gradually work into long-term requirements so as to avoid any sudden disruption of the market.

As we have indicated these were suggestions which have been passed on to us. We haven't tried to go into it any deeper and find out how sound these are or if ~~they~~ these are better ones. The point we wish to make ---

Representative Holifield. They are not your recommendations. These are the recommendations that have been made to FEA?

Mr. Cope. That is correct, sir.

Representative Holifield. Do you have a question on the first paragraph, Mr. Hosmer?

Representative Hosmer. Yes. I have difficulty understanding what you are getting at on page 5.

Is it that the announced criteria represent a policy with respect to imports? That is premature because we at this point do not yet know what our domestic resources are and that the import policy should be scaled in relation to that?

Mr. Cope. Congressman Hosmer, we treat that in the recommendation. What we are attempting to do there is to [illegible] do relate to import policy and tie into what we consider to be a basic issue of assuring the long-term stable supply of uranium. I am just enunciating the various things that bear on that issue.

Representative Hosmer. If AEC goes bulling ahead with these criteria that are proposed is it your feeling then that it should be prepared to revise them as some of the other facts come in that are needed to base the policy that is most closely aimed at the national interest?

Mr. Cope. We suggest in our recommendations that the proposed monitoring policy of the AEC is a very important aspect of it. This is a complicated business and we know that it is difficult to predict what the market conditions will be three, five, ten years in the future.

Representative Hosmer. I am thinking of a little shorter range in the future. The testimony that was put in the record by Mr. McGee of the Kerr-McGee Company pointed out that up to the period 1981 and by that year your imports would be allowed at a rate of 40 percent of the feed furnished the AEC's complex, the previous year 30 percent, and 20 percent -- even so that in actuality the load growth at that time open to foreign importation would considerably exceed 50 percent of all the new contracts that have not yet been entered into.

There is a bunch of contracts now in existence and it is only their incremental requirements over and above that have not been contracted for yet that are really affected by this import policy.

For instance, their figures show that in the year 1980 where there is a total of 20.4 million pounds, I don't know what their figure is, of requirements that are uncommitted. This leaves 84.4 percent of the imports of that bunch wide open and the effect on the United States industry could theoretically be rather difficult and disastrous in this short a range period.

What do you think of that analysis? I wonder if the AEC thought about that when they put out this criteria?

Mr. Cope. I don't know whether the AEC did or not. I guess our response to that would be somewhat along this line. Certainly the assurance of a stable domestic uranium industry is exceedingly important and if the import policy in any way is going to inhibit the establishment of that stable industry, then the import policy should be adjusted accordingly.

Representative Hosmer. It is extremely important to the nuclear utility industry over the long range but sometimes price to them is exceedingly important over the short range.

So, we have a conflict between the two in which the ultimate interest of both the utilities, the mining and milling industry in the country is liable to slip down the track, isn't it?

Mr. Cope. That is part of the problem, the weighing of two desirable objectives and trying to determine what is the best course.

Representative Hosmer. I would hope that (the AEC) ~~FSEA~~, whoever they are next year, and by whom they may be staffed and executed, will find it in their hearts and minds to give some attention to your recommendation that this thing be carefully monitored.

I am very fearful, when you spin one of these agencies apart and let the pieces land into a new bosom you don't know whether you are going to get clasped very well or not, with all due consideration, Mr. Holifield, to your complete reorganization plan but with total fear and trepidation with respect to what was done to it on the other side of the Capitol.

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Representative Holifield. I am suffering from that surgical operation, itself, in contemplation.

Do I understand you to say that you believe this formula set up by the AEC is a practical formula, well considered, and has enough gradualness to it to not jeopardize the domestic supply, or are you fearful of it?

Mr. Cope. Mr. Chairman, our statement was that this appears to be consistent with a stable industry. I think I would have to reply that at this stage we cannot judge whether this is a good one or poor one.

Representative Holifield. You can understand that it does go in very gradually and it can be stopped at any time, it would not be mandatory that they go ahead with this if it were not in the national interest.

Mr. Cope. We took that into account, sir, in our recommendations.

