ERDA-48
VOL. 1 OF 2

A National Plan For Energy Research, Development & Demonstration:

Creating Energy Choices For The Future

Volume 1:
The Plan

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
WASHINGTON, D.C. 20545

June 28, 1975

The President of the United States

The President of the Senate

The Speaker of the House of Representatives

Sirs:

I enclose for your consideration Volume I of "A National Plan for Energy Research, Development, and Demonstration" containing the Plan. Volume II, the Program Implementation (including both nonnuclear and nuclear programs) will be submitted under separate cover at a later date.

This report was prepared in response to Section 6 of the Federal Nonnuclear Energy Research and Development Act of 1974, which requires ERDA to develop a comprehensive plan for energy research, development, and demonstration. According to the Act, the Plan is to be designed to achieve solutions to energy supply system and associated environmental problems in (a) the immediate and short-term (to the early 1980's); (b) the middle term (the early 1980's to 2000); and (c) the long-term (beyond 2000).

The Plan was developed in consultation with other government agencies and with representatives of the private sector so as to make it an integral part of a broader national response to energy challenges. Nonetheless, the responsibility for the content remains ERDA's.

The conclusions contained in the Plan confirm the urgent nature of the energy challenges confronting the Nation--a sense of which underlay the legislation establishing ERDA. The Plan develops the necessary priorities for meeting these challenges. In a number of areas, national efforts must be redirected and accelerated if we are to meet the most critical goals.

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

The Executive Summary outlines the specific conclusions and recommendations. These are presented more fully in the body of the Plan. To remain a vital part of agency program management, the Plan will be modified annually - beginning in January 1976 - to reflect changing circumstances, new opportunities, and experience.

I urge the Congress - and the Public - to study and debate these recommendations as part of a common effort to establish the most effective possible national energy policy. There are few current tasks more critical to the long run well-being of this Nation.

Sincerely,

Robert C. Seamans, Jr.
Administrator

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SUMMARY

A serious and continuing energy problem exists in this country.

Imports, in the form of petroleum, petroleum products, and natural gas account for 20 percent of the total domestic energy consumption, at an annual cost of over $25 billion in 1974.

This heavy reliance on imported energy has serious national security implications. Dependence on imports makes the United States vulnerable to undesirable external influences on U.S. foreign and domestic policy. Foreign powers can threaten life styles and economic stability by curtailing the supply of petroleum or effecting arbitrary and sudden price changes. The quadrupling of the world price of petroleum in the past two years has disrupted the U.S. economy and the economies of all other importing nations.

This Plan recognizes five national policy goals as a focus for energy policy:

- To maintain the security and policy independence of the Nation.
- To maintain a strong and healthy economy, providing adequate employment opportunities and allowing fulfillment of economic aspirations (especially in the less affluent parts of the population).
- To provide for future needs so that life styles remain a matter of choice and are not limited by the unavailability of energy.
- To contribute to world stability through cooperative international efforts in the energy sphere.
- To protect and improve the Nation's environmental quality by assuring that the preservation of land, water, and air resources is given high priority.

The national energy problem is best understood as one of limited choices today.

- The U.S. energy system currently relies most on the least plentiful domestic energy resources, and least on the most abundant resources.
- Over 75 percent of the Nation's energy consumption is based on petroleum and natural gas. Domestic supplies of these commodities are dwindling.
- Coal, the most abundant domestic fossil fuel, provides less than 20 percent of current energy needs.
- Uranium, the domestic energy source with the greatest energy potential, provides about 2 percent of the Nation's energy.
- Solar energy, available to all, but diffuse, provides a negligibly small percentage of current needs.

To overcome this problem and to achieve our National policy goals, the Nation must have the flexibility of a broad range of energy choices.

It is not possible to predict what our Nation's interests and its people's desired life style will be at the end of this century. Whatever those interests and desires are, however, energy should serve them. The present situation in which national policy and social choice are constrained by over reliance on one form of energy cannot be allowed to recur.

For these reasons, today's challenge is to create a wide range of energy options for the future. The National Plan for energy R,D&D is designed precisely to create those options for future generations.

The Plan has been developed within the context of the President's overall energy policy and programs.

The Plan delineates the innovations in technologies required to overcome energy problems. If price structures, regulations, or incentives change, many of the required technologies may be developed in the private sector in response to market demands and without Federally assisted R,D&D.

To generate the necessary options, the Plan is designed to facilitate the changeover from dependence on a narrow base of diminishing domestic resources to reliance on a broader range of less limited or unlimited alternatives.

The first technological need is to extend the life of our oil and gas resources. The reappraisal of the Nation's oil and gas resources just released by the U.S. Geological Survey, and independently supported by a current study of the National Academy of Sciences, demonstrates the need for this step (see Figures 1 and 2).

The implication of the new estimates are that current rates of oil and gas production by conventional methods will be difficult to maintain, even with additional Outer Continental Shelf and Alaskan production. Without enhanced recovery, the estimates indicate that production of domestic oil will begin to drop rapidly in the mid 1980's, as will the production of domestic natural gas. It is unlikely that major new energy sources could be ready by that time.

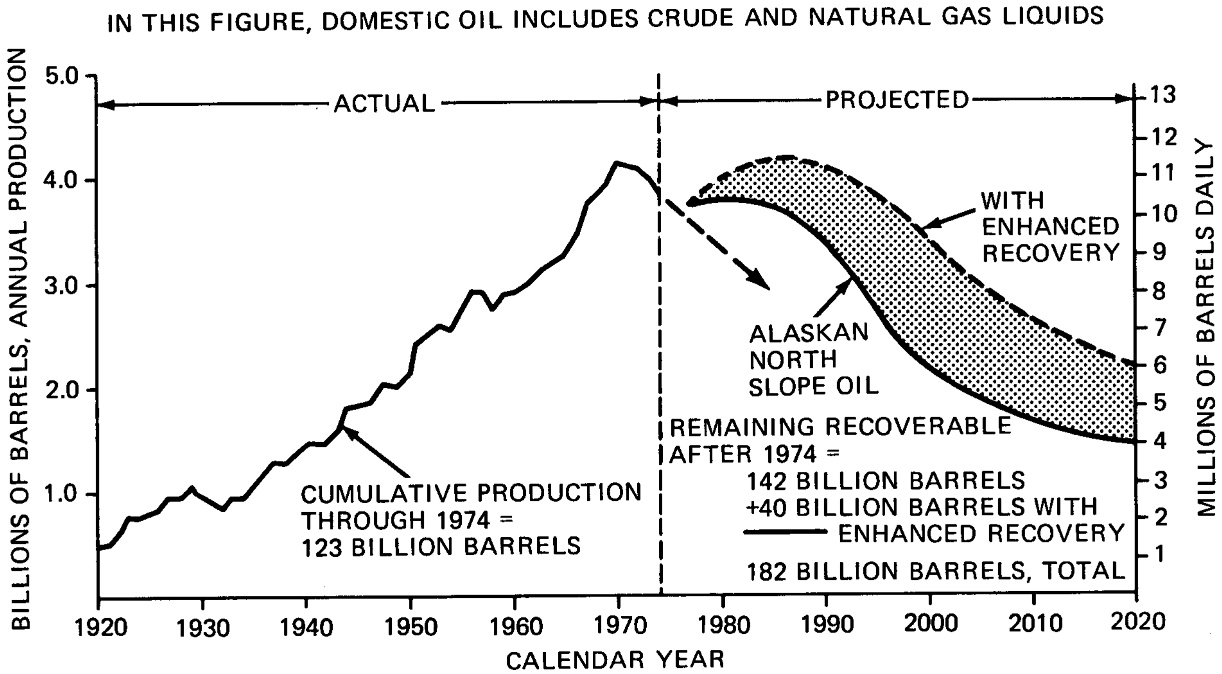

Figure 1. Projected Domestic Oil Production

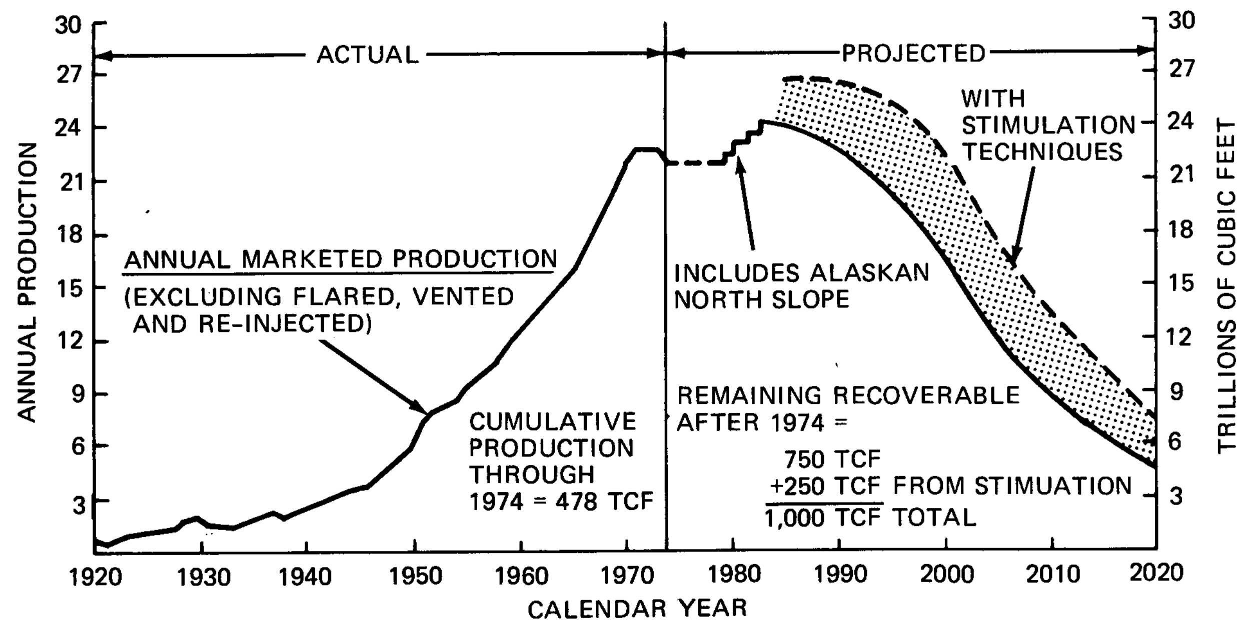

Figure 2. Projected Domestic Natural Gas Production

Enhanced recovery, which requires some technological development, will buy roughly 10 years of time. These 10 years are crucially important to the country because they double the time available for the development of new energy sources.

A second basic step is to tap the domestic energy resources available to us. Figure 3 represents estimates of recoverable domestic resources of commonly considered fuels. In this figure, the amount of energy is shown graphically by area, with the shaded portions indicating additional resources that may become available if the technology can be developed for recovery.

Finally, two additional major resources exist, both of which can represent essentially inexhaustible sources of energy if the technology to use them can be perfected. These are solar energy and fusion energy. In both cases the potential is substantial, although significant problems remain to be solved in their development. These sources, together with nuclear breeding, represent the major candidates for meeting energy needs of the future. Even if these technologies should prove successful in satisfying the technical, economic, institutional and environmental requirements for implementation, their major energy supply contributions will occur in the twenty-first century.

There are other potential sources of energy production, many of them limited in one way or another. A full list of sources is shown in Table 1.

• Coal	• Oil
• Crops	• Oil Shale and Tar Sands
• Fertile Nuclear	• Sunlight
• Fissile Nuclear	• Tides
• Geothermal	• Waste Heat
• Hydroelectric	• Waste Materials
• Natural Gas	• Water (fusion and hydrogen)
• Ocean Heat	• Windpower

Table 1. Fuels and Energy Sources

This transition to new energy sources must be made more swiftly than ever before.

The historical perspective of Figure 4 shows that in the past it has taken some sixty years from the point at which a transition to a new energy resource was first discernible until that resource, in turn, reached its peak use and began

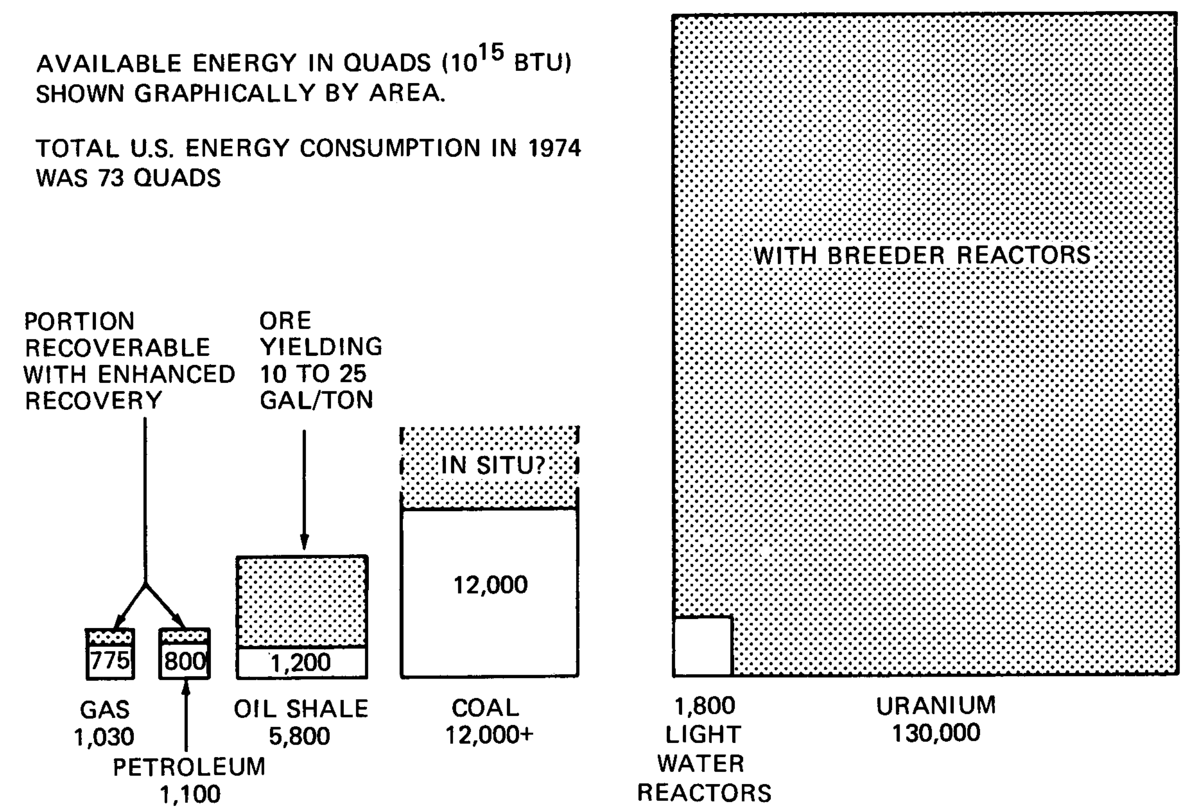

Figure 3. Available Energy from Recoverable Domestic Energy Resources

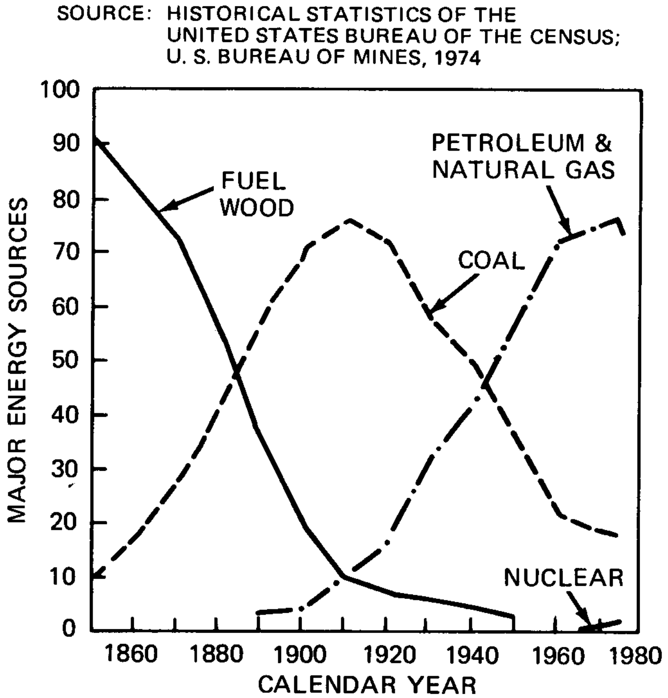

Figure 4. U.S. Energy Consumption Patterns

to decline relative to other sources. Domestic supplies of oil and gas appear to have reached that sixty-year peak. Their relative shares in the U.S. energy market are expected to decrease with time. It is essential, therefore, to plan now for the transition from oil and gas to new sources to supply the next energy cycle. The Nation cannot afford to wait another 60 years to complete the next transition. Only an aggressive program of technological development can expedite this process. It is urgent to begin now.

To accomplish this transition a framework of national energy technology goals has been established.

These goals, shown in Table 2, emphasize not only the development of technologies related directly to the supply of energy but also development of supporting technologies that focus on:

- The crucial importance of reducing energy waste and increasing the efficiency of energy use in all sectors of the economy through application of existing and new technologies.
- The major role of technology in protecting and enhancing the environment, a concept which must be fully integrated into all aspects of energy production and use.
- The necessary supporting structure of basic research and technical "spin-offs" from other high technology areas to undergird and lead to continuing innovation in the energy technology area.

I. Expand the domestic supply of economically recoverable energy producing raw materials
II. Increase the utilization of essentially inexhaustible domestic energy resources
III. Efficiently transform fuel resources into more desirable forms
IV. Increase the efficiency and reliability of the processes used in the energy conversion and delivery systems
V. Transform consumption patterns to improve energy utilization
VI. Increase end-use efficiency
VII. Protect and enhance the general health, safety, welfare and environment related to energy
VIII. Perform basic and supporting research and technical services related to energy

Table 2. National Energy R,D&D Goals

All the national energy technology goals must be pursued together. Concentration on only one or a few technological avenues is not likely to solve the energy problem.

A number of strategies have been advanced to solve the energy problem. The first is to place primary national emphasis on reduction of energy waste and inefficiencies to ease supply problems. The second is to put primary emphasis on the use of the vast energy residing in the Nation's coal and oil shale resources to produce synthetic fuels that will substitute directly for diminishing supplies of oil and gas. The third is to emphasize the alteration of consumption patterns, shifting from reliance on petroleum and gas to reliance on electricity, which can be provided from all the domestically abundant energy sources.

To derive a fuller perspective, these strategies need to be contrasted with views of the future in which (a) no significant new initiatives are undertaken, (b) a key technology (such as nuclear power) is eliminated from consideration, and (c) some combination of all of the primary responses is assumed to have a high—even unrealistically high—degree of success. ERDA has examined all six strategies called scenarios in this report:

Scenario 0	No New Initiatives
Scenario I	Improved Efficiencies in End-Use
Scenario II	Synthetics from Coal and Shale
Scenario III	Intensive Electrification
Scenario IV	Limited Nuclear Power
Scenario V	Combination of All Technologies

Analysis of these scenarios focuses on drawing forth insights on the nature of:

- The energy system itself, viewed as a system.
- The role of technologies within the system.
- How the above characteristics change with time.

It should be emphasized that the scenarios are not forecasts or predictions. They are illustrations of possible strategies—"paper and pencil experiments."

The same demand for energy services was used as a basis for all scenarios. The demand assumes continuation of historical trends by use sector modified to reflect recent price increases. The appropriate technology mix of each scenario, together with the oil and gas production estimates shown in Figures 1 and 2, leads to estimates of the amounts of imported fuel needed to satisfy demand. Results are shown in Figure 5.

The import levels for the primary Scenarios I, II and III are unacceptably high in the year 2000, representing an increase over today's levels and in some cases an accelerating increase. These levels reflect, of course, the result of emphasizing only a single set of technological approaches to deal with the energy problem. The analysis suggests that:

- All scenarios, except V, are unacceptable individually: they show increasing imports. That is, only the successful development and implementation of a large number of technologies in a combination of approaches can make importing fuel a matter of choice.
- Curtailment of any major existing option (such as nuclear power) places heavy demands on all the remaining options and precludes an acceptable solution (low level of imports or no imports).

The target area for R,D&D contribution is represented by the shaded area in Figure 5, bounded on the top by the curves for the primary Scenarios I through III and bounded below by the extensive technological success assumed in Scenario V.

The actual future levels of imports will depend not only on the technological results within the above spectrum but also upon:

- The actual amount of oil and gas found and produced in the United States.
- The actual life style (demand for services) either chosen for the future or forced upon the public by a continuing energy supply problem.

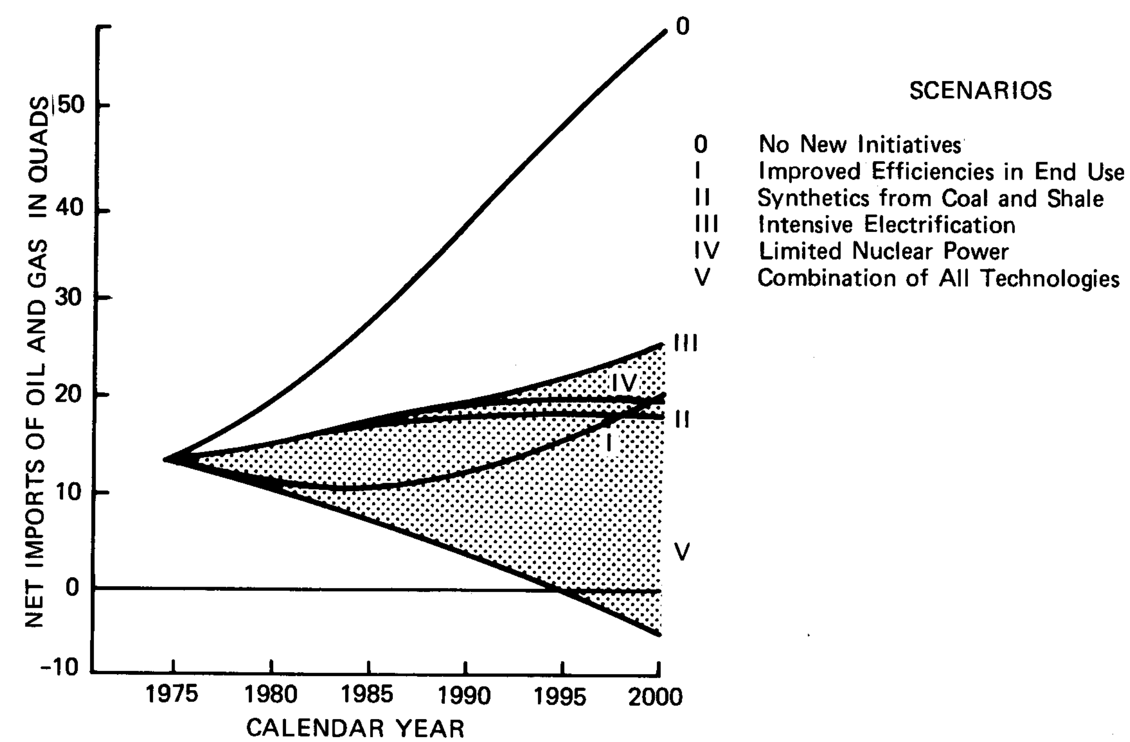

Figure 5. Imports of Oil and Gas

Near-Term Major Energy Systems	Coal—Direct Utilization in Utility/Industry Nuclear—Converter Reactors Oil and Gas—Enhanced Recovery	Highest Priority Supply
New Sources of Liquids and Gases for the Mid-Term	Gaseous & Liquid Fuels from Coal Oil Shale	
"Inexhaustible" Sources for the Long-Term	Breeder Reactors Fusion Solar Electric	
Near-Term Efficiency (Conservation) Technologies	Conservation in Buildings & Consumer Products Industrial Energy Efficiency Transportation Efficiency Waste Materials to Energy	Highest Priority Demand
Under Used Mid-Term Technologies	Geothermal Solar Heating and Cooling Waste Heat Utilization	Other Important Technologies
Technologies Supporting Intensive Electrification	Electric Conversion Efficiency Electric Power Transmission and Distribution Electric Transport Energy Storage	
Technologies Being Explored for the Long-Term	Fuels from Biomass Hydrogen in Energy Systems	

Table 3. National Ranking of R,D&D Technologies

Based upon an analysis of scenarios, the status of the candidate technologies, and the extent of the resources they would use, a national ranking of R,D&D technologies has been developed to identify priorities for emphasis in the Plan.

The ranked list is presented in Table 3.

For the near-term (now to 1985) and beyond, the priorities are:

- To preserve and expand major domestic energy systems: coal, light water reactors (the highest nuclear priority), and gas and oil both from new sources and from enhanced recovery techniques.
- To increase the efficiency of energy used in all sectors of the economy and to extract more usable energy from waste materials.

For the mid-term (1985–2000) and beyond, priorities are:

- To accelerate the development of new processes for production of synthetic fuels from coal and for extraction of oil from shale.
- To increase the use of under-used fuel forms, such as geothermal energy, solar energy for heating and cooling, and extraction of more usable energy from waste heat. None of these technologies has a major long-term impact, but each can be quite useful in relieving mid-term shortages.