Representative Holifield. You are willing to risk A, B, and C, 10, 15, up to 20 percent by 1979, you would be willing to risk that? You feel there is enough stability in the domestic market now and enough demand in the domestic market that that would not --

Mr. Cope. ~~I guess that~~ We ~~feel~~ this stability still has to be demonstrated, that there are some indications ~~it~~ [illegible] is becoming more stable [illegible] and perhaps by the time the importation policy comes into actuality, which is [illegible],

~~that~~ this will give ~~us some~~ time to determine whether there is a stable industry.

Representative Holifield. And if it looked bad at that time, there would be no reason for going ahead next year.

Mr. Cope. It should be looked at again.

Representative Holifield. Go ahead.

Mr. Cope. Recommendation.

In contrast to oil, uranium is widespread throughout the world and one therefore fears less the cartelization of uranium. Hence, from the viewpoint of being subject to the vagaries of foreign sources we probably can import uranium with less risk than we can import oil. Further, the impact on our foreign exchange balances is negligible compared with that of oil.

However, maintaining the uranium embargo might be considered for two reasons:

(1) The prospects of cheaper foreign ore would inhibit the development of a stable domestic market necessary to providing the incentives for the development of domestic reserves to meet future requirements.

(2) Should the foreign supply not materialize as expected, or be suddenly interrupted, there could be a significant lag before the domestic industry [illegible] to meet these additional demands.

On balance, the import policy should be consistent with assuring adequate domestic uranium resources when needed. We, therefore, support lifting the embargo gradually and in a manner that will not jeopardize the stability of the emerging domestic uranium industry.

The AEC's proposed policy appears to be consistent with this goal. However, we are concerned about the apparent lack of incentives for private industry to conduct the exploration necessary to develop the potential reserves. Therefore, if AEC's policy is implemented, FEA considers it extremely important that they establish and carry out the proposed program to monitor the extent of importation of foreign uranium for domestic use and its effect on the domestic uranium producing industry and on the Presidential objective of achieving a national capability for energy self-sufficiency. Should this monitoring program indicate that the importation policy is having a significant adverse effect on the domestic industry's ability to develop potential reserves needed to meet future requirements, we suggest that it be reexamined in light of those findings.

FEA also supports the AEC's plans to pursue an expanded aggressive program directed toward obtaining a comprehensive assessment of the extent of potential domestic [illegible]

and milling technology in order to help assure the development of an adequate uranium fuel supply on a timely schedule.

We further suggest that strong consideration be given to developing a program which will encourage the utilities to enter into long-term contractual arrangements for their uranium ore needs with the expectation that this would lead to a more stable domestic uranium market which would provide the mining industry the incentives to develop the potential uranium resources needed.

(The appendices follow:)

Mr. Cope. We appreciate, sir, having had the opportunity to testify before this committee, and we hope our testimony has been helpful.

Representative Holifield. Dr. Cope, thank you for your testimony.

You recommend that we encourage the utilities to enter into long-term contractual arrangements for uranium ore. Is it not true that many of them would like to do that but have not been able to get the other side of the bargain to agree?

Mr. Cope. That is correct, sir. This is a very complicated issue. We are not suggesting that the blame is on one side or the other. But this goal is important enough that everyone concerned, including the government, should be trying to work to this end.

Representative Holifield. Have you any thoughts at all on the problem of tails assay and the amount of preproduction, whether we should have preproduction at this time or not?

Mr. Cope. I understand the problem, Mr. Chairman. I understand the payoff. In one case, with the higher tails assay, ~~that~~ we are able to essentially extend our enrichment capabilities but place a higher demand on the ore requirement. With the [illegible] of [illegible] percent [illegible], ~~that~~ we relieve the pressure on the ore requirements but we increase the pressure on the enrichment capability.

I do not have a suggestion as to which is the preferable way to go. Certainly it indicates that we have a problem on both sides of the fence.

Representative Holifield. Do you have any questions, Mr. Hosmer?

Representative Hosmer. No questions, Mr. Chairman. Mr. Hansen may have some.

Representative Holifield. Mr. Hansen, do you have any questions?

Representative Hansen. No questions, Mr. Chairman.

Representative Holifield. Thank you, Dr. Cope, and your associates.

Mr. Cope. Thank you, sir.

Representative Holifield. We look forward to hearing from you before this goes to the press.

Mr. Cope. All right.