For the long-term (past 2000), priorities are:

- To pursue vigorously those candidate technologies which will permit the use of essentially inexhaustible resources:

  —Nuclear breeders.

  —Fusion.

  —Solar electric energy from a variety of technological options, including wind power, thermal and photovoltaic approaches, and use of ocean thermal gradients.

  None of the above three technologies is assured of large scale application. All have unique unresolved questions in one or more areas: technical, economic, environmental or social. The benefits to be gained in achieving success in one or more of these approaches require that vigorous development efforts proceed now on all three.
- To provide the technologies to use the new sources of energy which may be distributed as electricity, hydrogen or other forms throughout all sectors of the economy.

  (As an example, long term efforts are needed to develop a full range of electric vehicle capabilities.)

Substantial effort is required now if the significant energy contributions defined above are to become available in the mid- and long-term as needed.

It should be noted that outlays for Federally supported programs may not necessarily conform to the national ranking developed here. This is because many of the technologies will be developed in the private sector and there are differences in the scope of the program effort and the extent of development required.

The above priority ranking and accompanying Plan itself reflect ERDA's determination that five major changes are needed in the nature and scope of the Nation's energy R,D&D program.

These changes, which must be made rapidly and simultaneously and many of which are already reflected in the President's program for 1976, are:

- *Emphasis on overcoming the technical problems inhibiting expansion of high leverage existing systems—notably coal and light water reactors.*

  Achieving an expansion requires the solution of several critical problems involving operational reliability and acceptable environmental impact.
- *An immediate focus on conservation efforts.*

  These efforts implement first generation existing technology, extend this technology with improved capabilities, demonstrate its viability and widely disseminate the results.

  The primary targets are automotive transportation, buildings and industrial processes.
- *Acceleration of commercial capability to extract gaseous and liquid fuels from coal and shale.*

  A two-pronged effort is needed to achieve this objective. Existing technologies must be implemented as soon as possible to gain needed experience with large scale synthetic fuel production. A Synthetic Fuels Commercialization program is now being developed to implement the President's synthetic fuels goal announced in the 1975 State of the Union Message. Also required is aggressive pursuit of parallel efforts, now underway, to develop a more efficient generation of plants with lower product costs and less environmental impact.
- *Inclusion of the solar electric approach among the "inexhaustible" resource technologies to be given high priority.*

  The technologies for producing essentially inexhaustible supplies of electric power from solar energy will be given priority comparable to fusion and the breeder reactor.
- *Increased attention to under-used new technologies that can be rapidly developed.*

  The technologies that are close to implementation and promise a significant impact for the mid-term and beyond are principally solar heating and cooling and the use of geothermal power.

To attain the national energy goals, it is necessary not only to demonstrate the technical feasibility of new energy systems but to ensure that the environmental, health, and safety aspects of these systems are socially acceptable. This will require that environmental effects assessment be initiated early in the R,D&D process and that environmental and safety controls be developed as an integral part of energy system design. Ensuring social acceptability demands vigorous program overview and assessment, open reporting of findings and progress, and frequent public interaction on the part of the R,D&D establishment.

To assist in the development of the energy supply technologies assigned priority in the Plan, supporting technologies are also required.

The Plan considers both broad supporting technologies (Table 4) and other supporting technologies (Table 5) which are specifically associated with the individual fuel cycles for each of the primary technologies. These specific supporting technologies acquire their importance from the priority and status of the primary technologies to which they are attached.

- Basic Research
- Biomedical and Environmental Research
- Systems Studies
- Information Dissemination
- Manpower Development
- Safety

Table 4. Broad Supporting Technologies

- Exploration and Resource Assessment
- Mining and Beneficiation
- Environmental Control Technology
- Nuclear Safeguards
- Support to the Nuclear Fuel Cycle
- Uranium Enrichment
- Fossil Fuel Transportation
- Waste Management

Table 5. Specific Supporting Technologies

Illustrative priority activities for specific supporting technologies are as follows:

- More rapid and complete assessment of domestic uranium resources.
- Expansion of coal availability and use

through improved mining and environmental control technologies.
- Increased effort toward understanding biomedical and environmental consequences of waste products generated and dispersed by fossil energy technologies.
- Emphasis on resolution of nuclear safeguards issues to strengthen the viability of the nuclear option.
- Increased effort on light water reactor fuel cycle technology where information and experience are required to resolve issues of chemical processing, plutonium recycle and waste management.
- Early expansion of U.S. nuclear fuel enrichment capacity.
- Vigorous dissemination to institutional and public audiences of information on conservation technologies.

Implementation of the National Plan for energy R,D&D will require coordination and cooperation among all sectors of the society.

The task of implementing the Plan is national in scope, involving the Federal Government (other agencies as well as ERDA), state and local governments, and the private sector. Necessary working relationships must be developed in detail. The guiding principle is that the Federal Government will provide overall leadership and will undertake only those efforts that industry cannot initiate. As a given technology approaches commercialization, the role of the private sector will be paramount. In this role, the private sector will:

- Interact strongly with the Federal Government in developing the economic, technical, safety, and environmental aspects of the National Plan for energy R,D&D
- Participate in joint programs/activities to ensure the significance of Federal activity and to minimize Federal cost
- In partnership with the Federal Government, define long-range needs, enhance market potential and transfer information from the public to private sector
- Play the major role (financially and technically) in large demonstration and near-commercial projects ·
- Commercialize the technology.

State and local governments and regional groups reflect regional and local perspectives on the energy situation. Their participation and involvement in the overall process is extremely important. These governmental units will be involved in questions of environmental control; in resource extraction, plant siting, and the revision of construction and building codes to accommodate innovative technologies; and in industrial regulation. It is ERDA's policy to seek the views and involvement of the states and localities to ensure that their interests and concerns are reflected in the formulation of national energy R,D&D policy.

The National Plan represents the first step in a continuing planning effort.

The initial planning effort reported here has emphasized a diagnosis of the problem; establishment of major national goals; definition of key priorities; and direction of resources to high leverage areas.

This planning, however, must evolve through continuing effort. There is need for (1) a deeper analysis of key uncertainties to confirm or modify priorities; (2) a more integrated treatment of the range of programs to allow for more extensive cross-comparisons among technologies; and (3) a more precise definition of programs to maximize assurance that each program responds to its greatest opportunities and produces results directly in support of national goals. Such a planning progression continually modifies programs and alters direction to take advantage of research efforts, analysis, experience and shifting circumstances—all of which are functions of time. Indeed, the legislation establishing ERDA recognizes these factors by requiring periodic updates of the Plan—the first being required in January of 1976. Public comment on this initial plan, together with additional analysis, will be reflected in subsequent planning products.

National security, the Nation's economy, and the ability to determine life style are all in peril today. Substantial assistance from new technology is critically needed, but significant results are not expected before 1985. Major efforts must be pursued now because of the time required to research, develop, and implement new energy technologies.

To ensure maximum flexibility for future energy systems and to allow for some failures in the development process, the Nation's energy Plan must provide multiple options which, taken all together, could exceed perceived needs.

Accordingly, today's national energy research, development, and demonstration programs must:

- Shorten the time for transition to new fuel forms based on abundant domestic fuel resources.
- Avoid overemphasis on single approaches which tend to foreclose future options.
- Open up new choices for the future.

The task of creating choices for the future must be urgently addressed now—and with full public participation.

Chapter I—Introduction

The National Energy Problem

The United States is a nation rich in domestic energy resources, and yet it is dependent upon the importation of large quantities of fuels. This situation did not occur overnight. Nor is it likely to go away overnight.

Today:

- Over 75 percent of the Nation's energy consumption is based on petroleum and natural gas. Domestic supplies of these essential commodities are dwindling.
- Coal, the most abundant domestic fossil fuel, provides less than 20 percent of current energy needs.
- Uranium, the domestic energy resource with the greatest energy potential, provides about 2 percent of the Nation's energy.
- Solar energy, available to all but diffuse, provides a negligibly small percentage of current needs.

Imports, in the form of petroleum, petroleum products, and natural gas, account for 20 percent of the total domestic energy consumption at an annual cost of over $25 billion in 1974.

This heavy reliance on imported energy has serious national security implications. Dependence on imports makes the United States vulnerable to undesirable external influences on U.S. foreign and domestic policy. Foreign powers can threaten life styles and economic stability by curtailing the supply of petroleum or effecting arbitrary and sudden price changes. The quadrupling of the world price of petroleum in the past two years has seriously disrupted the U.S. economy and the economies of all other importing nations.

Despite the oil embargo of October 1973, which brought this dependence to public view, and despite some actions by Federal and state government, by industry, and by the American people to conserve energy and to increase its supply, the current situation remains critical:

- The domestic production of petroleum and natural gas is down.
- The cost of an imported barrel of oil is up.
- The rate of coal production has not changed.
- Utility companies have cancelled or deferred, for economic reasons, a substantial portion of additional planned electric-generating capacity.
- Consumers have been subject to significant price increases; however, substantial energy waste continues.

The United States is more vulnerable now than in the fall of 1973 to an oil embargo.

National Policy Goals Related to Energy

It does not take a projection to a far-distant future to realize that present trends are leading to unacceptable circumstances.

The following set of national policy goals are recognized as a basis for strengthening the public's resolve to deal with the current problems and for directing future energy efforts:

- Maintain the security and policy independence of the nation.
- Maintain a strong and healthy economy, providing adequate opportunities and allowing fulfillment of economic aspirations (especially in the less affluent parts of the population).
- Provide for future needs so that future life styles remain a matter of choice and are not limited by the unavailability of energy.
- Contribute to world stability through cooperative international efforts in the energy sphere.
- Protect and improve the Nation's environmental quality by assuring that preservation of land, water, and air resources is given high priority.

All of these goals are intimately related to the availability, environmental acceptability, and flexibility of energy supplies. It is clear that if energy choices are limited, social and economic choices also will be abridged.

The Need for Choices

To achieve the foregoing goals, the Nation must have the flexibility of a broad range of energy choices.

It is not possible to predict now what our Nation's interests and its people's desired life style will be at the end of this century. Whatever those interests and desires are, however, energy should be available to serve them. The present situation in which national policy and social choice are constrained by overreliance on one form of energy cannot be allowed to recur.

It would be presumptive now for the Nation to select a single technological course of action toward long-term energy independence. The successful exploitation of new energy sources and continuing reductions in the growth rate of energy demand require a broad range of approaches. Central among these is the development and deployment of new technology, which is the focus of this Plan. Because technology development is uncertain, commitment now to one set of technologies for the future ignores the possibility of failure. Even if success were guaranteed, it would be impossible to ensure that the resulting technology would be best suited for future conditions.

Finally, it is reasonably certain that the Nation would be better served by leaving to the future the ultimate choices of total energy consumption, which technologies are actually implemented, and to what degree. To provide limited options for the future would undermine the strengths of the marketplace and individual choice of life style.

For these reasons, today's challenge is to create a wide range of energy options for the future. The National Plan for energy research, development and demonstration (R,D&D) is designed precisely to create those options both for the near- and mid-term and for future generations.

Scope of the Plan

This report presents the first step in the evolution of such a plan. It is the first step because accurate information is not available to answer all questions adequately now. The plan presented herein reflects the best judgment of the U.S. Energy Research and Development Administration (ERDA) based on information currently available. The Plan will be modified as new information and experience become available and refined through the processes of public discussion and review of its major features. It will be updated by ERDA early in 1976 and at least annually thereafter.

The National Plan has four primary elements:

1. *National Energy Technology Goals* (Chapter III)—these goals are formulated after an examination of the current energy problem (Chapter I), the existing domestic resource base (Chapter II), and the possible responses to our current situation.
2. *Ranking of Technologies* (Chapter VI)—the technological options needed to meet the R,D&D goals are identified through an analysis of possible futures in the form of six scenarios (Chapter IV). These scenarios develop an understanding of the capabilities and possible shortfalls of energy supply and conservation technologies as they might contribute to energy supply and demand in 1985 and in the year 2000 and beyond. Evaluation of these energy futures (Chapter V) leads to a national ranking of the technologies and considerations for program emphasis (Chapter VI). The role of the very important supporting technologies is discussed.
3. *Federal R,D&D Program* (Chapter VIII)—the Federal Government has a responsibility to undertake R,D&D in those cases where there is such urgency, risk, or magnitude to the effort that private industry cannot reasonably be expected to carry the entire burden. Reflecting the ranking of the national technologies, the program of the Energy Research and Development Administration contains the major thrust and supporting technologies required in the Federal R,D&D effort. The roles of the various participants in this effort are discussed in Chapter VII. The objectives, key activities, and major milestones or decision points of the program are summarized in Chapter VIII. The complete Program Implementation Plan is provided in Volume II.
4. *Assessment of Impacts on the Plan* (Chapter IX)—the potential impact on the Plan of such factors as available manpower, raw materials, equipment and the environment are considered. This report also includes a description of major unresolved issues to be addressed in the future evolution of the Plan (Chapter X).

Chapter II—The Problem: Limited Choice

The Importance of Resources

If the national interest is best served by creating new energy choices for the future, then the national energy problem is best understood as one of limited choices today.

- The energy system currently relies most on the least plentiful domestic energy resources and least on the most abundant resources.
- There are significant technological obstacles to using the most abundant domestic resources.
- It is necessary to develop and commercialize new energy technologies faster than has ever been done before.

A crucial requirement in the development of a National Plan for energy R,D&D is an understanding of the Nation's energy resource base. That understanding must begin with knowledge of both resources currently in widespread use and known to exist and those currently unused or under used. Despite the great visibility given new and exotic energy forms in the public and technical literature, the fact remains that the United States currently depends on coal, petroleum gases and liquids, hydroelectricity, and nuclear power for 99 percent of its energy needs. More critically, 75 percent of the needs are met solely by petroleum and natural gas—both of which are limited and projected to decline rapidly.

The following discussion of our resources will develop and illustrate two key points:

- The Nation does possess very large domestic fuel resources that are under used or not used at all
- The magnitude of the recoverable resource and, in many cases, even its availability is dependent upon technology.

Reliance on a Narrow and Declining Resource Base

The urgency of the need for transition to a new energy source emerges clearly from the intensive reappraisal of the Nation's oil and gas resources just released by the United States Geological Survey (USGS) and independently supported by a current study of the National Academy of Sciences (NAS). The "high probability" estimates of "undiscovered recoverable" oil and gas resources have been used as a basis for analyses of potential future production.

ERDA has used these resource estimates together with optimistic assumptions about the resolution of non-technical issues—Federal leasing, pricing and pipeline approvals—to generate production estimates. The results of these analyses are depicted graphically in Figures 2-1 and 2-2.

The implication of the new USGS and NAS estimates is that current rates of oil and gas production by conventional methods will be difficult to maintain, even with additional Outer Continental Shelf and Alaskan production. Without enhanced recovery, the USGS estimates indicate that production of domestic oil will begin to drop rapidly in the mid 1980's, as will the production of domestic natural gas. It is unlikely that major new energy sources will be ready by that time.

Enhanced recovery, which requires some technological development, will buy roughly 10 years of time. These additional 10 years are crucially important to the country because they double the time available for the development of new energy sources. But, as Dr. McKelvey, Director of the USGS, said in releasing the new estimates:

> "These and other higher and lower estimates all carry the same message on several important policy questions. All indicate that substantial amounts of fluid hydrocarbons remain to be discovered if exploration is encouraged. All indicate that one of the largest targets for future production is the oil presently remaining in place that might be available if recovery technology is advanced. All emphasize the importance of frontier areas, and all show that it is necessary soon to develop other sources of energy as the mainstay of our future energy supply."

Commonly Considered Energy Resources

Table 2-1 lists current recoverable resource estimates for commonly considered domestic fuels—both fossil fuels and uranium—based on current technology.

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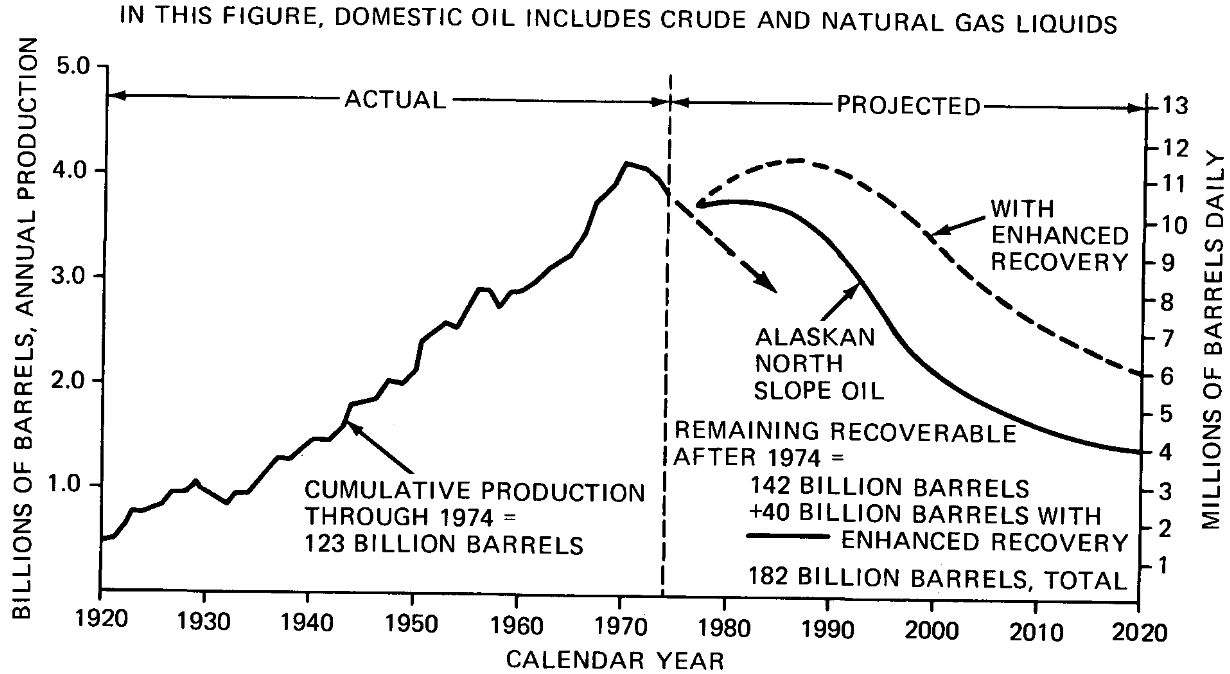

Figure 2–1. Projected Domestic Oil Production

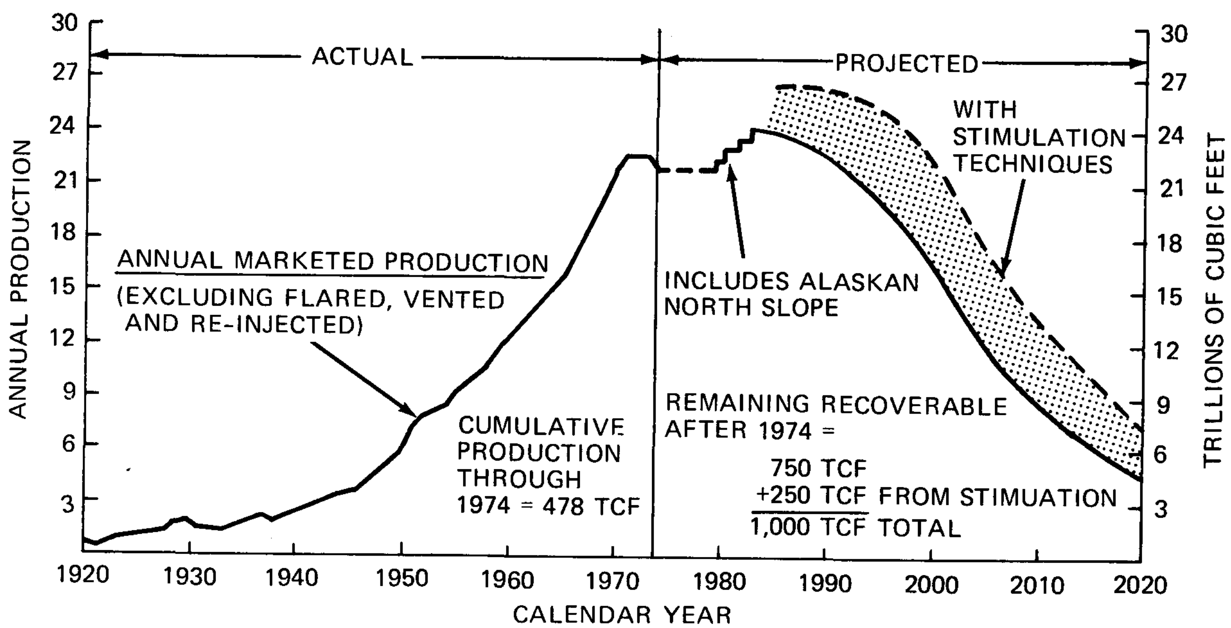

Figure 2–2. Projected Domestic Natural Gas Production

Figure 2–3 presents graphically the same information contained in Table 2–1. The shaded areas in Figure 2–3 indicate the additional resources that may become recoverable if the technology can be developed to make this feasible.

These data indicate clearly the Nation's present dependence on the least available domestic energy resources. Three-quarters of the national energy supply comes from petroleum and natural gas, and the resource base for both combined is smaller than the next largest domestic energy resource. Base-loaded electric generation is shifting to nuclear power, but uranium resources for today's generation of nuclear converter reactors are

not great in comparison with more abundant resources. Of the abundant resources, only coal is in substantial use today, and its share of the energy market has been steadily declining over the past 60 years. While the exact validity of each recoverable resource estimate is questionable to some degree, there is little reason to believe that the basic resource picture will change dramatically.

Oil and Gas. The amount of oil and gas considered to be economically recoverable is subject to wide variations, reflecting different assumptions about undiscovered resources, technology, and price. Responsible estimates of remaining recoverable resources vary by a factor of two. But most estimates agree that at current levels of use, domestic supplies of oil and gas cannot support projected energy demands. Enhanced recovery of oil and gas could expand the domestic resources base only slightly, but such expansion is still significant because of its potential contribution to near-term supplies.

Coal. The total amount of coal actually in the ground in the United States is several times larger than the amount shown on Table 2-1. Extremely thin or very deep seams are known to exist but are not believed to be economically recoverable. The economics could change with advances in mining technology; there are techniques for in situ conversion now under development that could significantly expand the coal resource base. By most estimates, however, our coal resources are very large even without further technological development. The present challenge is to recover and use them with minimum environmental impact.

Oil Shale. Estimates of economically recoverable oil from shale also reflect assumptions about technology and economics. Shales vary considerably in their oil content per ton, and recovery efficiencies are not firmly established. If technology can be developed to recover oil economically from the more dilute shales (containing between 10 and 25 gallons per ton), the oil shale resource base can be considered very large indeed. Without that technology, the resource base is comparable to the domestic oil or gas resource, one-tenth as large as coal.

Uranium. Estimates of recoverable uranium resources currently contain a high degree of uncertainty, but a thorough new resource assessment is now in progress. As with other resources, recovery estimates depend on technology and price; the figure given in Table 2-1 assumes a recovery cost of $30 per pound or less of uranium concentrate. However, the effective size of the uranium resource base in energy terms depends more on the technology for using uranium than on the amount of uranium in the ground. The size of the uranium resource, if used in current light water reactors, is nearly as large as that for the remaining domestic oil and gas resources.* However, success with the breeder reactor concept could turn the domestic uranium supply into a nearly unlimited resource.

Resource	Amount	Units	Equivalent Quads** (10^{15} Btu)
Coal	600	Billions of Tons	12,000
Natural Gas	750	Trillions of Cubic Feet	775
Petroleum***	142	Billions of Barrels	800
Shale Oil	200	Billions of Barrels	1,200
Uranium	3.6	Millions of Tons of U_3O_8	1,800

*Recoverable resources include both already identified resources and estimated undiscovered resources that are considered to be economically recoverable with existing technology. Resource estimates are subject to large uncertainties because they include resources which have not yet been found. Point estimates have been used for R,D&D planning, but the high degree of uncertainty should be recognized.

**For comparison, total U.S. energy consumption was 73 Quads in 1974.

***Includes Natural Gas Liquids.

Note: Appendix A presents information on conversion factors.

Table 2–1. Selected Recoverable Domestic Energy Resources*

Unused or Under-Used Energy Resources

Several important domestic sources of energy exist which are not shown in Figure 2-3. Some of these resources are very large. Unfortunately, the means are not now available to tap them in a way that would contribute significantly to total domestic energy needs in the immediate future. The more important of these resources are discussed below.

Geothermal. In the U.S., geothermal steam is used to generate electricity today in The Geysers, north of San Francisco. The total heat resource within the earth's crust in the form of hot dry rock, high temperature water or steam, lower temperature hydrothermal regions, and geopressurized water is undoubtedly very large. However, any single geothermal field probably has a definite lifetime as a useful energy resource. The lifetime may be quite long given sufficient water recharge. The only resource estimate available is a total for localized hydrothermal systems: 400 to 800 Quads, equivalent to one-quarter to

* The extraction of this amount of energy assumes the use of plutonium recycle in reactors and also assumes an assay of 0.2 percent unrecovered uranium–235 isotope in the fuel enrichment process.

one-half the total remaining oil and natural gas resource recoverable with current technology. An appraisal of the Nation's geothermal resources is currently being conducted by the USGS.

Solar Energy. The solar energy falling on about three percent of the country's land area, if utilized at about 10 percent efficiency, could meet the total projected U.S. energy requirements in the year 2000. However, the technical problems associated with using solar energy are substantial. Generally, these problems are related to the characteristics of solar energy flux which is relatively low in energy value and is intermittent. Thus, the practical application of solar energy requires the availability of large collecting structures and energy storage. (For example, 20,000 to 30,000 acres of thermal collector area is required for a 1,000 megawatt electric plant at today's collection efficiencies.) There is also considerable variation in the extent of further development required among solar energy technologies and their applications before they can become economically viable. Whereas some water and space heating systems are close to commercial introduction in this country, in other solar power systems considerable technological development is required before this resource can be used efficiently and economically. If such problems can be solved, solar energy can become a major essentially inexhaustible resource.

Fusion. In theory, fusion energy is capable of providing all the energy needed for an indefinite period. Through the R,D&D process scientists are attempting to turn that theory into practice. There will be very difficult technical problems to solve even after success has been achieved in producing the necessary controlled thermonuclear reaction. Nevertheless, the resource base is so large that success would ensure a virtually limitless energy resource.

Other Sources. There are numerous other potential sources of energy. Many of them, such as hydropower and the tides, are limited in their application to a few favorable locations. Others, such as crops (which include trees as well as any other organic material grown for energy purposes), are limited by the status of technology and the uncertainty of the economics.

The Technology and Time Problem

The preceding survey of domestic resources demonstrates that the limited choices available to

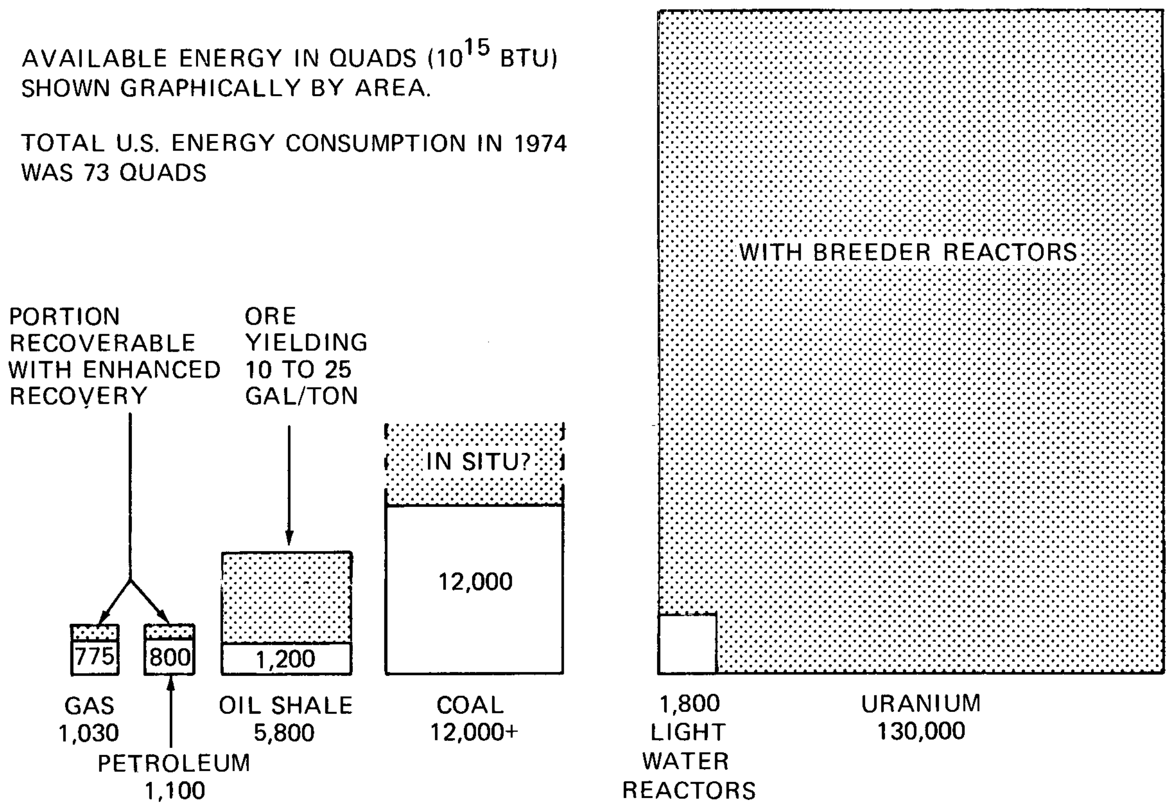

Figure 2–3. Available Energy From Recoverable Domestic Energy Resources

the Nation today are a matter of the way the energy system has evolved, not a condition imposed by any lack of natural wealth. As a result of this evolution, primary reliance is currently being placed on the least abundant energy resources, and as yet the capability does not exist to use fully the more abundant energy resources which the Nation possesses. Thus, crucial emphasis in the R,D&D Plan must be on facilitating the changeover from dependence on diminishing resources to reliance on less limited or unlimited alternatives.

This transition from limited to unlimited energy supplies poses substantial technological problems. Of equal importance will be the difficult institutional problems which transition will impose. And both the technological and the institutional problems must be solved more quickly than such problems have ever been solved before.

The historical perspective of Figure 2–4 shows that it has taken some 60 years from point at which a transition to a new major energy resource was first discernible until that resource, in turn, reached its peak use and began to decline relative to other resources. Domestic supplies of oil and gas appear to have reached that 60-year peak. Their relative shares in the U.S. energy market are expected to decrease with time. It is essential, therefore, to plan now for the transition from oil and gas to new resources to supply the next energy cycle.

The Nation cannot afford to wait another 60 years to complete the next transition. Only an aggressive program of technological development can expedite this process. It is urgent to begin now.

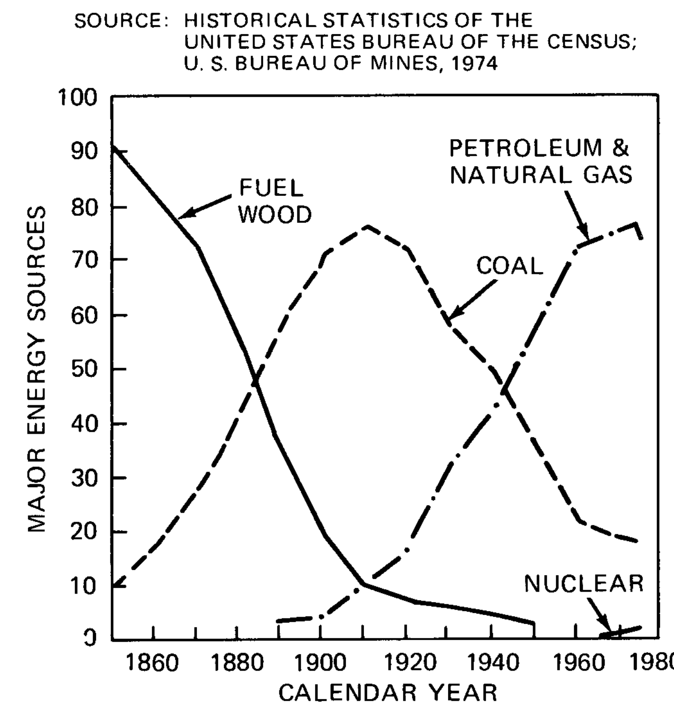

Figure 2–4. U.S. Energy Consumption Patterns

Chapter III—National Energy Technology Goals

Responding to the Problem

In its immediate response to the energy situation, the Nation is currently limited to two choices: importing more oil and natural gas or making do with less energy. Successful achievement of national goals, however, mandates a more positive policy that exploits domestic resources and reduces unnecessary waste in energy consumption.

The Nation has several possible courses of technological development which can assist in solving the energy problem. The first course of action is to produce more of the major fuels in use today. Secondly, new technologies can be developed and introduced to expedite the transition to resources that are presently under used (e.g., solar energy for heating, geothermal, shale) or that are essentially inexhaustible (e.g., fertile uranium for breeding, fusion fuels, or solar energy for electrical generation). Thirdly, to better use more plentiful resources, actions can be taken to alter present patterns of end-use consumption. These actions can facilitate the shift of major end-use sectors from dependence on scarce fuels to more plentiful resources. As an example, the electrification of land transportation would terminate its present dependency on oil and gas and allow needs to be met by any of the basic resources, any of which can be used to generate electricity. Finally, efficiency improvements can be made both in converting resources into energy and in the end-use devices which use this energy to meet societal needs.

All of these desirable courses of action, if they are to achieve their full potential, require the development and implementation of new or improved technology.

National Energy Technology Goals

The framework for organizing a National Plan for energy R,D&D must be established in relation to national policy goals and positive responses to the energy problem made possible by technology. To provide this framework, these four responses discussed above have been expanded into a set of national technology goals. Two additional goals have been added to cover activities which support all technological approaches. The recommended set of a national energy technology goals is as follows:

- I Expand the Domestic Supply of Economically Recoverable Energy Producing Raw Materials
- II Increase the Use of Essentially Inexhaustible Domestic Energy Resources
- III Efficiently Transform Fuel Resources into More Desirable Forms
- IV Increase the Efficiency and Reliability of the Processes Used in Energy Conversion and Delivery Systems
- V Transform Consumption Patterns to Improve Energy Use
- VI Increase End-Use Efficiency
- VII Protect and Enhance the General Health, Safety, Welfare and Environment Related to Energy
- VIII Perform Basic and Supporting Research and Technical Services Related to Energy.

Limitations on the Process of Achieving National Technology Goals

The successful commercialization of new energy technologies is dependent upon the creation and implementation of a National Plan for energy R,D&D.

Before a such a plan can be formulated, it is necessary to consider what can and cannot be included.

The Plan can include:

- Diversified research and development programs.
- Realistic objectives for each program.
- Priorities among technologies for higher levels of development effort.
- Decision points for abandoning unpromising or unsuccessful avenues of R,D&D or for accelerating successful programs.
- Means to disseminate information about promising and significant avenues of R,D&D to all potentially involved sectors.
- Demonstration of viable technologies for commercialization.

The Plan *cannot* include:

- A total solution to the energy problem.
- Guarantees of success for any particular program.
- Provisions for immediate results.
- A pre-selected energy future.

The above limitations on any national energy R,D&D plan flow naturally from the nature of the R,D&D process itself and from the external constraints imposed on it. Some of these constraints warrant further discussion.

R,D&D is a time-consuming process. From concept to market introduction, many deliberate acts must be performed to insure product viability. Theoretical calculations; experiment design, fabrication, and performance; engineering development; scale-up; testing; and many other operations must occur to bring the risk of failure within acceptable limits. Reliability and quality assurance inherently require extended performance evaluations. Without them, economics are purely speculative.

For an R,D&D product to be economically viable, it must accommodate the realities of the market in which it will compete. Factors such as price, market size, capital and life-cycle costs, their financing, and consumer conveniences are important in introducing and establishing a new technology. To determine its viability, each element in the R,D&D program considered for introduction or continuation must constantly reassess these factors. The marketplace tends to optimize in the short term, and it is difficult to predict economic conditions that will prevail at the time of decision. Some technology options currently being pursued may never be completed or adopted for these reasons.

Energy industries are capital intensive and therefore slow to make fundamental changes. The current energy system is highly inflexible. The existing and costly investments in large production, transportation, delivery and use systems based on oil and gas must be taken into account. Transitions to new systems must occur without major disruption of existing systems. Existing investments must be paid for and represent an inertial force on the system.

If plant and equipment replacement is to be considered in a competitive market, it will be resisted by management if the financial results are contrary to stockholders' interests. Even if new investments appear warranted, energy industries must compete for capital. The cost of capital will be directly reflected in price and/or return on investment decisions.

The inertial forces of economics exerted on the Nation's energy system do not act alone. Institutional and social factors have related resistive effects. New billion dollar industries do not spring up overnight, for reasons that go well beyond economics. Management and technical expertise must be carefully developed, facilities and equipment procured, and organizational responsibilities and interfaces defined. Many such new industries will be required to implement the technologies made available by any far-reaching R,D&D plan.

To attain the national energy goals, it is necessary not only to demonstrate the technical and economic feasibility of new energy systems but to ensure that the environmental, health, and safety aspects of these systems are socially acceptable. This will require that environmental effects assessment be initiated early in the R,D&D process and that environmental and safety controls be developed as an integral part of energy system design. Ensuring social acceptability demands vigorous program overview and assessment, open reporting of findings and progress, and frequent public interaction with the R,D&D establishment.

There are important regional considerations to be taken into account as well. The existence of localized energy supplies requires appropriate concern for the inevitable local impacts of new or expanded energy facilities. Different regions of the Nation have different resources and different energy needs. Even within a region, urban and rural energy requirements are vastly different.

The regulatory system of Federal, state and local governments is complex. Commercial energy activities are strongly influenced by these bodies. They are often conservative in accepting new concepts and adapting their policies to new situations. Industry is often reluctant to invest in new production facilities when it is uncertain as to whether the regulatory system will modify policies or react favorably to new ventures.

Just as industry and regulatory bodies are steeped in their normal ways of doing things, so also is the public. New products must demonstrate improved economics or convenience before the consumer will buy. First cost is often taken as the hallmark of economy, whereas life-cycle cost is the true measure. In most cases, more efficient products have higher initial cost, thus inhibiting market acceptance. Also, if early experience with a new product is unfavorable, the product may be unable to achieve its market potential even when the basic approach is sound and the initial problems have been solved.

The R,D&D program that is necessary to find solutions to today's energy problem must address all of these issues and ensure that its results are

economically, environmentally, institutionally and socially acceptable. Such a program cannot be limited to technological considerations but must seek to ensure success on a broader basis, as measured by corporate and public implementation and acceptability.

Chapter IV—Scenarios of Future Energy Systems

Overall Analytic Approach

A National Plan for energy R,D&D should be guided by the goals thus far established. It must also reflect the reality of actual domestic energy resources as described in Chapter II. To translate this understanding into an R,D&D program, however, it is necessary to weigh the potential of a wide spectrum of technological options currently under investigation.

Major technological options are presented in the Glossary. This glossary defines and illustrates the principal technologies to be considered in the Plan. There are 21 main R,D&D technologies and 14 "supporting" technologies.

This chapter considers these technological options in the framework of a complete energy system for future energy supply and demand. This system is studied by constructing a series of different limiting scenarios. These scenarios illustrate selected approaches to the Nation's energy future. Their analysis becomes the basis for deriving the broad strategic thrusts of the Plan which are described in the next chapter. (This method was selected in preference to a single projection of the future which attempts to predict far in advance how energy supply and demand forces would resolve themselves.)

In the extended time frame (in excess of 25 years) that must be considered in long-range energy R,D&D, it is not practical to project a single view of the future with any degree of accuracy. In that period whole new energy industries may (or may not) come into being. Forms of energy use may be radically changed. Certainly, relative energy prices and costs of utilization will shift as a consequence of technological innovation.

It is possible to attempt to "bracket the future," however, by examining distinctly different key energy options and their potential to meet future needs (to the degree that these needs can be defined, in terms of current life styles and consumption patterns, and projected forward). The approach, then, is to draw forth insights on the nature of

- the alternative energy systems themselves,
- the role of technologies within the system, and
- how these systems and roles change with time.

The Scenarios

Out of the current state of knowledge and analysis of energy problems emerge several markedly different potential responses. The first is to place primary national emphasis on the reduction of energy waste and inefficiencies to ease supply problems. The second is to put primary emphasis on the use of the vast energy residing in the Nation's coal and oil shale resources to produce synthetic fuels that will substitute directly for diminishing supplies of oil and gas. The third is to emphasize the alteration of consumption patterns, shifting from reliance on petroleum and gas to reliance on electricity, which can be provided from all the domestically abundant energy sources. These three responses become the principal fixed points from which an unknowable future is viewed.

To derive a fuller perspective of their potential, these responses need to be contrasted with views of the future in which (a) no significant new initiatives are undertaken, (b) a key technology such as nuclear power is eliminated from consideration, and (c) some combination of all of the primary responses is implemented at a high—even unrealistically high—degree of assumed success.

In total, then, the analysis focuses on six "scenarios" of the future, each one of which is extreme in form but when taken together illuminate key strategic energy R,D&D problems and options. These six are as follows:

Scenario 0	No New Initiatives
Scenario I	Improved Efficiencies in End-Use
Scenario II	Synthetics from Coal and Shale
Scenario III	Intensive Electrification
Scenario IV	Limited Nuclear Power
Scenario V	Combination of All Technologies

These scenarios are not forecasts or predictions. They are intended as illustrations, as analytic tools, indeed as "paper and pencil experiments."

The Analytic Process

The scenario analysis employs the "Reference Energy System" developed by Brookhaven National Laboratory. This system deals with future energy demand in terms of key end-use categories (e.g., space heating and transportation) that are constant for a given set of scenarios. The demands are specified not in terms of energy, but in terms of services (passenger miles to be driven, square feet of floor space to be heated and cooled, tons of steel to be made). The services can be met with different energy levels, depending on the technology assumed. The system then examines the potential of technologies and energy resources specified within a scenario to meet those services. The system depicts any computed difference as being madeup by imported fuels. Figure 4–1 displays the actual energy system for the year 1972 and illustrates the relationship of energy sources (the left-hand column) to end-use (the right-hand column) as linked within the system by processing and distribution stages.

The system is described more fully in Appendix B, where the detailed analytic results are presented. The central conclusions of each scenario analysis are presented in the following sections.

Results and Conclusions

The scenarios are first defined in terms of the technologies being considered. Then the results are summarized focusing on (a) capability to meet total energy needs—shown principally in resulting import requirements, (b) capacity to meet specific fuel needs such as liquids, and (c) any particular resource constraints or industrial limitations that are illuminated by each scenario.

Scenario 0—No New Initiatives

Scenario 0 was designed to provide a reference point against which to assess the potential of major energy R,D&D options analyzed in the subsequent scenarios. As such, the inputs for the "Reference Energy System" analysis of the scenario (Table 4–1) assume a continuation of current patterns of energy production with shortfalls in domestic supplies made up by imports.

As shown in Figure 4–2, comparing total energy consumption against time for all the scenarios, Scenario 0 results in an annual energy growth rate of 3.5 percent until 1985 and of 3 percent thereafter. Total annual consumption reaches 164 Quads in the year 2000.

Supply Assumptions

- Oil and gas production draws on remaining recoverable domestic resources
  - —According to lower estimates by the U.S. Geological Survey (1975) and the National Academy of Sciences (see Figures 2–1 and 2–2)
  - —Without tertiary or other new recovery
- Coal and nuclear converter reactors continue to expand to meet electricity demand, limited by ability to construct or convert plants
- Other energy sources (e.g., geothermal, hydroelectric, and urban wastes) expand according to historic projections of existing technologies which do not reflect recognition of a serious energy problem.

Demand Assumptions

- Current consumption patterns continue with no improvement in residential, commercial, or industrial end-use and most transportation efficiencies
- A 40 percent efficiency improvement for energy use in automobiles is realized by 1980 because of a trend toward smaller autos.

Table 4–1. Inputs for Scenario 0—No New Initiatives

Projected oil imports reach 13 million barrels per day in 1985 and 28.5 million in 2000, which can be contrasted with the current level of about 6.5 million a day.

These import levels are unacceptable in light of the national policy goals established. If existing sources of energy were not able to grow at the relatively high rates assumed in this scenario, imports would grow even faster. Increasing energy prices and concerns about increasing national and economic vulnerability would force major modifications in services and outputs based on energy if the trends of this scenario were to continue for very long.

Scenario I—Improved Efficiencies in End-Use

Scenario I was designed to show the potential of an intensive program of (1) energy conservation through efficiency (i.e., no reduction in services or products) and (2) parallel use of energy resources already potentially available and characterized by considerations of efficiency (e.g., recovery of energy from waste materials and enhanced recovery of oil and gas). Consequently, energy demand is reduced from that projected in Scenario 0, but the sources of energy remain essentially the same, with the addition of some previously neglected sources which generally require end-user initiatives for implementation. The key assumptions are summarized in Table 4–2.

The analysis shows that improved end-use technologies can have substantial impact on total energy consumption (see Figure 4–2). Total pro-

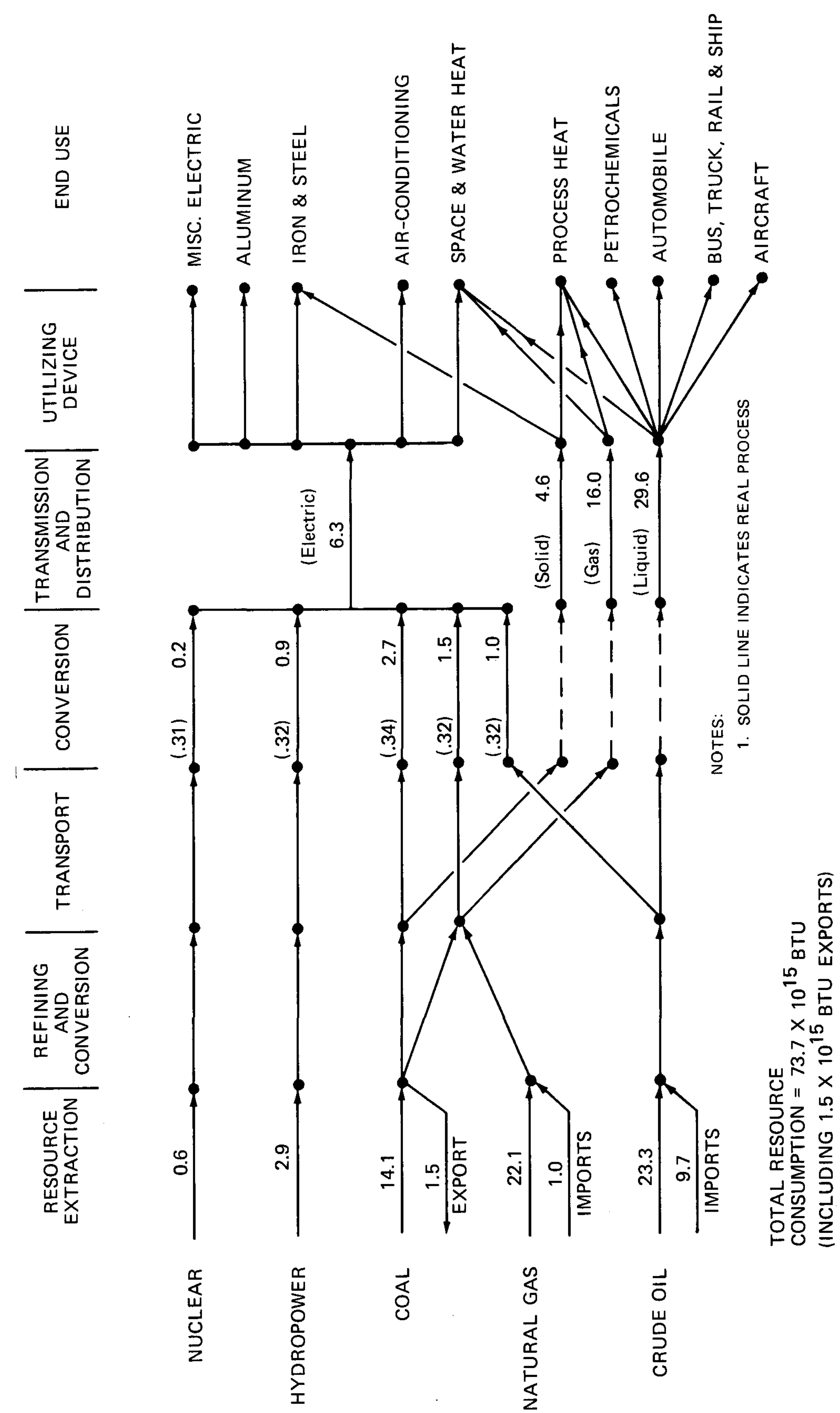

Figure 4–1. Reference Energy System 1972

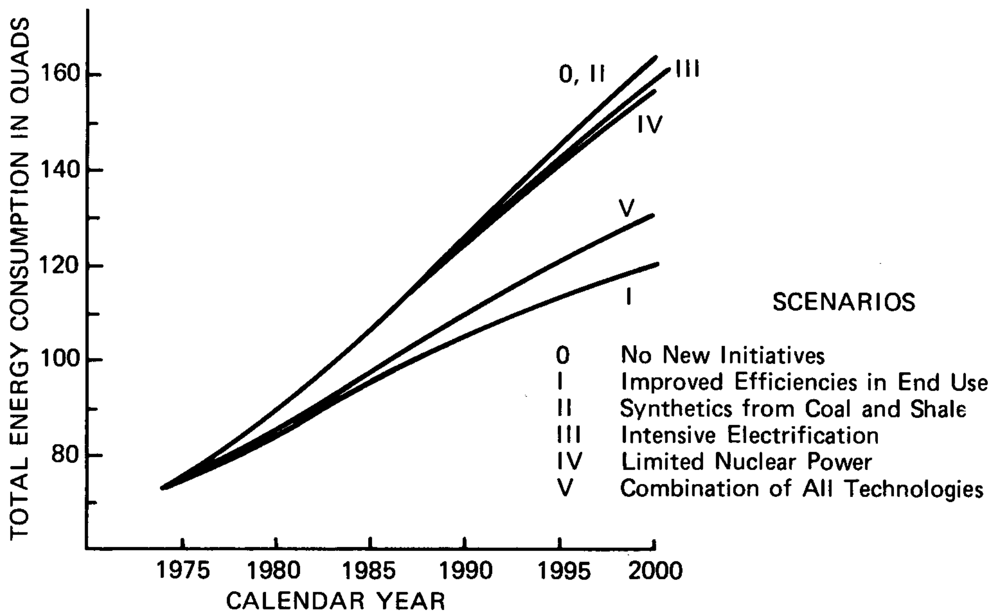

Figure 4–2. Total Energy Consumption

jected annual growth rate is reduced from about 3 percent to less than 2 percent, so that total consumption in 2000 is only 121 Quads, a 25 percent reduction from that in Scenario 0.

Supply Assumptions*
- Domestic oil and gas production is increased above the base case (Scenario 0) by new enhanced recovery technologies
- Solar heating and cooling are introduced
- Geothermal heat is used for process and space heating
- Waste materials are employed as fuels or are recycled to save net energy in production.

Demand Assumptions*
- Residential and commercial sector technologies are improved with regard to
  —The structure itself in order to reduce heating and cooling requirements
  —Improved air conditioners, furnaces, and heat pumps
  —Appliances and consumer products
- Industrial process efficiency improvements are achieved in
  —Process heat and electric equipment
  —Petrochemicals
  —Primary metals
- Efficiencies of electricity transmission and distribution are increased
- Improved transportation efficiencies derived from new technologies (in contrast to efficiencies from smaller vehicles) are assumed for land and air transportation
- Waste heat (e.g., from electric generation) is employed for other low-grade uses now requiring separate energy input.

* Other assumptions are essentially those of Scenario 0.

Table 4–2. Inputs for Scenario I—Improved Efficiencies in End-Use

This dramatic reduction in energy demand is translated into reduced import levels only throughout the near-term. In 1985, imports are 5 million barrels of oil a day, down from the 6.5 million barrels a day current level. Imports grow, however, to 10 million barrels a day in 2000, substantially above today's levels (although at approximately the same percentage level of future total energy needs as today). The import needs continue to grow after 2000.

While the potential impact of these technologies is great, the effort to implement them is just as great. Decisions and actions by literally millions of end-users will be necessary. For example, all new homes and office buildings constructed after 1985 would have to use one of the new technologies, as well as improved construction standards. Moreover, some existing buildings would have to be retrofitted. Similarly, widespread action would be required by industrial concerns in the generation of process heat.

The particular conclusions to be drawn from these results are that conservation (efficiency actions) can substantially improve the near-term situation, but becomes inadequate as a single solution in the longer term. This is particularly so in meeting the rising need for liquid fuels.

These conclusions need to be tempered by the fact that achieving these results is not exclusively a matter of technology development. Indeed, much of the technology for near-term application already exists in at least "first generation" form. It is, rather, a matter of developing educational programs and other policies that will assist end-users in making the decisions necessary to implement these technologies. Beyond the initial phases, however, substantial new technology is needed to continue the drive towards efficiency in energy production and use to achieve the full set of benefits which are indicated by the scenario.

Scenario II—Synthetics from Coal and Shale

Scenario II is based on increasing the limited supply of liquids and gases. The scenario assesses the impact of drawing on abundant coal and shale resources to produce liquids and gases as direct substitutes for conventional fuels. Of all the scenarios, this approach requires the least disruption of end-use technologies and existing distribution infrastructure. The key input assumptions for the analysis are shown in Table 4–3.

Supply Assumptions*
- Substantial new synthetic fuels production is introduced from
  —Coal
  —Oil Shale
  —Biomass
- Enhanced oil and gas recovery levels of Scenario I are included
- Under-used solar, geothermal, and waste sources included in Scenario 0 are not included here.

Demand Assumptions*
- No end-use efficiency improvements are assumed.

* The assumptions, unless otherwise stated, are those of the previous scenarios to ensure that comparisons are being made only of the impacts of stated energy options.

Table 4–3. Inputs for Scenario II—Synthetic Fuels from Coal and Shale

The total energy consumption projected by this scenario analysis is virtually the same as projected by Scenario 0 (see Figure 4–2). The import levels are, however, substantially improved from that case as a consequence of the substitution of synthetic products for imports. The import levels are projected at 8.5 million barrels a day in 1985 and 9.0 million a day in 2000.

Although an improvement over the results of Scenario 0, the import levels for this scenario are still higher than those projected by Scenario I for 1985 (5 million barrels a day) because new production facilities cannot be introduced quickly enough to meet projected demand. Indeed, the scenario includes a 10-fold increase in coal synthetics between 1985 and 2000. The implied 16 percent per year growth rate will be difficult in itself to sustain.

The attempt to pursue this set of technologies as described in the scenarios has two consequences which need to be highlighted. First, of all the scenarios, this places the largest demands on coal, e.g., doubling of production by 1985 and doubling again by 2000. Second, growth in electric power would be based primarily on nuclear converter reactors to allow new coal production to be used for synthetics.

Scenario III—Intensive Electrification

Scenario III examines how the total energy picture would be affected by an intensive shift to electrification, with (1) maximum use of all sources to generate electric power and (2) maximum reliance on electricity for end-uses. The key input assumptions are summarized in Table 4–4.

Supply Assumptions*
- Electric power is intensively generated by coal and nuclear power as in prior scenarios
- New technology energy sources are introduced as available to generate electricity
  —Breeder reactors
  —Solar electric (wind, thermal, photovoltaics and ocean thermal)
  —Fusion
  —Geothermal electric
- A minimal contribution is assumed from waste materials (as in Scenario 0).

Demand Assumptions*
- Improved electric conversion efficiencies are introduced
- Widespread use of electric autos begins
- Technologies to improve efficiency of electricity transmission and distribution are implemented

* Supply assumptions are consistent with Scenario I and demand assumptions with Scenario 0, unless otherwise stated.

Table 4–4. Inputs to Scenario III—Intensive Electrification

The results of this scenario analysis show levels of total energy consumption comparable to other scenarios without a conservation effort (i.e., Scenarios 0 and II). But the resulting requirements for imports are disappointing. Imports are projected to rise from the current 6.5 million barrels a day to 8.5 million in 1985 and to 13 million in 2000. These results are less desirable than for either Scenario I or II. Essentially, these results occur because the assumed rate of construction of coal and nuclear plants for utilities is insufficient in the near-term to avoid growing reliance on imported oil. More importantly, the scenario reflects the longer term problem of electricity: its inability to substitute directly for liquid fuels in transportation, buildings, and industrial plants. Additional generating plants or introduction of new energy sources producing only electricity would not correct this situation. Other technological developments in end-use devices and changes in infrastructure are required, and these take time to achieve. The shape of the import curve after 2000 is still rising. One significant issue here is the question of how rapidly electrification of land transportation could be achieved.

Scenario IV—Limit on Nuclear Power

The analysis represented by Scenario IV examines what might be required if for any reason (technological or political) the development of a major technology were constrained. This scenario is constructed to ask the question: "If a large block of new energy production capability, such as nuclear, were unavailable, how many other new technologies would have to be simultaneously and successfully introduced so as to produce about the same import results as the preceding three scenarios?"

In this example, nuclear power is limited to essentially the number of plants already built or on order. Coal is arbitrarily directed toward synthetics, as in Scenario II, rather than toward electricity production which would also be a feasible response. The specific key inputs are shown in Table 4-5.

Supply Assumptions

- Converter reactor energy levels are constrained to 200,000 megawatts electric
- Coal electric is at the levels in other scenarios to permit coal to be employed for synthetics
- Additional sources of electricity depend on
  - —Accelerated geothermal development (more than a factor of two over Scenario III)
  - —Accelerated solar development (a factor of two over Scenario III)
  - —Fusion as in Scenario III
- Solar and geothermal heating are used (as in Scenarios I and III)
- Synthetic fuels are produced from coal, shale, and biomass at the level of Scenario II.

Demand Assumptions

- Industrial efficiency aspect of conservation scenario (Scenario I) is included
- Electric transmission efficiencies are not included, as electricity use grows too slowly to justify changes.

Table 4–5. Inputs to Scenario IV—Limit on Nuclear Power

The analytic results indicate that all of the new supply technologies introduced in Scenarios II and III, plus a major portion of the conservation technologies in Scenario I, must be successfully developed and simultaneously commercialized at high levels to compensate for the loss of nuclear energy growth in the post-1985 period.

As shown in Figure 4-2, total energy consumption is projected at nearly as high a level as the other non-conservation scenarios (0, II and III) even though the industrial efficiency portion of Scenario I has been included.

In this scenario, import levels for the year 2000 were set at approximately the average of Scenarios I, II, and III (i.e., 10 million barrels of oil per day in 2000). As indicated in previous scenarios, these levels are unacceptably high. Achievement of more acceptable import levels would be exceedingly difficult since most major technologies have already been included in the scenario. These technologies have already been assumed to achieve early and high levels of both R,D&D success and commercialization and could not be further accelerated. Thus, this scenario involves considerably more risk to achieve the same results as the other scenarios and offers much less opportunity for improvement in the future.

Scenario V—Combination of All New Technologies

Scenario V analyzes a case in which a combination of all major energy packages, including nuclear, are simultaneously commercialized (i.e., improved end-use, synthetic fuels, and electrification). The specific inputs for this scenario are those previously summarized in Tables 4-1 through 4-5. It should be noted, however, that the inputs are not simply additive; rather, potential energy supplies are drawn on only as necessary to meet projected demand.

The scenario results highlight the unbalanced impact of the total set of technologies in meeting energy needs:

- A surplus of options for producing electricity is likely to exist (e.g., neither coal nor nuclear options are hard pressed to meet demand in Scenario V).
- Ability to meet liquid and gas requirements remains marginal even if all current technological options are vigorously pursued.
- Many technologies can compete to meet end-use needs in some markets (e.g., utilities, industrial processes, and space heating); few can compete in others (e.g., transportation and petrochemicals).

The results of the analysis show reduced total energy consumption, because of conservation efforts (see Figure 4-2). Imports also appear favorable, showing a slight annual surplus of 4 Quads (2 million barrels of oil per day). The appropriate conclusion to be drawn is that if all R,D&D technologies were pursued, if all were successful, and if all were fully implemented, then it would be possible to meet our energy requirements with domestic supplies, and hence achieve zero net imports. Such a conclusion must recognize this scenario as an ideal, not a prediction that these results are possible. Complete success in all these complex endeavors is highly unlikely.

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Chapter V—Establishing a Strategic Framework for the Plan

Insights from the Scenarios

Thus far, this report has developed the first of several key aspects of the National Plan for energy R,D&D: It has defined the problem to be addressed and has articulated the principal national policy and technology goals to be achieved. It has also projected several possible future responses of the energy system in the form of scenarios.

By examining the advantages and shortfalls of each of these limiting scenarios, it is possible to highlight the principal problems to be addressed by energy R,D&D policy and to begin to frame a strategy for dealing with these problems.

This chapter draws on the scenario analyses to develop a strategic approach for the R,D&D effort necessary to the attainment of national policy goals. Principal thrusts of this R,D&D strategy are based on insights from the scenarios and include actions to:

- Ensure adequate energy to meet near-term needs through approaches that (a) permit immediate expansion of existing energy systems and (b) press conservation (efficiency) measures
- Address the critical liquid fuels gap emerging in the mid-term by developing synthetic fuels production and by continuing conservation
- Develop the technologies to exploit the essentially inexhaustible energy sources as the most promising way to meet long-term needs
- Undertake development of other promising and under-used technologies which can act to relieve pressure in the near- and mid-term and which can provide a needed extra margin for successful attainment of energy goals

From these central strategic elements the R,D&D plan is structured. The remainder of this chapter discusses the treatment of each of these strategic elements and the implications of the strategies in setting subsequent program priorities.

Press Conservation and Existing Technologies

The first strategic element of the Plan is to ensure adequate energy to meet near-term needs until new energy sources can be brought on line. This can be accomplished by:

- Establishing on a secure basis those technologies that will permit an immediate expansion of existing principal energy resources—oil, gas, coal, and uranium.
- Pressing major conservation technology efforts that both reduce energy consumption and shift consumption to non-petroleum sources.

The importance of these technologies in meeting near-term requirements is most evident in Figure 5-1, which contrasts import levels over time for each of the scenarios. The target area for successful R,D&D achievement is the shaded area in the figure, lying between the extremes set by the upper boundary of the limited approaches of Scenarios I, II, III and IV and the lower boundary of simultaneous success for all approaches of Scenario V. It is evident that only Scenario I maintains import levels at or below current levels during the near-term. (Scenario V does so also because it contains the same technologies.)

The reason that Scenario I demonstrates a relatively high degree of short-term efficacy in contrast to others is that the technologies in other scenarios cannot be introduced at significant levels before the mid-term. Either the R,D&D lead-time or the time to establish whole new industries is too long.

The efficacy, itself, results from two factors. The first factor is the large energy potential in oil, gas, coal, and nuclear sources which can be realized rapidly if short-term technological problems can be solved. For example, coal is currently produced and used at levels lower than 30 years ago.

The second factor is the capacity of improved end-use technologies to reduce energy consumption of all forms. Indeed, the analysis of Scenario

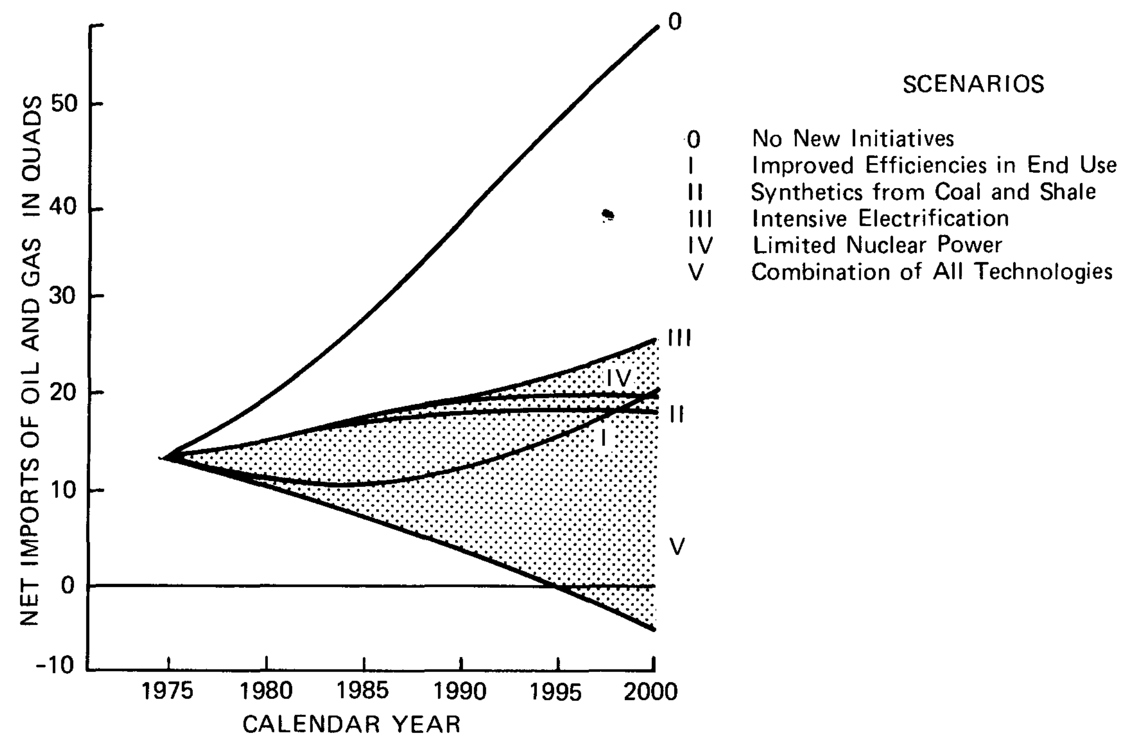

Figure 5–1. Imports of Oil and Gas

I shows that by 2000 the reduction is a 25 percent improvement over that projected for most other scenarios. Much of this percentage impact can be realized in the near-term because at least first generation technology exists now. It is this impact that helps hold down projected Scenario I import levels.

Figure 5-1 provides some key insights about technologies, but one must be careful in interpreting the specific import estimates. The import levels in 1985 and 2000 are a function of several key factors in addition to new technology. The analysis assumed levels of domestic oil and gas production and the demand for services in each of the scenarios. If more oil and gas were actually found than the amounts suggested by Figures 2-1 and 2-2 or if a lower demand for energy services were experienced, then imports would be lower. Conversely, if offshore areas and other frontier areas were not developed successfully for their oil and gas content, then imports would be greater. These shifts, while critical from a national energy policy perspective, do not significantly affect near-term energy R,D&D strategy.

The potential for increasing oil and gas production through advanced recovery techniques is illustrated in Figure 5-2. This shows the projected contribution of domestic oil and gas to total liquids and gas consumption calculated for each scenario. The evident impact of the advanced recovery technologies is to delay the decline of domestic oil and gas production by about a decade.

Address the Critical Liquid Fuel Gaps

Beyond the near-term, the technologies highlighted in the first strategic element unfortunately become inadequate to hold imports to acceptable levels, as demonstrated in Figure 5-1.

Consequently, a second strategic element of the Plan is to address the critical liquid fuels shortfall that continues to grow in the mid-term. The approach is to develop a targeted set of actions including all the programs described in the first strategic element and a special program of synthetic fuels development as well.

Throughout the scenario analyses, it was evident that the limiting factor to successful achievement of national policy goals in the mid-term is the liquid fuels shortfall. As shown in Figure 5-1, all the scenarios (excepting Scenario V) show high oil and gas imports that occur solely because of this gap. Scenario V itself eleminates the gap only after 1995 and then marginally.

At the same time, all the scenarios show greater

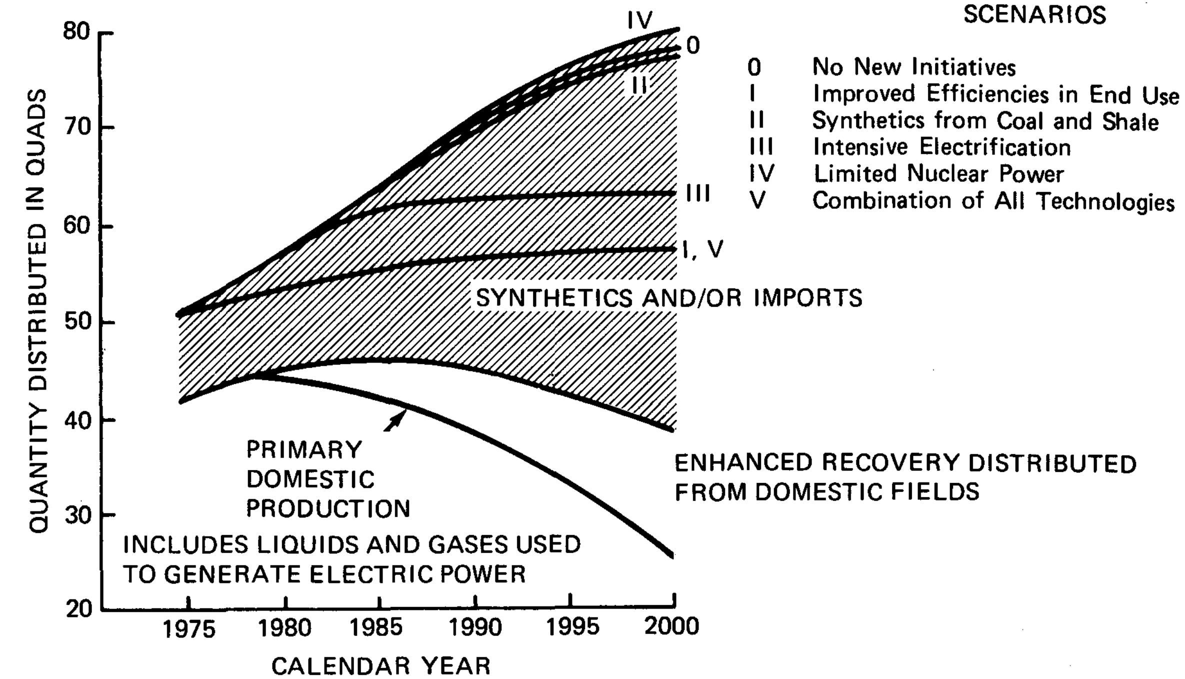

Figure 5–2. Total Liquids and Gases

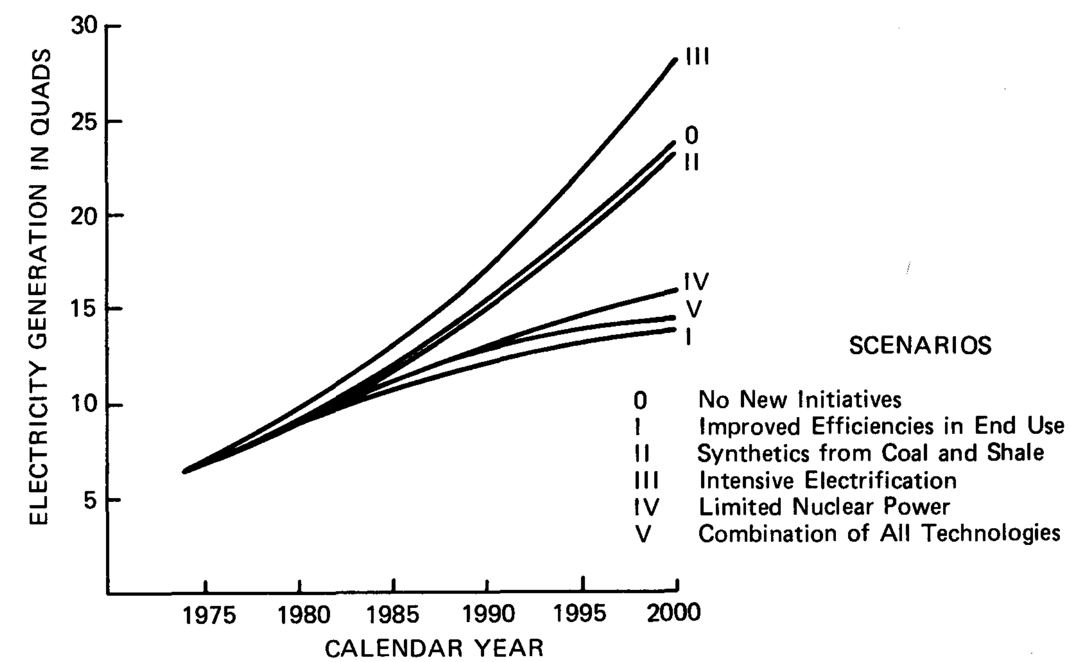

Figure 5–3. Total Electric Generation

potential to produce electric power than is required by the demand projections in the post-1985 period. Figure 5-3 compares total electricity generation in each scenario. Only Scenario III pushes electrification potential to its limit.

In effect, this analysis leads to the conclusion that total domestic energy supply levels could be increased beyond that projected if the energy could be used in the form of electricity. A certain irreducible level of demand for liquid fuels is projected to continue to the extent that it becomes the limiting strategic energy factor beyond the near-term.

Scenario V shows that only some combination of technologies will make the liquid fuels gap manageable. The principal such technologies are:

- *Improved end-use technologies*, initially introduced in the near-term as part of the first strategic element of the Plan.
- *Synthetic fuels* to create direct substitutes for the liquid fuels gap that grows despite a constant level of consumption. Because of falling domestic petroleum and natural gas production, conservation measures are instituted to keep consumption from increasing.

The conclusion reached by the analysis, then, is that to meet mid-term requirements and to buy the time to prepare for long-term requirements, it will be necessary to pursue all the complex technology "packages" and explore all the separate technologies included in each.

Develop Long-Term Energy Sources Now

The third element of the strategic framework requires that the development of essentially inexhaustible energy technologies be actively pursued now. Even though these technologies are not likely to contribute significantly to energy requirements until the next century, at that time they become essential to meeting national needs.

Most of the energy resources and conservation measures that are the mainstay of strategic energy planning throughout the near- and mid-term slacken in their capacity to support further energy growth in the long-term. For example, no current estimates of oil and gas reserves would provide for more than 50 years production at projected rates of consumption, and, with conservative resource estimates as shown on Figure 5-2, absolute levels of production fall steadily after 1985.

Similarly, if coal production quadruples by 2000—as several scenarios indicated it must to support synthetic fuels development (Figure 5-4)—it is imprudent to depend only upon coal to meet the major growing energy needs of the twenty-first century.

Uranium resources as used in converter reactors would also be significantly committed by 2000. Figure 5-5 compares current estimates of uranium resources against the amounts of uranium that would be committed under each scenario.

Finally, once conservation technologies approach theoretical limits of efficiency, further sav-

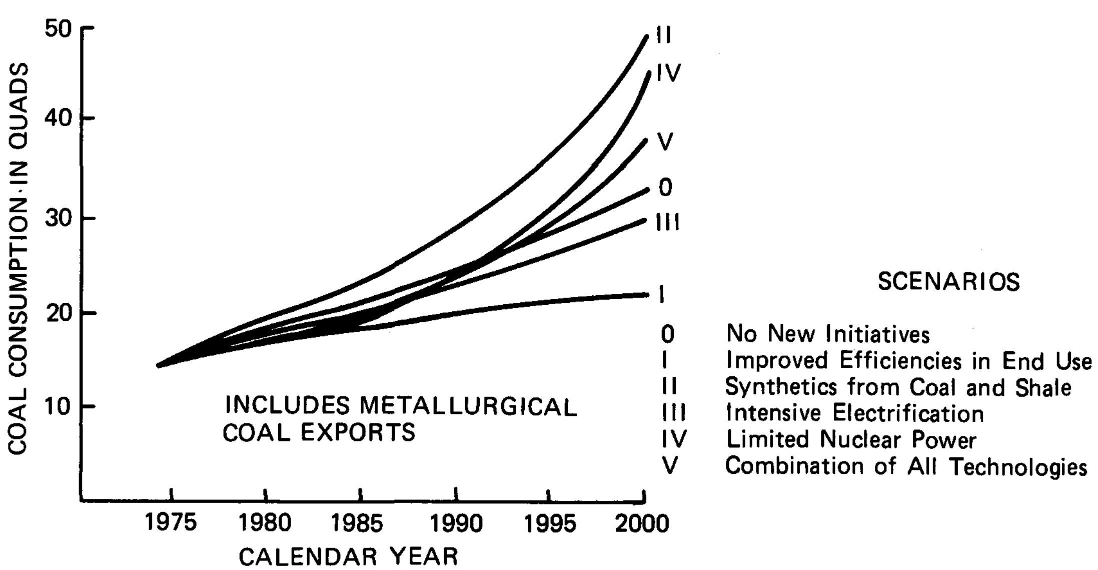

Figure 5–4. Coal Consumption

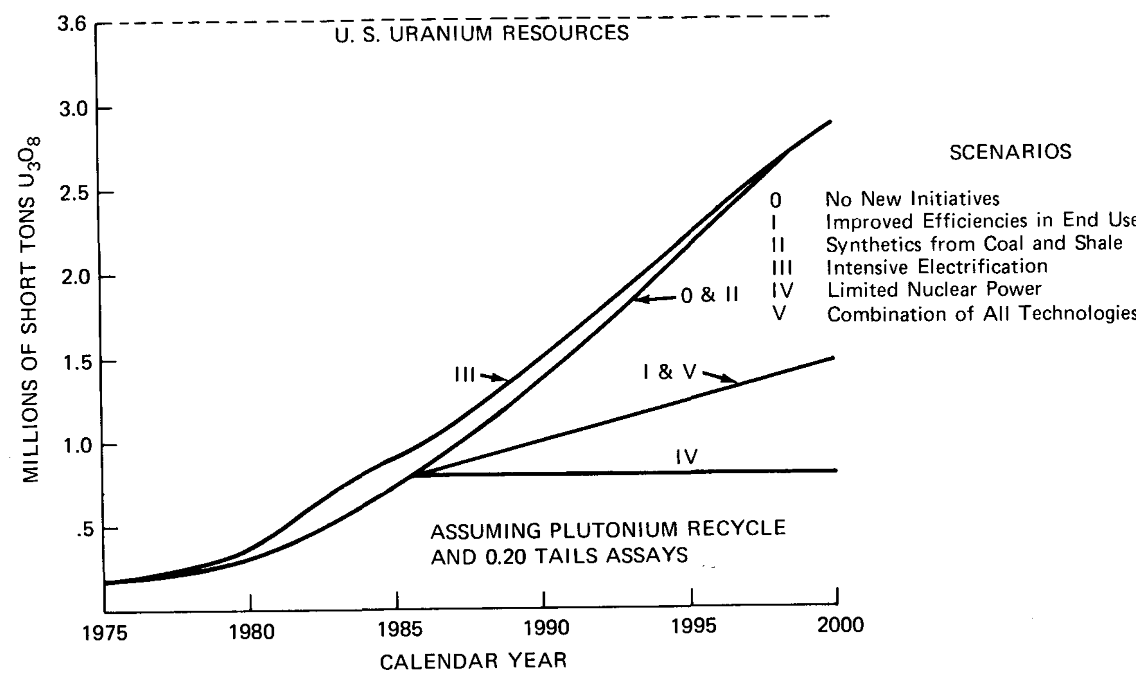

Figure 5–5. Quantity of Committed Uranium

ings become more difficult to achieve. Thus, some time after the year 2000, the Nation will have to come to rely on essentially inexhaustible sources of energy. Each of these, however, is unproven and requires long technological lead time to develop. Certainly, most of the technical problems associated with these technologies are anticipated to be at least as difficult as those encountered in the development of converter reactors. For example, a quarter of a century was required for converter reactors to supply about 2 percent of total national energy demand even with substantial government funding and widespread industrial support.* Active programs based on long-term approaches must be pursued today so that these technologies will be available when they are urgently required.

In the case of the breeder reactor, development must be vigorously pursued along with the fusion and solar electric approaches. If successfully developed, the breeder reactor must be introduced commercially as a natural complement and supplement to the existing light water reactors. This compatibility is of much greater importance than the exact date on which the success of the breeder concept may be achieved.

* The lesson drawn from the analogy must, of course, be tempered by the fact that nuclear development took place during an era of inexpensive and plentiful fossil energy sources.

Because all of these inexhaustible resources will produce electricity, a group of electrification technologies also must be developed to complete the system framework in which these resources could be used.

Undertake R,D&D in Other Promising and Under-Used Technologies

The fourth and final element of the Plan's strategic framework involves the development of other promising and under-used technologies which, while not critical, can act to relieve pressure and provide the extra margin needed for successful attainment of national policy goals.

For reasons described earlier in the report, not all of the R,D&D pursued will prove to be both technologically and commercially successful. Consequently, a soundly conceived R,D&D Plan must provide some "excess" to allow for possible failures and timing shortfalls. These technologies can help to supply that margin.

The Urgency for Action

The above discussion outlines the broad action thrusts to be embodied in the National Plan for energy R,D&D. A sense of urgency, which runs implicitly throughout this discussion, reflects the following premises:

- *The effort is formidable*. Attempts to modify the way in which all sectors of society use energy and to establish whole new industries and new infrastructures to deliver energy are surely the work of a generation.

- *The margin for failure is small.* The scenario analyses indicate that success in developing all the technologies barely meets national policy goals. The very nature of technological R,D&D, however, precludes complete success in achieving results and includes substantial uncertainty as to when results will be available.
- *Risks for the Nation are great.* Failure to succeed carries with it the risk of incurring unacceptable environmental, economic and social costs that would result from dislocations. These costs (e.g., from economic recession) would be great in comparison to the R,D&D investment required.
- *The schedule—in terms of decades—is implacable.* The main elements of the Plan must produce results when needed if overall goals are to be achieved.
  —*Near-term* results require implementation of improved end-use technologies and increased capacity of conventional and nuclear fuels.
  —*Mid-term* results require establishment of a synthetic fuels industry and steps to allow for continued growth in electrification.
  —*Long-term* results require the availability of essentially inexhaustible sources of energy.

The overall challenge can best be illustrated by referring again to Figure 2–4, which depicted the timing for introduction of major new forms of energy. The exhibit showed a 60-year lead time to make the transition from one standard form of energy to another. Built into the strategy of this Plan is the need to make a comparable transition in half the time and in a far more complex world.

Chapter VI—Technology Priorities

Criteria for Assessing Technologies

As the previous chapter indicated, all the technologies discussed in the Plan will be drawn upon to some extent in achieving national policy goals. Nonetheless, the development of some technologies is absolutely essential, while the development of others is more supportive and complementary. This distinction is based on four criteria:

- In which time frame does the technology produce its initial energy impact?
- Does the energy output of the technology substitute directly for oil and gas supplies?
- What is the stage of development of the technology in the spectrum from the laboratory to the marketplace?
- How substantial an energy contribution would successful development of the technology make possible?*

Table 6–1 summarizes the key characteristics of each technology with respect to each of the factors. These considerations and the strategic considerations discussed in the previous chapter provide a basis for the priority ranking of the technologies listed in Table 6–2.

The ranking in Table 6–2 signifies that those technologies with highest priority must be pursued vigorously, with a high level of support. Technologies of lower priority will be given more measured support to permit response to favorable developments. (Within these technologies certain high leverage sub-elements may warrant high priority approaches). Lowest priority is assigned to those technologies which require research activity to assess their future potential.

It should be noted that outlays for Federally supported programs may not necessarily conform to the national ranking developed here. This is because many of the technologies will be developed in the private sector and there are differences in the scope of the program effort and the extent of development required.

* In Table 6–1, the year 2000 was selected as a consistent point of reference for the measurement of future impact. This allowed for development and implementation of most technologies and began a period in which total needs become most difficult to meet.

Ensuring Adequate Energy to Meet Needs

Two groups of technologies must be pursued in support of the first strategic element of the Plan to ensure that adequate energy is made available over the near-term to meet needs until new energy sources can be brought on line.

The first group includes those technologies which will permit an immediate major † expansion of existing energy resources. The second group extends existing near-term supplies through the introduction of end-use efficiencies. The technologies designed to increase use of the Nation's most abundant current resources are:

- Coal—Direct utilization in utilities/industry
- Nuclear converter reactors
- Oil and gas—Enhanced recovery

These technologies are essential to meeting energy needs for the near-term and beyond. Yet, despite energy potential, the scenarios showed that development of these technologies must be vigorously paralleled by implementation of conservation technologies if import levels are to be minimized. The important near-term areas for conservation (efficiency) technologies are:

- Conservation in buildings and consumer products
- Industrial energy efficiency
- Transportation efficiency
- Waste materials to energy

These technologies tend to be fragmented among a myriad of users, for whom the energy cost may be only a small part of overall cost. While the impact of any one may be only moderate to significant, total successful implementation of conservation technologies could make a major contribution to meeting national energy goals.

Developing Means for Addressing the Critical Liquid Fuels Gap in the Mid-Term

The second major element addresses the critical liquid fuels gap projected for the mid-term and

† To allow quantitative comparison, the report adopts the convention: (a) a major impact is one with more than 9 Quads in 2000, (b) a substantial impact is one between 4.5 and 9 Quads in 2000, and (c) a moderate impact is one with less than 4.5 Quads in 2000.

TECHNOLOGY	TERM OF* IMPACT	DIRECT** SUBSTITUTION FOR OIL & GAS	R,D&D STATUS	IMPACT IN*** YEAR 2000 IN QUADS
GOAL I: Expanded the Domestic Supply of Economically Recoverable Energy Producing Raw Materials				
Oil and Gas—Enhanced Recovery	Near	Yes	Pilot	13.6
Oil Shale	Mid	Yes	Study/Pilot	7.3
Geothermal	Mid	No	Lab/Pilot	3.1-5.6
GOAL II: Increase the Use of Essentially Inexhaustible Domestic Energy Resources				
Solar Electric	Long	No	Lab	2.1-4.2
Breeder Reactors	Long	No	Lab/Pilot	3.1
Fusion	Long	No	Lab	—
GOAL III: Efficiently Transform Fuel Resources into More Desirable Forms				
Coal—Direct Utilization Utility/Industry	Near	Yes	Pilot/Demo	24.5
Waste Materials to Energy	Near	Yes	Comm	4.9
Gaseous & Liquid Fuels from Coal	Mid	Yes	Pilot/Demo	14.0
Fuels from Biomass	Long	Yes	Lab	1.4
GOAL IV: Increase the Efficiency and Reliability of the Processes Used in the Energy Conversion and Delivery Systems				
Nuclear Converter Reactors	Near	No	Demo/Comm	28.0
Electric Conversion Efficiency	Mid	No	Lab	2.6
Energy Storage	Mid	No	Lab	—
Electric Power Transmission and Distribution	Long	No	Lab	1.4
GOAL V: Transform Consumption Patterns to Improve Energy Utilization				
Solar Heat & Cooling	Mid	Yes	Pilot	5.9
Waste Heat Utilization	Mid	Yes	Study/Demo	4.9
Electric Transport	Long	Yes	Study/Lab	1.3
Hydrogen in Energy Systems	Long	Yes	Study	—
GOAL VI: Increase End-Use Efficiency				
Transportation Efficiency	Near	Yes	Study/Lab	9.0
Industrial Energy Efficiency	Near	Yes	Study/Comm	8.0
Conservation in Buildings and Consumer Products	Near	Yes	Study/Comm	7.1

*Near—now through 1985
Mid—1985 through 2000
Long—Post-2000
**Assumes no change in end-use device.
***Maximum impact of this technology in any scenario measured in terms of additional oil which would have to be marketed if the technology were not implemented. Basis for calculation explained in Appendix B.

Table 6–1. Consideration for Energy Ranking of Technologies

beyond. Results from enhanced recovery of domestic oil and gas will be critically important to this effort, as will conservation and efficiency measures described above.

In addition, two new technologies are required:

- Gaseous and liquid fuels from coal
- Oil shale

Exploiting Essentially Inexhaustible Energy Sources

The third element of the strategic framework is developing the technologies to exploit essentially inexhaustible sources of energy. This element addresses the enormous energy potential residing in uranium-238 resources, the oceans' deuterium, and the sun. Of all the technologies considered, the technologies for unlocking this potential are furthest from practical implementation and present the most difficult R,D&D problems. They are:

- Breeder reactors
- Fusion
- Solar electric

Any one of these three technologies could conceivably meet a major portion of long-term energy needs. One or more of them will be critically needed in the twenty-first century and could make useful contributions to supply at an earlier date, if available. All have some serious technical, environmental, or cost problems. Thus, because of the critical need for success and the uncertainty of solutions to the problems, all three technologies must be vigorously pursued now.

Near-Term Major Energy Systems	Coal—Direct Utilization in Utility/Industry Nuclear—Converter Reactors Oil and Gas—Enhanced Recovery	Highest Priority Supply
New Sources of Liquids and Gases for the Mid-Term	Gaseous & Liquid Fuels from Coal Oil Shale	Highest Priority Supply
"Inexhaustible" Sources for the Long-Term	Breeder Reactors Fusion Solar Electric	Highest Priority Supply
Near-Term Efficiency (Conservation) Technologies	Conservation in Buildings & Consumer Products Industrial Energy Efficiency Transportation Efficiency Waste Materials to Energy	Highest Priority Demand
Under-Used Mid-Term Technologies	Geothermal Solar Heating and Cooling Waste Heat Utilization	Other Important Technologies
Technologies Supporting Intensive Electrification	Electric Conversion Efficiency Electric Power Transmission and Distribution Electric Transport Energy Storage	Other Important Technologies
Technologies Being Explored for the Long-Term	Fuels from Biomass Hydrogen in Energy Systems	Other Important Technologies

Table 6–2. National Ranking of R,D&D Technologies

Developing Other Important Technologies

The fourth and final strategic element emphasized in the previous chapter would undertake development of a series of other important and under-used technologies to provide an energy "margin" in the event of R,D&D failure in other areas.

Although a range of technologies exists—and more are sure to emerge over the upcoming period of intensive energy development—a number of technologies offer particular promise in terms of their potential contribution and the status of their technological development.

Geothermal energy, solar heating and cooling of buildings, and waste heat utilization offer the prospect of mid-term implementation on a significant scale.

As the electric utility system continues to grow, a set of electric-related technologies becomes increasingly important: (a) electric conversion efficiency, (b) electric power transmission and distribution, (c)electric transport, and (d) energy storage. These technologies strategically complement the essentially inexhaustible energy technologies given highest priority in the national ranking.

For the long-term, fuels from biomass and the use of hydrogen in energy systems need to be explored.

Supporting Technologies

A successful implementation of this R,D&D strategy will require other supportive efforts which underlie all the basic R,D&D technologies. These key efforts are: (1) basic research, (2) biomedical and environmental research, (3) systems studies, (4) information dissemination, (5) manpower development, and (6) safety.

Other supporting technologies are more closely connected to the individual primary technologies and achieve their priority and status from the technologies to which they are attached.

A listing is presented in Table 6–3.

Illustrative priority activities in this area are:

- More rapid and complete assessment of domestic uranium resources
- Increased effort in assessment of recoverable shale and geothermal resources, and related environmental control technologies
- Expansion of coal availability and use through improved mining and environmental control technologies
- Increased effort toward understanding biomedical and environmental consequences of waste products generated and dispersed by fossil energy technologies
- Emphasis on resolution of nuclear safeguards issues to strengthen the viability of the nuclear option

- Increased effort on light water reactor fuel cycle technology where information and experience are required to resolve issues of chemical processing, plutonium recycle, and waste management
- Early expansion of U.S. nuclear fuel enrichment capacity
- Emphasis on integration of safety and environmental analysis at an early stage of technology design for major emerging technologies, such as the coal synthetics and solar electric technologies
- Increased effort on overall systems studies, including consideration of regional and economic impacts of evolving national energy systems
- Vigorous dissemination to institutional and public audiences of information on conservation technologies
- Emphasis on manpower development in critical areas.

• Exploration and Resource Assessment
• Mining and Beneficiation
• Environmental Control Technology
• Safety
• Nuclear Safeguards
• Support to the Nuclear Fuel Cycle
• Uranium Enrichment
• Fossil Fuel Transportation
• Waste Management

Table 6–3. Specific Supporting Technologies

New Directions

The Plan sets some new directions, different from those implicit in past R,D&D policy. Many are already reflected in the President's program for 1976. The most important of these are:

- *Emphasis on overcoming the technical problems inhibiting expansion of high leverage existing systems—notably coal and light water reactors.*

Achieving an expansion requires the solution of several critical problems involving operational reliability and acceptable environmental impact.

- *An immediate focus on conservation efforts.*

These efforts implement first generation existing technology, extend it with improved capabilities, and demonstrate its viability and widely disseminate the results. The primary targets are automotive transportation, buildings, and industrial processes.

- *Acceleration of commercial capability to extract gaseous and liquid fuels from coal and shale.*

A two-pronged effort is needed to achieve this objective. Existing technologies must be implemented as soon as possible to gain needed experience with large-scale fuel production. A Sythetic Fuels Commercialization program is now being developed to implement the President's synthetic fuels goal announced in the 1975 State of the Union Message. In parallel, efforts now underway to develop a more efficient generation of plants with lower product costs and less environmental impact will be pursued aggressively.

- *Inclusion of solar electric among the inexhaustible resources to be given high priority.*

The technologies for producing essentially inexhaustible supplies of electric power from solar energy will be given priority comparable to fusion and the breeder reactors.

- *Attention to neglected new technologies that can be rapidly developed.*

The technologies that are close to implementation and promise a significant impact are principally solar heating and cooling and the use of geothermal power.

The progress of each energy development effort must be accompanied by and phased with appropriate technological effort on the development of controls for the mitigation of energy-related health and environmental effects. Potential hazards must be assessed and the adequacy of proposed controls must be verified. Where necessary, overt action must be taken to carry out required R,D&D for control system development. The required technology must be identified and pursued early in the energy program development process to ensure the availability of required controls before significant commitments are made to develop a given resource.

Chapter VII—Roles of Key Participants in Achieving National Energy Goals

Rationale for a Federal Role in R,D&D

Government involvement in the allocation of scarce resources is justified in situations where the private sector market mechanism fails to effect the desired allocation of resources. Such situations can arise in the creation of new technology when private returns from investment are significantly less than the social returns.

Under ordinary circumstances the entire energy R,D&D program might be left to the private sector to be conducted in response to normal market forces—as was the case in the historic development of public utilities employing fossil fuel technology. In the present critical period, however, the urgent need to develop new sources of energy and the obstacles to this timely action in the private sector will require an active Federal role. Public sector participation is necessary because of:

The long lead-time required for major new technologies. The new energy sources that will be required are, by and large, known to be technically feasible. Private industry is not in a position to invest heavily in these activities, however, when they are not expected to produce an economic return within three to five years.

Commercial uncertainties and financial risk associated with the new technologies. Uncertainties make it infeasible to identify with precision which of several new energy technologies will prove to be technically workable and economically acceptable in the marketplace. Indeed, past R,D&D experience suggests that some options will not be commercially implemented; yet, if industry postpones development until the uncertainties are resolved, the delay is likely to be intolerable from a national viewpoint. Indeed, in cases such as fusion, the uncertainty may only be resolvable by an extended prior Government R,D&D program.

Need to accelerate progress beyond normal commercial capability. In most technology areas the private sector pursues independent R,D&D at a pace dictated by the financial perceptions and interests of individual institutions. Where the national interest—based on widespread benefits—mandates an acceleration beyond normal commercial efforts, Federal involvement will be required.

Legal and institutional barriers. The introduction of a number of new technologies, e.g., use of waste energy and solar heating and cooling for buildings, will involve overcoming legal and institutional barriers. Typically in such cases, the potential benefit to the Nation as a whole will be greater than to any single consumer or institution. Thus, an external agency—i.e., the Government—must provide the direction for program design and investment.

Environmental, health, and safety constraints. Many of the new technologies may have potentially adverse impacts on safety and the environment. Unless such negative impacts are controlled within acceptable standards, political and social forces will inhibit timely commercialization of the new technologies. Federal leadership will be crucial in reconciling energy programs with environmental, health, and safety constraints and in ensuring that the rate of progress on the development of suitable controls keeps pace with the progress of energy development.

The principal consequence of these factors is that the Federal Government will have to bear a significant portion of the financial risk associated with accelerated programs of R,D&D and commercial development. It will need to ensure that the results of these programs are integrated and timely. Also, the Government must act to coordinate energy development with other national goals.

The Federal role in achieving national energy goals has a definite time orientation. Because existing market infrastructure cannot be changed appreciably in the near-term, the Federal Government must work closely with industry and consumers to determine their needs and facilitate the development of new technologies to fit into existing facilities. The private sector will, nevertheless, play the dominant role in the creation of near-term technologies.

For technologies which have application in the mid-term, the Federal role will be to stimulate the development of basic processes. Such processes will be needed to establish industries which do not currently have a significant effect on the market, e.g., synthetic oil and gas. It will also be necessary to ensure the development of the infrastructure to support the commercialization of the technology. The development of mid-term technologies will be a joint effort between the private and public sectors.

The development of technologies having application in the long-term is predominantly a Federal responsibility. This is because the payoff and risks for these programs, at this stage in their development, are such that they are expected to produce a high social return but cannot produce a calculable private return on present R,D&D investment.

The Federal policy toward the development and commercialization of new technology is the basic factor in defining these respective roles of Government and the private sector. The policy is one of encouraging maximum private sector participation and involvement in energy R,D&D. Federal agencies will not manage or fund programs which industry can pursue profitably on its own, and those higher risk programs which the Government does manage will be brought to the point of commercial feasibility as rapidly as possible and turned over to the private industrial sector.

Thus, if one views R,D&D as having four phases—(1) basic and applied research, (2) engineering development, (3) prototype/demonstration, and (4) initial commercial capability—governmental involvement will generally be greatest in the first two phases; less in phase three; and in phase four often not at all.

Government policy needs to be tailored to facilitate a major involvement of the private industrial sector and to maximize rapid commercialization. Such a policy will require the reconciliation of two interests—the Government's broad public responsibility and private industry's objectives to provide needed goods and services efficiently and profitably—so as to preserve the vital interests of both. On the one hand, social policy dictates that the Government support broad-based development of energy technology so as to further competition and enable small business concerns to share in the benefits of development. On the other hand, if business is to take a vital part, its proprietary interests and ability to commercially exploit results must be preserved.

In many cases a cooperative approach, or Government incentive or support relationship, may be necessary. The Government will determine the appropriate approach as follows:

- Identify those organizations, large and small, that have the necessary capabilities to commercialize a process successfully
- Identify the changes needed to eliminate hurdles and disincentives to commercialization
- Measure the effectiveness of candidate incentive options and the cost to the participants and to the Government
- Determine the intangible policy implications of the various alternative approaches to commercialization
- Choose and institute an incentive or support approach, recommend appropriate legislation where necessary, and monitor the entry into the marketplace.

Actual commercialization efforts are already in progress involving direct combustion of coal, synthetic fuels, nuclear fuel enrichment, and solar heating and cooling.

Roles of Key Participants in Energy R,D&D*

ERDA, other Federal agencies, state and local governments and the private sector have different responsibilities in the implementation of national energy R,D&D policy.

ERDA's Role

ERDA has been established by legislation as the lead Federal agency for energy R,D&D, responsible for directing and coordinating national activities toward achievement of energy R,D&D goals. To this end, ERDA will:

- Develop and administer a National Plan for energy R,D&D by (a) identifying those efforts in energy research, development, and demonstration that will create needed technology options for the future and (b) recommending how and to what extent these efforts should be Federally supported.
- Sponsor or conduct the research, development and demonstration programs appropriate to its responsibilities under the National Plan—including contracted research, joint projects, financial support of demonstration plants, and management of Government facilities.

* Appendix C presents a survey of R,D&D activities of Federal agencies outside of ERDA, the private sector, and foreign countries.

- Coordinate energy R,D&D with other Government agencies and the private sector, including R&D organizations and universities.
- Solicit information and planning assistance from state and local governments and from regional and consumer groups.
- Ensure that energy R,D&D programs are carried out consistently with national environmental, social, health, and safety considerations.
- Participate in and encourage international cooperation in energy R,D&D.

Unlike other technology-oriented Government agencies which both develop and use new technology, ERDA is responsible for technology development but expects private industry to use the technologies and make their benefits available to the Nation through the market. Thus, a primary concern of ERDA is to develop technologies which will be acceptable in the marketplace.

The Role of Other Federal Agencies

Other Federal agencies will carry out programs which complement or support energy R,D&D programs. Indeed, ERDA's enabling legislation directs the ERDA Administrator to: "utilize, with their [the Congress] consent, to the fullest extent he determines advisable the technical and management capabilities of other executive agencies having facilities, personnel, or other resources which can assist or advantageously be expanded to assist in carrying out . . . ERDA's energy R,D&D responsibilities. . . ."

The Federal Energy Administration (FEA) and the Energy Resources Council (ERC) are responsible for recommending a comprehensive national energy policy and assuring that overall energy programs are developed to meet the Nation's priority energy needs. The National Plan for energy R,D&D prepared by ERDA will be adapted to support the broader national energy policy as it evolves.

Moreover, ERDA and FEA will coordinate analysis and policy input in R,D&D program design. For example, to achieve full effectiveness, programs in conservation of energy are likely to require legal, financial, educational, and other implementation measures developed and managed by FEA, as well as technical R,D&D programs managed by ERDA. Also, FEA policies affecting supply and demand will help to determine how soon new energy technologies may become commercially viable. Consultation with the Department of Health, Education and Welfare will assist in determining the potential effects of energy system changes on the low income sectors of the population.

The Environmental Protection Agency (EPA) conducts a wide range of environmental effects and control technology research and development including flue gas desulfurization, particulate control, thermal pollution control and waste utilization. EPA coordinates the Federal interagency energy/environmental R&D program, effectively synthesizing the activities of 17 Federal agencies.

Other Government agencies will play important roles. For example, the Department of the Interior conducts programs in resource assessment and in mineral extraction. The Department of Transportation is the lead Federal agency in assessing the role of energy conservation technology in highway, rail and other modes of transportation. The Department of Housing and Urban Development operates a residential solar heating and cooling demonstration program. The Department of Defense's extensive and technically intensive R,D&D activities offer significant benefits to the energy R,D&D program. The National Aeronautics and Space Administration and its laboratories and space centers will provide additional opportunities for energy research. These efforts will be coordinated to eliminate research gaps and unnecessary overlaps.

All new technologies, of course, will have to meet standards set by other concerned Government agencies—the Nuclear Regulatory Commission, the Environmental Protection Agency, and the Federal Power Commission, for example.

The Role of State and Local Governments and Regional Groups

State and local governments and regional groups reflect regional and local perspectives on the energy situation. Their participation in the overall process is extremely important. These groups will be involved in questions of environmental control; in resource extraction, plant siting, and the revision of construction and building codes to accommodate innovative technologies; and in industrial regulation. It is the Federal Government's policy to seek involvement of the states and localities and to assure that their concerns are reflected in the formulation of national energy R,D&D policy.

The Private Sector Role

In the long run, the private sector has the most important role in achieving the national goals. In this role, the private sector will:

- Interact strongly with the Federal Government in developing the economic, technical, safety, and environmental aspects of the National Plan for energy R,D&D

- Participate in joint programs/activities to ensure the significance of Federal activity and to minimize Federal cost
- In partnership with the Federal Government, define long-range needs, enhance market potential and transfer information from the public to private sector
- Play the major role (financially and technically) in large demonstration and near-commercial projects
- Commercialize the technology

Cooperation with Other Nations

The Federal Government will participate in international cooperative R,D&D programs to:

- Permit the most effective use of the talents and resources of all concerned nations in solving common problems
- Assure that foreign energy R,D&D is integrated into domestic planning
- Broadly disseminate energy information to enhance international cooperation
- Facilitate U. S. industry participation in world energy markets

In formulating policy, the Government recognizes that governments and private industry will prefer to cooperate in projects nearing commercialization and involving proprietary rights on an essentially commercial industry-to-industry basis.

Moreover, cooperative international programs often present problems of distance, language, cultural differences, and coordination. In carrying out its international activities, the Federal Government will emphasize:

- Specific cooperative projects, in contrast to generalized agreements covering broad technical areas
- Industrial participation with equitable treatment of proprietary and commercial interests

These efforts, of course, will be carried out within the context of broader foreign policy objectives. In particular, to the extent that the U.S. can help other nations assure an adequate energy supply base, it can foster international stability and enhance the Nation's ability to influence world energy policies.

Chapter VIII—Summary of Federal Program Implementation

In Chapter VI, a national ranking of energy technologies and the implications of that ranking were developed. Chapter VII discussed the nature of the Federal role in the R,D&D process and described the expected roles of other potential contributors. This chapter summarizes the programs to be conducted by Federal agencies as a result of these considerations.

Volume II of this report, Program Implementation, describes the ERDA programs in greater detail. That detail includes identification of the key technological and institutional problems inherent to development of the technologies, the Federal role in the R,D&D process, and the general strategy for attainment of the stated objectives. A brief summary of the programs of other Federal agencies is presented in Volume II to complete the description of the Federal activity.

Federal programs for key energy technologies and selected supporting technologies are highlighted on the following pages.

In the objectives identified for the following technology programs, target contributions are expressed in ranges rather than in exact numbers. These ranges reflect, generally, the impact figures in Table 6–1. Because the figures in Table 6–1 (based on scenario assumptions) are not designed as specific projections, they are not appropriate as objectives for technology development.

Ranges of contribution are defined as follows:

Impact	*Quads* (Heat and Electrical Equivalent) 1985 LEVEL	2000 LEVEL
MODERATE	0–2.5	0–4.5
SUBSTANTIAL	2.5–6	4.5–9
MAJOR	OVER 6	OVER 9

Oil and Gas—Enhanced Recovery

Objective	Approach to Attainment
To support industry efforts to develop and demonstrate oil and gas recovery technology which will increase production rates and alternate yields from existing oil and gas fields to make possible major annual energy contributions in both 1985 (over 6 Quads) and 2000 (over 9 Quads).	• Use Federal/industry cost-shared demonstrations to accelerate implementation of industrially developed technology • Pursue parallel projects in chemical, thermal, and fracturing approaches to optimize use of techniques with different field characteristics • Establish an open national data base on enhanced recovery techniques for industry use • Indentify Federal incentives useful to securing earlier and more extensive commercial adoption • Demonstrate and achieve initial production data by: —1976: Chemical; massive hydraulic fracturing ; —1977–79: Fluid injection; thermal

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Oil Shale

Objective

To develop and commercially demonstrate in situ technology for the economic recovery of shale oil to make possible a moderate annual energy contribution both in 1985 (up to 2.5 Quads) and by 2000 (up to 4.5 Quads).

Approach to Attainment

- Give priority of effort to in situ technology development; monitor industrial development of above-ground processes that are more advanced
- Conduct small scale experiments and field tests to:
  - —Develop understandings of basic phenomena
  - —Assess commercial potential
  - —Motivate industry participation in demonstrations
- Develop environmental and socio-economic impact assessments of all shale processes in parallel with technology development to resolve public acceptability issues
- Conduct major field tests by:
  - —1977: 25 ton/day gas production
  - —1978: True in situ oil processing

Geothermal

Objective

To develop and demonstrate technologies for the production of both electric power and non-electric outputs from domestic geothermal resources to make possible an initial annual energy contribution by 1985 (under 1 Quad) and a moderate to substantial contribution by 2000 (2.5–6 Quads).

Approach to Attainment

- Give near-term priority to technologies utilizing moderate temperature, low salinity geothermal reservoirs with fluid reinjection in support of industry efforts
- Investigate technologies for utilizing more advanced and extensive reservoir types:
  - —Geopressured
  - —Hot dry rock
- Conduct a comprehensive national geothermal resource assessment to establish, by 1980, reserves to support significant energy production in the 1985—2000 period
- Complete environmental characterization and establish control technology requirements in parallel with technology programs
- Provide incentives for commercial development through Federal guarantee programs and leasing programs
- Conduct jointly funded Government/industry demonstration projects if appropriate for two 50 Mw(e) electric power plants in the 1979–82 period

Solar Electric

Objective

To develop and demonstrate technologies for the collection and conversion of solar energy to electric energy to make possible an initial annual energy contribution before 1985 and a moderate contribution (up to 4.5 Quads) by 2000.

Approach to Attainment

- Develop several technologies for commercial assessment: wind systems will be initial contributors; photovoltaic and solar thermal for peak/intermediate electric load applications; and ocean thermal for base load in the long-term
- Sponsor research and development to improve system efficiencies and reduce component costs leading to demonstration projects jointly funded by industry/utilities
- Develop approaches for dealing with institutional, legal and regulatory problems in parallel with technology development
- Conduct by 1985 a comprehensive national solar resource assessment.
- Establish in 1976 the Solar Energy Research Institute to assist in the advancement of solar energy use and in transfer of information and technology
- Milestone targets:
  - —1979–1982: 1–10 Mw(e) scale wind systems
  - —1985: Lower cost of photovoltaic elements by 1000-fold
  - —mid-1980's: 100 Mw(e) solar thermal demonstration plant
  - —late 1980's: 25 Mw(e) ocean thermal pilot plant

Breeder Reactors

Objective

To develop and demonstrate a safe, reliable, and economically viable breeder reactor for installation into utility systems to make possible an initial contribution beginning before 2000 and a very major contribution in the post-2000 period.

Approach to Attainment

- Use the liquid metal fast breeder reactor (LMFBR) as primary effort; develop other breeder technologies as back-up alternatives
- Develop LMFBR technology with extensive utility and industrial involvement
- Use planned major facilities to conduct developments and tests, e.g.,
  - —Fast Flux Test Facility (FFTF)—fuel development
  - —Clinch River Breeder Reactor (CRBR)—systems design, construction and operating experience
  - —Safety Reactor Experimental Facility—safety
  - —Hot Pilot Plant—chemical processing
- Use results of on-going design studies as basis for defining near-commercial plant design characteristics
- Specify government/private sector relationships for near-commercial plant (e.g., financing, siting, management, etc.)
- Review current programs and optimize schedules to reflect slippages in FFTF and CRBR (e.g., procurement placements, licensing targets, etc.)

Fusion

Objective

To conduct the necessary research and development to demonstrate the technical, engineering, and commercial feasibility of producing electric power from controlled nuclear fusion to make possible a very major energy contribution in the post-2000 period.

Approach to Attainment

- Provide major Federal support to high risk, high potential payoff fusion R,D&D experiments and tests
- Develop both magnetic and inertial confinement approaches
  - —Use Tokamak concept as most promising magnetic confinement approach
  - —Develop other alternatives such as: magnetic mirror, theta pinch, laser fusion and electron beam fusion
- Encourage near-term industry participation using industrial contractors for new facilities, subsystem supply
- Demonstrate reactor level conditions of magnetic confinement from the Princeton Large Torus, Doublet III or Tokamak Fusion Test Reactor facilities now underway and scientific breakeven in inertial confinement using laser or electron-beam facilities under construction or development
- Move program orientation from physics to engineering. Design and operate electrical power generating reactors in mid-1980's
- Design progressively larger experimental devices leading to jointly funded demonstration reactor prior to 2000

Coal—Direct Utilization in Utilities/Industry

Objective

To develop and demonstrate environmentally acceptable technologies for expanded direct coal utilization to make possible major annual energy contributions both in 1985 (over 6 Quads) and 2000 (over 9 Quads).

Approach to Attainment

- Direct priority emphasis to utility applications with technical efforts directed at:
  - —Stack gas cleaning and NO_x control—near term applications
  - —Clean direct combustion—mid-term application
  - —Advanced power generation—mid-term application
- Develop second generation clean combustion technology with improved reliability, component lifetimes, materials handling for pilot operation in 1981
- Use Federal cost-shared demonstrations to involve industry in clean combustion programs at utility and industrial sites
- Do limited materials and component development for advanced power cycles until concept viability is established
- Monitor coal production and transportation sectors for R,D&D bottlenecks which could impede future coal supply
- Develop automated coal mining techniques and new systems concepts

Waste Materials to Energy

Objective

To support and encourage the widespread use of economic and environmentally acceptable technologies to enable the use of wastes as substitutes for conventional fuels to make possible a moderate annual energy contribution (up to 2.5 Quads) by 1985 and a substantial contribution (4.5–9 Quads) by 2000.

Approach to Attainment

- Place initial priority on technologies which enable combustible wastes to substitute directly for conventional fuels
- View institutional rather than technological problems as primary limiting factors
- Direct support to:
  - —Demonstration of advanced concepts
  - —Technical information dissemination
  - —Identification of Federal incentives and policy actions necessary to accelerate widespread adoption
- Emphasize development of new concepts rather than existing product improvement through research and development on improved waste separators and conversion processes

Gaseous and Liquid Fuels from Coal

Objective

To develop and demonstrate advanced technologies for the conversion of domestic coal into gaseous and liquid fuels and chemical feedstocks to make possible an initial annual energy contribution from liquids and gases from coal beginning by 1985 and a major annual contribution (over 9 Quads) by 2000.

Approach to Attainment

- Give priority to:
  - —High BTU gasification processes—natural gas substitutes
  - —Liquefaction processes, which can:
    - Produce both fuels and feedstocks
    - Satisfy near-term needs for clean boiler fuels
- Support accelerated commercial development of first generation technology through technology transfer, operational improvements, identification of incentives
- Use Federal cost-shared pilot and demonstration plants to accelerate development of second generation coal conservation processes with improved economics and reliability
- Increase industrial readiness for commercial implementation by using industrial contractors extensively in all phases of pilot and demonstration plant activity
- Operate demonstration plants by:
  - —1980: Low sulfur boiler fuel (liquid)
  - —1981: Synthetic pipeline gas
  - —1981: Boiler fuel gas

Fuels from Biomass

Objective	Approach to Attainment
To develop and demonstrate technologies for the production and conversion of terrestrial and marine biomass into clean fuels and petrochemical substitutes to make possible a moderate (up to 2 Quads) annual energy contribution by 2000.	• Place primary early emphasis on systems concept studies to determine the most technically and economically promising approaches to biomass production including agricultural wastes and energy crops • Direct technical program efforts on: —Improving economics through system optimization —Improving growth and conversion processes —Establishing of technical feasibility of deep ocean kelp farming • Develop approaches to dealing with major institutional problems which may affect basic feasibility: —Land aggregation —Alternative land use —Ocean rights • Secure early involvement by agri-business and marine industries leading to cost-shared demonstration projects to enhance prospects for technology commercialization • Operate pilot plants by —1980–1981: Agriculture and wood plantation concepts —1982: Marine biomass

Nuclear—Converter Reactors

Objective	Approach to Attainment
To develop and demonstrate improved technologies for converter reactors and their associated fuel cycle elements to make possible major annual energy contributions both in 1985 (over 6 Quads) and 2000 (over 9 Quads).	• Direct priority effort to fully developing the light water reactor (LWR) and its fuel cycle • Support technology programs for the high temperature gas-cooled reactor (HTGR) concept and its fuel cycle • Develop cooperative Federal/industry programs for: —Improved LWR productivity —Fuel reprocessing —Plutonium/uranium fuel fabrication —Waste management, treatment, and disposition —Safeguards —Uranium enrichment technologies. • Develop high temperature direct cycle gas turbine and very high temperature gas cooled reactor concepts. • Complete, by 1980, Federally supported comprehensive uranium resource evaluation

Electric Conversion Efficiency

Objective	Approach to Attainment
In cooperation with the electric power industry, to develop and demonstrate technologies to improve the efficiency of electric energy conversion systems to make possible a moderate (up to 4.5 Quads) annual energy contribution by 2000.	• Place primary early emphasis on demonstration of economic feasibility of waste heat utilization in industry and utilities • Conduct research and development on materials and components for advanced cycle systems to reduce costs and improve efficiencies • Give priority of advanced cycle development efforts to processes which can utilize either: —Any high temperature heat source (Brayton gas turbine, Stirling cycle) or —Synthetic fuels (fuel cells) • Utilize industrial capabilities for: —Construction and operation of demonstration plants —Improved component fabrication techniques • Demonstrate by: —1977: Organic bottoming cycle —1982: Superconducting generator

Electric Power Transmission and Distribution

Objective	Approach to Attainment
To support industry efforts to develop and demonstrate improved technologies for electric power transmission and load management to make possible increased capital efficiency in utility systems and a moderate (up to 4.5 Quads) annual energy saving by 2000 through reduced losses.	• Emphasize the development of advanced electric transmission systems needed for use with advanced electric energy systems in development • Support high risk advanced technology projects with high payoff potential; apply limited efforts to improving reliability and economics of existing technologies • Involve utilities and industry extensively through: —Utility and Electric Power Research Institute advisory role —Prototype system testing at utility sites —Use of manufacturers to conduct major share of R,D&D • Use large scale systems theory, modelling, and simulation to improve system expansion and optimization methods • Demonstrate by: —1979: First generation superconducting cable —1980: 800–1200 kV DC transmission line

Solar Heating and Cooling

Objective	Approach to Attainment
To develop and commercially demonstrate technologies for solar heating and cooling of buildings and solar heating for agricultural and industrial applications to make possible an initial energy contribution before 1985 and a substantial annual contribution (4.5–9 Quads) by 2000.	• Place program emphasis in near-term on heating and cooling of residential and commercial buildings • Demonstrate, by 1979, installation of solar heating and cooling systems in residential and commercial buildings • Involve both small and large industry at outset of planned demonstration • Direct Federal activities to: —Developing the market and technology base —Alleviating financial, legal, and infrastructural barriers —Wide dissemination of results • Coordinate Federal agency activities directed at: —Demonstration installations —System performance improvements and cost reductions

Electric Transport

Objective	Approach to Attainment
To develop and demonstrate technologies to enable the widespread use of transportation vehicles utilizing on-board energy storage systems to make possible a moderate (up to 4.5 Quads) annual energy contribution by 2000.	• Emphasize development of high performance batteries for use in electric powered autos and trucks; pursue other on-board storage systems (e.g., flywheel) • Use Federally supported programs to: —Encourage entry of high technology firms —Establish partnership relationship with industry through cost-shared contracts —Conduct supporting research at National Laboratories • Develop coordinated Federal approaches to reduce institutional barriers to widespread adoption of successful technologies: —Identify possible Federal incentives —Establish government markets (e.g., Post Office Demonstration Fleet) • Demonstrate prototype electric auto capabilities by: —1977: 60 mile range —1981: 100 mile range —1983: 200 mile range

Energy Storage

Objective	Approach to Attainment
To develop and demonstrate technologies for energy storage applications in the utility, industrial, transportation and residential sectors to make possible increased capital efficiency in energy generation and the use of alternative energy sources.	• Develop technologies for electrical and thermal storage for a broad range of applications; emphasize storage technologies for electric utility load leveling and solar energy systems • Use systems analyses to evaluate characteristics of alternative utility storage approaches and to determine technical development priorities • Support joint government/utility stored energy demonstration programs at utility sites • Conduct materials development program for battery, flywheel, and hydrogen storage concepts • Milestone targets for demonstration: —1983: Flywheel system —1984: Hydrogen fuel cell —1985: Underground pumped hydrosystem

Transportation Efficiency

Objective	Approach to Attainment
To support industry activities to develop and demonstrate environmentally acceptable technologies to permit reduction in petroleum energy consumption and alternative fuel utilization in highway vehicles and other transportation modes to make possible a substantial annual energy savings both in 1985 (2.5–6 Quads) and 2000 (4.5–9 Quads).	• Work closely with the automobile industry through jointly funded projects and information exchange to promote early commercialization • Give highest priority to highway vehicles with particular emphasis on automobiles: —Improve current highway vehicle power system —Develop new power plants and propulsion systems • Utilize high technology non-auto industry firms for high risk, high payoff projects • Develop energy-conservative aircraft technologies • Milestone targets for demonstration: —1978: Continuously variable auto transmissions —1979: Stirling engine powered automobile

Industrial Energy Efficiency

Objective	Approach to Attainment
To support the development and demonstration of improved industrial and agricultural process technologies which will make possible a substantial annual energy savings in 1985 (2.5–6 Quads) and in 2000 (4.5–9 Quads).	• Identify key areas for potential research, development, and demonstration through comprehensive systems analysis • Emphasize activities for Federal R,D&D support which: —Have general applicability across large user industries —Offer major potential savings in fragmented or technically underdeveloped industries • Place high priority on efficiency standards and applied engineering research on comprehensive heat management technologies • Key activities in securing commercial adoption will be: —Information dissemination —Technical information exchange —Joint participation in field demonstration projects • Milestone targets for demonstration: —1982: Waste heat pump —1983: Advanced thermal storage

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Conservation in Buildings and Consumer Products

Objective	Approach to Attainment
To develop and demonstrate technologies for more effective energy use in buildings, community systems, and end-use devices to make possible substantial annual energy contributions both in 1985 (2.5–6 Quads) and 2000 (4.5–9 Quads).	• Use Federally sponsored R,D&D to lead in adoption of new technologies through: —Limited technology development —Demonstration of economically integrated systems using developed technology —Development of model codes, performance and design standards • Concentrate initial development efforts on means to deal with highly fragmented sectors: building industry, building owners, local government • Emphasize the demonstration of total systems rather than components through —Total energy management —Integrated utilities projects • Support activities directed at both new and retrofit applications • Reduce institutional barriers to large scale adoption: —Disseminate information on life cycle costing —Encourage innovative financing —Investigate Federal use of incentives • Conduct R,D&D to establish thermal performance standards for new buildings

Environmental, Health, and Safety Factors

Objective	Approach to Attainment
To determine effects of energy-related activities on environment, health and safety (EH&S) and ensure timely development of energy systems technology directed at control of emissions, management of nuclear and nonnuclear waste, and energy materials transportation.	• Place highest near-term emphasis on potential effects from oil, gas, solar, geothermal, coal, and nuclear fission energy sources • Conduct activities primarily in National Laboratories and universities to derive data for integrated assessments: —Characterization of pollutants —Environmental transport process —Ecological and health effects —Socio-economic studies • Complete integrated assessments prior to new energy technology demonstration phase to: —Guide environmental controls to be incorporated during technology development —Establish guidelines for safe and socially acceptable commercial application • Coordinate with Federal and state agencies conducting related research or engaged in standard setting • Provide and operate facilities for storage/disposal of radioactive waste • Provide a strong information dissemination program to: —Inform public on planning/action taken in Federal EH&S programs —Encourage public acceptance of new technologies on basis of demonstrated compliance with relevant EH&S standards.

Basic Research

Objective	Approach to Attainment
To develop, extend and apply: basic knowledge of physical phenomena underlying energy related technologies and fundamental laws governing energy and matter and to develop their transformations; and to develop new insights and concepts in physical and mathematical sciences which may have applicability to energy processes.	• Identify fundamental phenomena, processes and techniques underlying energy technologies and extend the frontier of scientific knowledge in these and related fields of physics, chemistry, mathematics, biological and engineering sciences • Support a broad range of basic research activities applicable to energy development in universities, National Laboratories, and research centers involving scientists of distinguished capabilities • Increase emphasis on scientific specialties important to fossil, solar, and geothermal energy sources, and to conservation • Emphasize research areas which will increase understandings in common areas of interest: —Molecular sciences (energy process control) —Material sciences (high temperature; specialty materials) —Nuclear sciences (nuclear design data) —High energy physics (fundamental processes of nature)

Chapter IX—Potential Constraints to Implementation

The National Plan for energy R,D&D presented above has outlined an ambitious set of programs which must be implemented by public and private sectors if the Nation is to meet its goals. The Plan was derived by determining which energy resources, and which technologies for exploiting those resources, appeared to have greatest leverage.

In the successful implementation of the Plan, other factors can be critically important. Some of these factors have been considered in the detailed supporting analysis but have not been thus far explicitly treated. Among them are: (a) economic viability of the programs, (b) capital requirements, (c) industrial constraints with regard to manpower, equipment, raw material and transportation, (d) water resource constraints, and (e) environment, health and safety. Each of these factors has been considered in the Plan's development—at least at a broad level. The conclusions are, essentially, that none of these factors should present insurmountable obstacles to achieving the Plan's goals. This is not to say, however, that targeted action is not necessary to meet requirements identified in each area.

Before considering potential constraints to the implementation of the Plan, it is important to recognize that there would be economic, environmental and other problems if the Plan were not implemented. Many of the elements of the Plan are, in fact, aimed at ameliorating difficulties which would occur if no new technologies were developed and implemented.

Economic Viability of Programs

Many of the technologies included in the R,D&D Plan are not sufficiently developed to warrant firm judgments as to their ultimate commercial viability. Projections can be made regarding energy supply and demand in general, however, and on that basis cost and efficiency targets can be set that determine whether any particular technology is likely to be competitive in the marketplace.

Indeed, the Reference Energy System used to analyze the scenarios can calculate the optimal economic employment of a new technology within the overall energy system. Despite the inherent limitations of any such analysis, its results support the technical judgments made in ranking the technologies. In particular, the analysis suggests that the programs given priority in the ranking are likely to be commercially viable; more specifically, it indicates that within each time frame the following technologies look most attractive economically:

Near-Term Implementation—favors (a) enhanced oil and gas recovery, (b) electrical energy storage technologies, and (c) efficiency improvements in automotive vehicles, space heating, and air conditioning.

Mid-Term Implementation—favors (a) second generation coal liquefaction and gasification plants, (b) use of geothermal and nuclear power for electricity generation, (c) technology to make better use of waste heat in industrial processes, and (d) solar heating and cooling.

Long-Term Implementation—favors development of the technologies that will increase efficiency of electricity generating cycles, electric transmission facilities, and the electrification of transport, since the long-term energy sources all produce electric power. Concerning the long-term prospect of the essentially inexhaustible energy technologies themselves, however, any judgment on economics is still speculative.

Capital Requirements for Financing Energy Investments

The requirements for incremental capital needs in the energy field are large enough to raise questions about the capacity of the economy to provide those funds. Over the past 25 years, annual energy investment has averaged 23 percent of the total of business fixed investment; the proportion, however, has been greater during the past five years. Nevertheless, domestic energy investments have not been sufficient to keep domestic production in line with the rapid growth of energy consumption.

Moreover, future energy production as foreseen by the R,D&D Plan will most likely come from high technology, high capital cost facilities. In the near-term, the largest investments will be needed for the construction of nuclear and coal-fired electric power plants, coal mining, and off-shore oil and gas production. For the mid-term period, large investments will be associated with the potential development of synthetic fuel plants, oil shale recovery, geothermal electric power plants, and facilities for the use of waste heat, as well as the continued expansion of nuclear and coal power plants. All the technologies currently being developed for the long-term—solar electric plants, fusion reactors, and breeder reactors—will require similar large investments.

For the next quarter century, the investments per unit of energy for the combined energy system may range from 50 percent to 70 percent greater than today's investment per unit of energy. New investments for the next ten years alone have been estimated at $450 to $600 billion. The lower growth rates anticipated in the future will ameliorate the effects of the increases in per unit capital cost.

The Federal Energy Administration, along with several banking institutions and consulting firms, has made estimates of the availability of funds and the methods of financing these capital requirements over the next 10 to 15 years. The consensus of these studies is that the capital markets will be capable of meeting the energy investment demands within the range of the historic proportion of energy investment to total business investment. If these projections turn out to be reasonably accurate, the other sectors of the economy will not be greatly affected in competing for available funds. These projections are consistent with a long-term continued growth in real gross national product and a slowing in energy consumption growth rates.

Specific energy sectors may, however, experience some difficulty in getting an appropriate share of investment funds because of constraints of equity financing, long-term debt, and short-term liabilities. The electric utility sector is a prime example of this situation today. Similarly, attempts by the coal industry to attract new capital for rapid expansion may be hindered by uncertainties regarding the clean use of coal and the execution of long-term contracts.

Industrial Constraints

R,D&D program implementation on a commercial scale will be dependent upon the availability of ancillary resources—notably (a) manpower, (b) manufactured equipment, (c) raw materials and (d) transportation.

Because there are a limited number of *new* technologies that can make significant contributions in the near-term, the impact of this Plan on critical supporting resources is not likely to greatly alter committed patterns of development. The principal impacts of the Plan on these resources will be more apparent in the mid-term period and continue through the long-term period.

Although an extensive quantification of all types of requirements is premature, it appears probable that any potential constraints existing today for manpower, equipment, and transportation resources will be resolved by normal market adjustments within the lead times normally encountered.

The water resources and raw materials categories, however, have far less capability to accommodate changes. Adjustments such as new water storage facilities or substitute material developments require longer time. Thus, the problem areas known today are more likely to continue as limiting factors.

The following sections discuss these categories more specifically:

Manpower—The labor employed in today's energy related activities, including construction, operation, and delivery of energy, currently accounts for only slightly more than 2 percent of the total work force. The developments anticipated by the Plan shift to more capital intensive energy production facilities, but this shift will probably result in only moderate changes in the proportion over the next two decades. However, there may be a relatively larger labor requirement in the construction fields, in the demand for architect-engineers and operators, and in those occupations that require a significant amount of time for education or training. For example, the skilled labor craft requiring the greatest increase appears to be pipe/steam fitters, who comprise at least one-fourth of the construction tradesmen on oil refineries, synthetic fuel plants, or electric power plants.

The dynamic character and mobility of the labor force, however, particularly among skilled and educated persons, has historically adjusted to apparent shortage situations. And the lead time anticipated by the Plan should permit natural adjustments. Unskilled labor is relatively less mobile, so that local labor shortages may periodically occur, particularly in supplementing indigenous labor in the sparsely populated Western areas.

The Plan recognizes the critical nature of manpower requirements and includes a program for manpower development. However, the thrust of the program is properly supplemental to the action of normal market forces; it will attempt to anticipate impending changes and provide incentives to labor for beginning education and training programs somewhat before the pressures of the market make such needs painfully apparent.

Manufacturing Equipment—New multiple technology developments will place some competing burdens on industrial capacity, but given a properly functioning economy, bottlenecks should be limited to certain types of equipment that require long lead times. Existing shortages of certain manufactured equipment, however, have been identified as potentially important constraints in the near-term. Among these items are drag lines for surface mining of coal and uranium, drill rigs for exploration and production of oil, gas, and uranium, and fixed and mobile drilling platforms for offshore oil exploration. In addition, steel piping and tubular goods may be periodically in short supply.

In the mid-term, the expansion of heavy steel plate production to provide pressure vessels for synthetic plants and electric power plants could be a problem. Also, the long lead time on large steam turbine generators could hamper efforts to speed up construction times for power plants.

In the longer term, the domestic industrial base can remedy equipment shortages unless they are caused by a shortage of raw materials. Also, the more efficient use of energy in the various sectors of the economy will alleviate the many potential constraints associated with the slow growth of energy producing facilities.

Raw Materials—Raw materials shortages (non-fuel), on the other hand, are a current problem and may become increasingly significant in the future. Some energy processes require materials that are predominantly available from foreign sources. Other energy processes have increased demand for materials currently in short supply because of inadequate industrial capacity.

The most severe future problems are in the availability of aluminum, chromium, and alloying elements for steel. The country is almost entirely dependent on imports for supplies of these materials.

Energy producing facilities in particular will be in competition for these materials. For example, based on the nature of the facilities envisioned for the mid-1980's, the energy industry's share of total domestic consumption of aluminum may rise from a current 3 percent to 10 percent, and steel may rise from a current 7 percent to 10 percent.

The Plan contains no specific programs to deal with the potential effects of equipment or material shortages because the industrial response to requirements cannot be anticipated and market forces will determine how shortages are met. At present, concerns such as these are the responsibility of the Federal Energy Administration.

Transportation—An analysis of the energy scenarios indicates increasing pressure on the Nation's transportation network from two sources. First, the volume of fuel transported is expected to grow substantially. Second, the new sources of energy through the near- and mid-term are generally located farther away from the population centers than today's supplies—requiring an expansion in delivery capability.

The most severely affected mode of transport for future energy deliveries is rail. The delivery of coal to electric utilities, to industrial boilers, and to synthetic fuels plants may necessitate a four-fold increase in rolling stock by the end of the century. Moderate increases in new track will be needed, but the primary need is to upgrade the existing track system. Greater efficiency in scheduling the use of tracks and turnaround of railway cars can alleviate the growth pressures.

Substantial new investment in pipeline facilities will also be required. The future production of oil and gas from Alaska and the Outer Continental Shelf can take very limited advantage of existing pipelines. To the extent that enhanced oil and gas recovery is successful, the need for new pipeline is reduced.

Coal movement by slurry pipelines may become the most efficient way to transport large volumes of coal in areas that are not constrained by water resources. New investment in slurry pipelines can substitute for rail transport of coal.

Such increases in transportation capacity will create problems only to the extent that the transportation industries are unable to fund the necessary development. That problem is one of financial and regulatory policy and is being addressed by the Department of Transportation.

Water Resources

Water resource constraints are anticipated to be more severe and to require more targeted corrective action than any of the areas discussed above. The currently available reliable supply of freshwater runoff, underground water, and saline water is about 400 billion gallons per day (bgd). The current withdrawal of water for all uses is 315 bgd and the consumption portion of this total is 85 bgd. The projected total national withdrawal of water for all uses in 1985 will grow to 600 bgd, of which 130 bgd will be consumed. The Nation must increase its reliable water supply by at least 50 percent in the next decade, with much of the new increase needed to meet expanded energy production requirements. Because the total potention freshwater runoff in the U.S. is 1200 bgd, this increase can be accommodated through improvement in facilities and methods for trapping the additional supplies needed, but regional problems are expected to persist.

On the basis of the scenario analyses, the largest water requirements created by energy technologies will be from the continued shift to electric power. In addition, the future substitution of synthetic fuels and oil shale production for natural gas and crude oil will create a ten-fold increase in water requirements per unit of energy. This requirement is not large on a national scale but will place pressure on regional and local water supplies.

Energy industries will have to compete for water with farming, recreation, growing population, and commercial activities, all of which have a growing need for this limited resource.

As a consequence, legislation has been enacted that requires the Water Resources Council to make assessments of water resource requirements and water supply availability prior to the commercial application of new technology. The Council will then make an evaluation of the environmental, social, and economic impacts of the dedication of water to such use.

Environment, Health, and Safety

A variety of technological options are being developed for energy production. At some time in the future it will be necessary to choose among these alternatives. The decisions will involve environmental, health, and safety considerations and constraints, in addition to the kinds of economic and industrial constraints discussed previously. These decisions will also depend on public confidence that the proposed energy systems are safe and secure. Informed cost/benefit decisions will depend upon the availability of environmental, health, and socio-economic data and on the status of environmental control technology development.

Problems, time constraints, and technology requirements related to control will vary considerably among energy programs. Examples of some of these problems are shown in Table 9–1. Whereas the spectrum of energy-specific environmental control requirements is diverse, each program control requirement must be treated in a timely manner to prevent problems from escalating. If neglected, these problems could prevent the commercialization of the energy system involved, or burden its development with inefficient and costly add-on control equipment. In designing control programs, consideration must be given to economic factors. Alternative approaches to environmental control should be evaluated on a risk/cost/benefit basis to ensure that funds are not expended for control in instances where neither the potential effects nor public concerns warrant such expenditures.

In certain energy technology areas, alternative back-up systems will have to be developed to obviate delays in commercializing the energy system or to prevent stymying the energy system through lack of suitable controls. Although the major control effort would be concentrated on the approach judged most favorable (in terms of technology availability and benefits/cost/risk factors), backup options will have to be maintained as warranted by the degree of success of the prime approach. This is a high-risk (but necessary) area of research and development.

Energy Areas	Examples of Pollutant/Safety Problems	Examples of Waste Problems
Coal Cleaning and Preparation	Process Water Contamination	Waste Water/ Residues
Coal Combustion	Flue Gas SO_x Control NO_x Control	Flue Gas Desulfurization Solid Wastes
Coal Extraction	Reclamation in Surface Mining	Mine Refuse
Coal Gasification	Particulates and Trace Metals Control	Char/Ash/Slag Disposal
Coal Liquefaction	Process Water Contamination	Char/Ash/Waste Liquids
Fission	Carbon-14 Control	Radioactive Wastes
Fusion	Accidental Tritium Release	Tritium Contaminated Wastes
Geothermal	H_2S Abatement	Silicate/Chloride Salts
Land Transportation Systems	NO_x and Catalyst Induced SO_x	Abandoned Autos
Petroleum and Natural Gas	Oil Fires	Oil Spills
Shale Oil	Surface Disposal and Rehabilitation	Mine Back Filling for Subsidence Control
Solar	Local Atmospheric Perturbations	Bioconversion Wastes
Transmission and Storage	High Level Electric Field Effects	Battery Disposal
Waste Utilization	Pollutant Characterization	Ash Disposal

Table 9–1. Illustrative Environmental Control Problems

Finally, a consistent, coordinated approach among Government agencies responsible for environmental protection must continue to enhance the achievement of environmental goals. The cooperation of industry in this process is critical, since the ultimate success of environmental controls will be demonstrated and largely utilized by privately owned facilities.

It is important to understand that the future production and use of energy will pose some risk to public health and the environment, no matter how vigorously environmental control programs are pursued. Science, engineering, regulations, and social change may reduce health and environmental risks but, in general, cannot eliminate them. The critical question for energy R,D&D therefore is: What level of acceptable risk has to be met in order to ensure an abundant, economical domestic supply of energy? In finding answers to that question, R,D&D efforts must be continuously vigilant to avoid two adverse outcomes that could prevent an acceptable balance between energy benefits and risks: 1) significant unanticipated adverse health and welfare impacts that may accompany the energy benefits and 2) unwarranted public fears of the risks that may delay or deny energy benefits.

The danger of the first adverse outcome can be minimized through an intensive environmental health and safety effort which requires that each technology area have an integrated, fully funded program. Such a program should have corrective overview assessment activities crossing all technology areas to ensure that the right questions are being asked and considered at an early stage in R,D&D planning. The risk of the second adverse outcome can be minimized through maximum public disclosure and education. Encouragement of a continuous interactive process with the public is the one indispensable factor in the maintenance of stable national energy policies and options.

Chapter X—Future Evolution of the Plan

Previous chapters have developed a National Plan for energy R,D&D designed to guide future efforts. Of necessity, this Plan evolved from knowledge and experience readily available to ERDA in its first months of existence. The limited time available to produce the first report constrained the potential scope and depth of analysis that might have been undertaken. Accordingly, initial effort has emphasized a diagnosis of the problem; establishment of major national goals; and direction of resources to the high leverage areas.

This planning, however, must evolve through additional stages. These require (1) a deeper analysis of key uncertainties to confirm or modify priorities; (2) a more integrated treatment of the range of programs to allow for more extensive comparisons among technologies; (3) a more precise definition of programs to maximize assurance that each program responds to its greatest opportunities and produces results directly in support of national goals. Such a planning progression continually modifies programs and alters direction to take advantage of research efforts, analysis, experience and shifting circumstances—all of which are functions of time. Indeed, the legislation establishing ERDA recognized these factors by requiring periodic updates of the Energy Plan—the first being required in January of 1976.

Deeper Analysis of Key Uncertainties

In updating the Plan, particular attention will be devoted to resolving crucial uncertainties that will profoundly influence the outcome of R,D&D efforts. Some uncertainties can be narrowed by research and analysis; others must be dealt with by minimizing unacceptable risk—e.g., through backup programs and parallel-path program development. Essentially, the way a plan deals with uncertainties determines, on one hand, the probability of its overall success and, on the other hand, its net costs.

These points are most evident in an examination of the five principal areas of uncertainty that were identified in the development of the Plan:

Extent of fuel resources. The large differences that exist in estimates of fossil fuel and natural uranium reserves influence both priorities among programs and the pace required of individual programs. In developing the Plan, judgments are required between effort to determine resources more precisely (where a confirmation of large estimates provides more lead time to develop a replacement technology) and effort to accelerate the development of the technologies. For example, the time when oil and natural gas are significantly depleted determines when a synthetic liquid fuels commercial capacity will be required; and the depletion rate of available uranium determines when breeder reactors need to be functioning.

Technological feasibility of options. The technologies considered in the Plan vary substantially in their prospects for success. For example, solar heating has already been physically demonstrated; advanced conversion technologies have been scientifically validated, but it is not clear that materials and reliability problems can be economically overcome; and fusion, thus far, is only theoretically an efficient source of net energy.

In the planning process, feasibility judgments must be made which can significantly influence the course of technology development. One such judgment is the extent to which a technology warrants government support; virtually commercialized technologies require only a limited government role. Another decision regards estimated lead-time for development and the timing of support for a technology; fusion will be supported now, even though there will be no payoff until after 2000. Finally, judgments must be made concerning acceptable investment levels; a technology with only a moderate energy payoff and high uncertainty results in a low program priority.

Eventual commercial attractiveness of options. There is considerable uncertainty regarding the final demonstrated design of many technologies. In terms of unit cost and requirements for scarce materials and capital, many current judgments on future attractiveness of competing technologies are necessarily speculative. In high priority areas, the R,D&D strategy is to pursue a number of competing technologies, some of which may not be commercialized. In areas of lower priority, when commercial viability is dubious, the R,D&D emphasis is correspondingly reduced.

Degree of environmental and social constraint. Advance judgments are necessary concerning the potential adverse environmental impact of new technologies and the extent to which that impact can be satisfactorily controlled. Thus, for example, limited availability of water in the West and waste disposal problems may limit the potential energy contribution of oil shale and have caused the emphasis in the program effort to be on in situ processes. Another critical judgment has been made in the case of nuclear power, where the view has been taken that environmental and safeguards problems are sufficiently likely to prove tractable to continuing development effort (and thereby be resolved to the public's satisfaction) so that such continuing development effort is warranted.

Future energy requirements. The total of U.S. energy requirements and the actual mix of fuels will depend on economic growth patterns, forms of utilization, and conservation practices. For example, broad-scale successes on the conservation front would provide role lead-time for the implementation of new technologies. As illustrated by the scenarios, the Plan assumes levels of growth and conservation savings that will require rapid introduction of a number of new technologies.

To deal with the uncertainties above, the Plan required a wide range of assumptions, which were made with varying degrees of confidence. The rule in virtually all cases was to make conservative assumptions that would produce actions minimizing severe risks for the Nation. A desire for cost-effectiveness, however, dictates that uncertainties be narrowed and programs modified so that acceptable results can be produced with the least investment. Accordingly, in support of future Plan revisions, research and analysis will be directed toward improving understanding of critical assumptions. And this, in turn, will in some cases result in modifications to the R,D&D Plan.

It must be emphasized that decisions taken now relate to the initial level and content of R,D&D efforts. They do not represent unvarying commitments for the future conduct of either development or implementation actions. These decisions will be taken sequentially, and they will be constantly reexamined.

Enhanced Integration of Programs

A prime consideration for the establishment of ERDA was to provide an institutional means for integrating energy R,D&D programs to meet national needs coherently and effectively. As a first approximation, the ERDA R,D&D Plan provides the strategic framework to accomplish this integration by rating a spectrum of programs against national energy technology goals and by setting priorities. While this analysis minimizes duplication of program effort, on one hand, and avoids obvious gaps, on the other, it ony begins to mesh programs so as to enhance their net effectiveness.

What is needed to achieve improved program integration and effectiveness is the development of an analytical structure for evaluating technological options on a basis which ensures full comparability. For many major technological options, systems analyses have not yet been conducted to evaluate benefit-cost ratios. Where such analyses exist, the benefit-cost comparisons have often been based on methodologies employing differing assumptions, and comparability is difficult or impossible. Furthermore, no analyses have included a quantitative evaluation of risk and uncertainty.

The basic motivation for conducting most of the R,D&D energy programs described in the National Plan is to obtain information which will reduce the risk and uncertainty associated with a major commitment. Recent developments in analysis have yielded techniques which allow a decision-maker to assess the value of the information produced by an R,D&D program. Such assessments can produce measures for judging how much should be spent on R,D&D programs. Clearly, programs should not be funded at levels which exceed the expected value of the results produced.

Thus a high priority must be assigned to efforts which will promote more effective system analyses of technological options. Such efforts can contribute significantly to future energy R,D&D plans by establishing a better rationale for program priorities and resource allocations.

There are five key areas in which such integrating analyses need to be further developed:

- *Tradeoffs among factors of energy contribution, technological feasibility, cost, and environmental impact.* While each technology area has been individually screened according to these factors, a fully accepted means to employ tradeoffs within a given program and across several programs has yet to be developed. In particular, these analyses need to reflect and be consistent with broad national security considerations.
- *Pace of program capital investments.* The Program Implementation Plan (contained in Volume II) lays out key milestones for each program, many involving construction of capital facilities such as demonstration plants. Although timing of each of these milestones is keyed to achieving program objectives, it may be unrealistic in terms of the disproportionate burdens it places on financing management and production facilities. These factors must be analyzed broadly to establish a realistic pace for capital investment. Priorities must then be set to adjust program development to that pace.
- *Balance of R,D&D effort to include allied non-R,D&D measures.* To achieve national energy goals in many cases, a full range of program efforts needs to be considered: financial and tax incentives and regulation as well as R,D&D programs. The Plan gives heavy emphasis to technical efforts. Future analysis should right the balance.
- *Assessment of integrated impact of all related National programs on key end-users or targets.* The Plan presents many program activities with potential impact on the same set of users. The electric utilities, the most prominent example, would be expected to use simultaneously (a) power generation capability from nuclear, fossil, solar and geothermal energy, (b) energy storage and distribution technologies, (c) direct electric conversion technologies, and (d) energy from waste technology, as well as (e) supply waste heat to other users. More analysis is required to ascertain the practicality and coherence of these programs in their implementation stages.
- *Consideration of regional program impact.* Many of the technologies are regionally specific in their application. Some may produce benefits usable only in particular areas, e.g., some types of solar and geothermal energy applications. Others have environmental consequences which are limited in their impact, e.g., mining of coal and oil shale. Future stages of planning need to consider program implementation on a regional basis to ensure that the requirements of some areas are not critically neglected.

More Precise Program Definition

Although the Plan has identified those technologies with greatest potential for exploiting sources of energy and has set priorities for their development, some programs need to be focused more precisely on achieving the Plan's R,D&D goals. The need for more focus is principally in the less mature programs where there has been limited time to diagnose the technical and resource problems and to identify potential solutions.

There are still additional areas of analysis which can make significant contributions to the Plan but which have not been sufficiently analyzed to permit their definition in this first edition.

The following are examples of such areas:

- *Determining the "net energy" contribution of the technologies.* In developing priorities for technologies, primary emphasis was placed on the quantities of energy that could be produced by a technology. A corollary consideration—known or estimable to a lesser extent—is the amount of energy consumed in producing the usable energy form. In the final analysis, it is the difference between the amounts that is of interest. Thus, for example, some technologies which promise significant amounts of energy output may require so much energy in the manufacture of plant or the processing of fuel that they will not prove as attractive as they first seemed. Further effort will be directed to understanding net energy implications for all major technologies.
- *Establishing the most effective form of Federal/industrial partnership to exploit energy savings in (a) industrial processes and (b) consumer products.* A myriad of different industrial processes and consumer products can be modified to become more energy conservative. Most of the opportunities will be pursued by industry when market forces make such action financially attractive. Nonetheless, governmental effort can have high leverage in cases where a generic technology—e.g., heat management—has broad applicability or in cases where large fragmented industries are financially unable to undertake such development. These areas need still better definition.
- *Identifying special institutional constraints that must be addressed in implementing particular program R,D&D.* For example, while solar heating and cooling technology is far advanced, many institutional aspects necessary for its implementation have still to be worked out.
- *Determining the environmental and technical problems in particular technology*

areas. For example, although the potential energy contribution of geothermal is attractive and the technology for exploiting some sources is already proven, there are substantial materials and environmental obstacles associated with the principally known hot brine sources which need to be better understood.

- *Clarifying the ultimate potential and specific application of hydrogen systems.* As indicated in portions of the Plan, hydrogen can be considered as a way of storing energy for localized mobile uses, such as the automobile and airplane. In addition, hydrogen can be used in storage and transmission (by pipeline) of larger amounts of energy. Problems in developing a national system infrastructure could be substantial and must be understood before the potential of hydrogen systems can be properly assessed.
- *Determining an appropriate Federal role in construction technology.* Projections of future national energy requirements anticipate enormous amounts of construction and capital equipment. As outlined in the previous chapter, capital investment could be between $450 and $600 billion by 1985. In a number of areas it is evident that R,D&D could reduce associated construction costs—e.g., in quality control, reliability, scheduling, standardization, improved construction materials, and tunneling. While the potential is understood, future program plans need to define how R,D&D is to be exploited in this way, and how the government might spur this effort.

Developing Operating Ties Among Participating Institutions

Although the Plan has outlined the general roles to be played by ERDA, other Federal agencies, industry, states, and foreign governments, the actual operating relationships still need to be forged in program execution. Further analysis, in turn, is needed to guide the development of these relationships to maximize their effectiveness.

Developing Better Integration of Basic Research and National Security Technology "Spin-Offs"

The nature of basic research is such that it supports many aspects of energy R,D&D programs. ERDA will foster and develop improved relationships with research facilities, both domestic and worldwide, and encourage the continuation of basic research endeavors supportive of energy technology needs.

National security and energy program R,D&D have common scientific and technological bases. Indeed, many clearly identified "spin-offs" from national security R,D&D programs have initiated or contributed significantly to energy system development. For example, nuclear reactor technology has derived from the naval reactors program of the Atomic Energy Commission. That contribution is continuing. Advanced computational techniques using sophisticated computers and software developed for national security R,D&D purposes have found ready application in energy programs. Materials research, engineering technique development, and safety analyses conducted in support of military hardware R,D&D programs have been directly usable in energy development programs. Within ERDA, common facilities are used for national security and energy R,D&D with significant potential for cross-fertilization and rapid application of new concepts.

For this reason, ERDA will maintain close liaison with national security R,D&D programs and continue to take maximum advantage of energy-related technological advances achieved in national security programs.

None of the areas discussed above are likely to change the fundamental direction set by the Plan. They do, however, provide an agenda for substantial analysis and management attention. This effort may well produce more coherent, targeted, and cost-effective sets of programs. Periodic updates of the National Plan for energy R,D&D provide the mechanism and stimulus for carrying out such effort. The plan to be prepared for Congress in January 1976 will begin to reflect the refinement of uncertainty, more integrative analysis, and better program definition.

Glossary

Specific Technology Program Descriptions

Oil and Gas—Enhanced Recovery

The application of techniques, processes and methods which permit the extraction and recovery of additional amounts of oil or gas. These applications represent improvements over current practice. They include hydraulic fracturing methods, the injection of solvents and heat to increase yield, and other secondary and tertiary methods to enhance recovery.

Oil Shale

The design, construction and operation of systems, components, and processes for the extraction of hydrocarbon products from shale and the conversion of the product to liquid or gaseous fuels or other chemical commodities. Included in the program is the development of in situ methods for product extraction.

Geothermal

The development, design, construction and operation of systems and components which will extract the heat energy contained in geological formations and convert it to power or to other beneficial uses. It includes such geothermal resources as hot rocks, dry or wet steam, hot brines, etc.

Solar Electric

The development, design, construction and operation of systems to collect the radiant energy of sunlight and transform the energy into electrical power. The technology includes the use of various collector systems, such as mirror concentrators, as well as various conversion systems such as photovoltaic devices. The technology also includes the use of solar-derived energy, such as wind or ocean thermal gradients, as an energy source for the production of electricity.

Breeder Reactors

The development, design, construction and operation of components and systems which use nuclear fuels for producing power or process heat but which produce fissionable material during the process at a rate greater than the rate consumed. The primary effort is directed toward the development of a liquid metal fast breeder reactor system but also includes efforts on gas cooled, molten salt and light water breeder reactor concepts.

Fusion

The development, design, construction and operation systems and processes by which elemental particles of the lighter elements are made to combine or fuse into elements of higher atomic weight with the resulting liberated energy harnessed to produce power. The technology program currently is investigating a number of methods to induce fusion including lasers and the use of magnetic confinement systems.

Coal—Direct Utilization in Utilities/Industry

The design, construction and operation of advanced components, systems and processes involved in the industrial and utility combustion of various types of coal; the transfer of the heat produced to steam or other working fluids for process or power use; and the systems and methods employed to reduce or control the generation of pollutants during combustion. Included are new combustion methods, such as fluidized bed combustion, more efficient boilers, and the use of additives during combustion.

Waste Materials to Energy

The development, design, construction and operation of systems and processes to utilize wastes or refuse and convert the energy contained therein to useful power or heat. It includes also processes for the recovery and recycle of valuable non-energy resources.

Gaseous and Liquid Fuels from Coal

The development, design, construction and operation of components, systems and processes which will convert various types and ranks of coal to other fuel forms including: clean gases of either high or low energy content; oils and other clean liquid fuels or solid fuels which have higher heat content, less ash and fewer impurities than natural coal. Gaseous fuels production includes both above-ground and in situ processes.

Fuels from Biomass

The development, design, construction and operation of systems and processes for the conversion of biological materials to energy sources. It includes such processes as the conversion of wood or other plants to alcohol and fermentation or decomposition of organic by-product materials to produce methane or other fuels.

Nuclear Converter Reactors

The design, construction and operation of components and systems which utilize nuclear fuels to produce power or process heat but which consume fissionable material at a rate greater than it is produced by the system. Included is the continued development of light water reactors and high temperature gas cooled reactors and the improvement of reliability, cost reduction and efficiency of the systems.

Electric Conversion Efficiency

The development, design, construction and operation of advanced devices for converting heat to electricity. Included are various mechanical, electrochemical, and thermodynamic devices, such as fuel cells, thermionic systems, thermoelectric systems, magnetohydrodynamic turbine generation employing different working fluids and multiple cycle systems.

Energy Storage

The development, design, construction and operation of advanced devices to permit the storage of energy until needed. It includes devices such as batteries, pumped storage for hydroelectric generation, flywheels, compressed gas and other methods or systems.

Electric Power Transmission and Distribution

The development, design, construction and operation of systems to transport electrical energy from the generation station to the eventual utilization device. Included are extra high voltage AC systems, DC systems, underground systems and cryogenic systems as well as system security and load management.

Solar Heating and Cooling

The design, construction and operation of systems to utilize and/or store the radiant energy of sunlight for comfort control of buildings and houses and/or to provide heated water for household, industrial, or agricultural use.

Waste Heat Utilization

The development, design, construction and operation of systems to utilize the waste or rejected heat incident to the production of electrical power or industrial products for beneficial purposes. It includes bottoming cycles as well as integrated total energy systems employed in residential, commercial and industrial complexes.

Electric Transport

The development, design, construction and operation of transportation methods which utilize electrical energy as the source of propulsion power. It would include electrical automobiles and trucks and electrified rail transport systems.

Hydrogen in Energy Systems

The development, design, construction and operation of systems, components, and processes for the production, transport, storage and utilization of hydrogen as a substitute fuel. It includes development of non-electrolysis processes for generation of the hydrogen product and methods for its storage and transport.

Transportation Efficiency

The development, design, construction and operation of more efficient transport systems, including ships, planes, trucks, autos, trains, pipe lines, etc., and the power systems involved.

Industry Energy Efficiency

The development, design, construction and operation of industrial processes and equipment which minimize the energy requirements involved in the fabrication, forming, conversion or production of industrial or agricultural products.

Conservation in Buildings and Consumer Products

The development, design, construction and operation of buildings and other consumer products to minimize the energy consumption involved. The technology includes methods and types of insulation and fenestration to reduce energy needs for comfort and light as well as systems of control to minimize the energy requirements. Also included are consumer products which would utilize less energy in their operation, such as appliances, TV's, and heating, cooling and ventilating systems.

Specific Supporting Technologies

Exploration and Resource Assessment

The development and application of advanced techniques to locate, identify and assess the amounts and kinds of energy resources or other useful material in geological formations. It includes a number of methods, such as magnetic and gravimetric measurement, seismic and acoustic scanning, and aerial and space photographs as well as drilling and sample analysis. The program also includes the compilation, analysis and reporting of resource data.

Mining and Beneficiation Technology

The development of techniques and methods and the design, construction and operation of systems and processes to extract useful resources from geological formations and to concentrate or upgrade ores to a higher content of the desired material. It includes various underground as well as surface extraction techniques and the methods and systems used to upgrade the ore or eliminate undesirable components of the naturally occurring deposits.

Environmental Control Technology

The development, design, and construction and demonstration of processes and systems to control the amount and kind of pollutants discharged to the environment as a result of energy conversion, extraction, or use. It includes such systems as scrubbers, filters, washers and precipitators to remove noxious gases or particulates from combustion processes; methods to control or remove radioactive gases or particulates from nuclear processes; and converters to modify exhaust from automobile engines. It also includes cooling towers and other means to permit the dissipation of waste heat with minimum adverse environmental impact.

Fossil Fuel Transportation

The development, design, construction and operation of advanced systems, and components for the transport of fossil fuels from point of origin to point to use. It includes systems such as unit trains, pipe lines, conveyor systems and others.

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Nuclear Safeguards

The development, design, construction and operation of systems and devices to account for and control nuclear materials and the systems and methods employed to prevent diversion, theft or other uses which could threaten the life or property of the public.

Support of the Nuclear Fuel Cycle

The development, design, construction and operation of facilities, systems, components and processes for the chemical processing of spent nuclear fuels from power reactors for the recovery of the fissionable material contained therein including refabrication of such material into fuels for reinsertion into the reactor systems. This includes systems for the management and control of the radioactive waste produced incident to the recovery of fissionable material and would apply to light water reactors, gas cooled reactors and breeder reactor systems.

Uranium Enrichment

The development, design, construction and operation of systems, processes and components to permit isotopic separation and the enrichment of the isotope U–235 in uranium for use as nuclear fuel. It includes a number of processes such as gaseous diffusion, centrifugation and some more advanced systems involving lasers, aeronozzles and others.

Waste Management

The development, design, construction and operation of systems and components to permit the safe management, transport and storage of radioactive wastes and the eventual disposal of such wastes in an environmentally acceptable nonhazardous manner. It also includes the management of noxious wastes resulting from the use of other energy resources.

Broad Supporting Technologies or Programs

Basic Research

A broadly based program of scientific investigation into the fundamental nature of the universe to elicit greater understanding of the nature and behavior of matter. It includes research in high energy physics, molecular sciences, material sciences, nuclear sciences, and biological sciences.

Biomedical and Environmental Research

The scientific investigation of the health and biological effects of radiation and other pollutants on the environment and its inhabitants. It includes studies to understand ecological relationships and how man-made disturbances affect these relationships as well as the development of systems and methods to measure the release of noxious or harmful substances.

Systems Studies

Methods and techniques to analyze and assess programs, activities and projects undertaken in order to permit planning of programs and review and assessment of efforts to date and to determine courses and the direction of these energy programs and their relative importance. It includes cost/benefit analysis, environmental impact analysis and studies to assess the likelihood of technical success, forecast possible futures resulting from specific actions and provide guidance for energy program planning and implementation.

Information Dissemination

A program for the creation and widespread distribution of the technical information and data developed by the energy program to permit broad knowledge, understanding and use of the data for public benefit.

Manpower Development

A program of training and education to assure that as new technologies are introduced or technologies are commercialized there will be an adequate pool of trained and knowledgeable personnel to design, construct and operate the new facilities and systems and to ensure that manpower constraints do not act to inhibit the wide-scale application of energy technologies.

Safety

The development, design, construction and operation of systems, components, and devices to protect the public and workers from the health hazards associated with energy production and utilization. Its major effort includes the development of devices and designs to prevent or minimize accidents and to mitigate the consequences of potential accidents to the public.

Appendix A—Energy Measurements and Conversion Factors

Gross Measures of Energy Used in the United States

- The two most commonly used gross measures of U.S. energy supply and demand are quadrillions of Btu (Quads or Btu x 10^{15}) and millions of barrels daily, oil equivalent.
- Two quadrillion Btu's per year are roughly equivalent to one million barrels daily (MMB/D).
- By moving straight across Fig. A–1, it is possible to match equivalent values in each of the commonly used measures of annual production or distribution for the major fuels and power sources.
- Uranium is entered as U_3O_8 in units of 10,000 short tons utilized in present thermal reactors.
- Solar energy is entered in units of 1,000 square kilometers of collector surface assuming 50% efficiency and the average amount of sunshine per year in the United States.

Conversion Factors

1 Quad = 180 million barrels of petroleum*
42 million tons of bituminous coal*
0.98 trillion cubic feet of natural gas*
293 billion kilowatt hours of electricity

* These values vary with the quality of fuel actually extracted and represent an average of recent production.

It is also of interest to note that 1 million barrels of oil per day is approximately equal to 2 Quads per year.

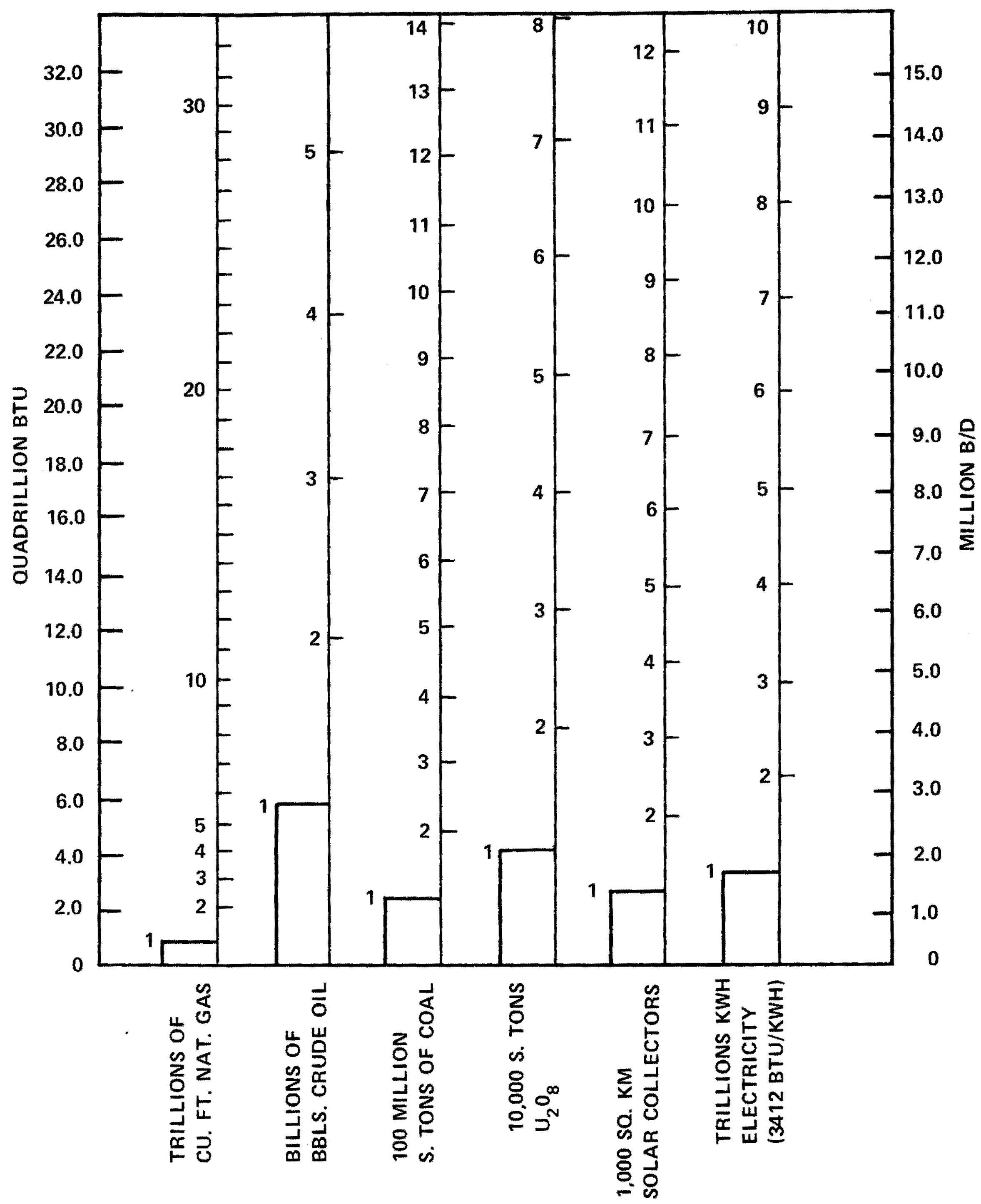

Figure A–1. Gross Measures of Annual Energy Supply/Demand Commonly Used in the United States

Appendix B—Inputs and Results of the Scenarios

Techniques for Looking Ahead

Developing insights about the Nation's energy future is a difficult and uncertain process. In the past, energy prices, technology and consumption patterns changed relatively slowly, providing a reasonable model for predicting the future. Today the situation is characterized by instability in energy prices, declining domestic petroleum resources, and challenge to both energy growth and economic growth. It is no longer possible to generate a single projection of the Nation's energy future and expect a majority to accept it as a basis for planning. Extrapolation from the past is inconclusive since the period chosen critically influences the results. The average energy growth rates experienced during the past year, the past 5 years, and the past 15 and 25 years differ significantly.

Several different quantitative approaches have recently been developed to deal with this problem. They include econometric models, input-output models, optimization models, dynamic simulation models and technical or engineering models. One of the most comprehensive is the Project Independence Evaluation System which incorporates a series of engineering and econometric models with linear programming integration models. This model produces supply and demand balances up to 1985 for many different fuels and different regions of the country.

The Project Independence and other such models require as inputs detailed projections or assumptions about cost, prices, elasticities and other economic variables, frequently on a regional and individual fuel basis. The more distant the future, the more difficult it becomes to provide these detailed inputs. R,D&D planning must look far into the future—the year 2000 at a minimum rather than 1985 as a maximum. It does not require precise quantities and costs, however.

The Reference Energy System

A less elaborate technique called the Reference Energy System has been developed for energy R.D&D planning using an engineering or technological modelling approach. This approach involves implicit economic parameters instead of the explicit economic parameters used for near-term efforts. The technological approach is not particularly useful for short-term planning but is preferable for long-term planning horizons because fewer assumptions are needed and these can be explicitly stated and varied as appropriate.

The Reference Energy System was developed by the Brookhaven National Laboratory and involves both hand calculations and a computer optimization model. The objective of both procedures is to complete an energy flow network such as is shown in Figures 4–1 and B–1 through B–12. In the hand calculation approach external judgments and experience are used to determine the detailed energy flows. The computer optimization model finds the least-cost solution on the basis of externally projected unit costs. The optimization model also provides environmental data, break-even prices for new technologies and other information which is used to analyze the scenarios.

Demand and supply inputs were developed independently on the basis of engineering, demographic and economic data. Each scenario presented in the report was initially generated by a judgmental procedure, and then the computer model was constrained to produce similar results providing as output the environmental and related residuals. In addition, less constrained optimization runs were made for comparison of new technologies. The strength of the approach lies in the complementarity of the mechanical optimization model and the judgmental hand approach.

The resulting supply and demand balances will differ from the precise balances which market forces would eventually achieve, but they are indicative. This degree of precision is comparable with the level of uncertainty in the inputs and appears adequate for making broad strategic comparisons. Insights which are relatively insensitive to variations in the inputs and other assumptions are more reliable than those which hinge on precise numerical answers. Thus, the projections made with this model do not represent forecasts of the future. Rather they provide an indication of the relative impact of various strategies for achieving long-term national energy goals and are valuable in establishing the priorities for technological options.

Demand Inputs

The demand or end-use inputs to the model are in terms of physical quantities, such as tons of iron, steel and aluminum to be produced; automobile passenger miles driven; and square feet of building to be heated. The same level of these inputs was used in each of the scenarios. The key values are given in Table B–1 together with comparable 1972 data. These inputs were developed from a number of independent studies and historical data.

Supply and Conversion Inputs

The production of energy resources is specified in terms of the tons of coal, barrels of oil, cubic feet of natural gas and gigawatts of electric power that could be produced from given resources. This technique requires that energy demands be met from the given resources. It is not necessary that all of the permissible production of the resources be used, however. The optimization model selects the lowest cost options within the supply constraints while judgments are used in the hand procedure. Any differences between demand and supply must be provided by imports or exports.

Technical inputs are also made in the form of process efficiencies. For example, improvements in electric power transmission show up as an improvement in the electric transmission, distribution and storage process efficiency while improvements in air conditioners show up as an improvement in the end-use device efficiency.

Results

The quantitative results from the scenarios are presented in Figures B-1 through B-12 and summarized in Tables B-2 through B-6. The figures are the result of hand calculations and show all of the different processes and flows which have been analyzed.

Tables B-3 through B-6 are based on constrained runs of the optimization model. The resources consumed were fixed at the levels of the corresponding hand calculations.

The total-cost line represents the total annual cost of operating the energy system. Included are all costs associated with supplying the energy used up through, but not including, the cost of the utilizing device. For example, the cost of mining coal, washing it, transporting it to a power plant, using it to make electricity and then distributing it to consumers would be included. The user costs, e.g., for air conditioners, would not be. The costs include resource costs, annualized capital costs (utility type financing) and operating costs. The costs associated with using solar energy for heating and cooling are borne by the users who install collectors and related equipment; consequently, these installations are considered to have a zero cost in this analysis.

The environmental data are generated by multiplying the applicable energy process flows by unit impact coefficients. The air pollution results are presented in terms of central source emissions (such as those from large electric power plants) and in terms of decentralized emissions from cars and houses.

Defining Impacts Used in Ranking Energy Technologies

The impacts of new technologies can be measured at several places in the energy system. Most analyses of new energy supplies focus on the energy resources consumed. This approach is not satisfactory when comparing the results of improvements in end-use technologies with results from new supply technologies. A more satisfactory approach, used in the preparation of Table 6–1 to make these comparisons, measures energy in the form in which it is actually marketed.

The Reference Energy System provides a useful means for making this calculation. All the energy which passes the "Transmission, Distribution & Storage" point in Figures B–1 through B–12 is distributed to end-users in the form of electricity, oil, gas, coal, or heat. To account for the differences in quality of these forms, they have been converted to the equivalent Quads of oil which would be needed to achieve the same results.

For example, electric generation in Quads was multiplied by two to obtain the equivalent amount of oil. This process reflects the losses expected in producing electricity from coal and in converting coal to synthetic oil.

Economic Observations

The total cost numbers shown in Tables B–3 and B–5 provide some key insights. Scenarios 0, II and III have essentially the same level of energy consumption but do not include the conservation technologies. Their costs are about the same in 1985 and 2000. The insensitivity of the costs with respect to major changes in technology —from imports to synthetics to electrification— is significant and suggests that the economic impacts of competing technologies are probably not that different.

Secondly, the total cost falls significantly as energy conservation technologies are introduced. The drop in cost is even more rapid than the drop in energy consumption, providing a definite external benefit to the community from conservation.

The method of computing costs—neglecting user costs—does not provide a true estimate of the savings due to new end-use technologies. The large difference between the costs in Scenarios 0, II and III and those in the conservation Scenarios I and V represents the amount which consumers could afford to spend, on an annualized basis, to make the technological improvements. By 2000 this amounts to some $150 billion per year or nearly one-third of the base cost for energy. For conservation to be cost effective, therefore, the cost of saving the energy would have to be less than this difference.

Another observation is the increase in average energy costs. From a current level of about $1.50 per million BTU, energy costs would rise to slightly over $2 per million BTU in 1985 and about $3 per million BTU in 2000 in constant dollars. Even with new technology, energy will cost more in comparison with other goods and services in the years to come.

Break-even prices, or the cost at which new technologies would tend to enter the energy system, are generated by the less constrained model runs. The greatest economic incentives on the supply side in 1985 are for additional domestic oil and gas and for the use of coal to substitute for oil and gas in process heat and petrochemical applications. On the end-use side the greatest incentives are for more efficient air conditioners, automobiles, other modes of transportation and space heat. The model also provides some analysis of peak electric loads and load factor improvements. It suggests a priority for storage and for peak applications to improve the utilization of high capital cost generating facilities.

In 2000 the break-even prices suggest incentives for synthetic liquid and gas production. These may be sufficient to make second generation coal gasification and liquefaction commercially viable. The greatest benefits in the electrical sector seem to be from additional nuclear or geothermal supplies, saving coal for direct and synthetic uses. On the consumption side, the break-even prices suggest potential benefits in waste heat utilization, solar heating and cooling, and industrial process improvements. Electrical storage is still much in demand.

Comparison of Results with Other Studies

While it is very difficult and perhaps not significant to compare the results of these scenarios with the detailed results of other recent studies, it is useful to compare total energy consumption and total electric generation. These two quantities are presented in most studies and are generally defined in the same way. The results for the scenarios are presented in Figures 4–2 and 5–3. Total domestic consumption of resources was used —oil and gas imports added to domestic resource production and coal exports subtracted.

The comparison is shown in Figures B-13 through B-16. The total energy comparisons place most of the ERDA scenarios in the middle range among other recent estimates. Scenarios I and V —the improved end-use technology cases—compare with the Project Independence, the Energy Policy Project and the Council on Environmental Quality conservation cases. The higher estimates shown in these comparisons generally do not include the effects of the 1973–74 embargo and subsequent price increases.

Most of the same observations hold true for electric generation as well. The scenario estimates for 1985 tend to be somewhat lower than most other recent studies because they recognize the delays in power plant construction which have been encountered in the past year. The scenarios with low total electric power production in 2000 reflect inclusion of new dispersed energy sources, such as solar heating and cooling, which directly replace electricity from central power stations.

These comparisons do not prove anything about either the scenario estimates or the other studies, but they do suggest that the scenarios form a reasonable basis for planning.

	1972	1985	2000
RESIDENTIAL			
Heating, cooling, & electricity	66.7×10^6 households	80.0×10^6 households	99×10^6 households
COMMERCIAL			
Heating, cooling, & electricity	23.5×10^9 ft^2 floorspace	32.0×10^9 ft^2	42.0×10^9 ft^2
INDUSTRIAL			
Process & direct heat	7.84×10^{15} Btu	3% growth/yr	3% growth
Petrochemicals	4.19×10^{15} Btu	5% growth/yr	5% growth
Electricity	2.57×10^{15} Btu	4% growth/yr	4% growth
Iron	84.5×10^6 ton	122×10^6 ton	153×10^6 ton
Aluminum	4×10^6 ton	8×10^6 ton	14×10^6 ton
TRANSPORTATION			
Private Auto			
Air—passenger	992×10^6 vehicle-mile	1467×10^9 vehicle-mile	2050×10^9 vehicle-mile
—freight	153×10^6 passenger-mile	421×10^6 passenger-mile	874×10^6 passenger-mile
Bus, truck & rail	4×10^6 ton-mile	30×10^6 ton-mile	99×10^6 ton-mile
—passenger	89×10^6 passenger-mile	11×10^6 passenger-mile	161×10^6 passenger-mile
—freight	461×10^9 ton-mile	72×10^9 ton-mile	1040×10^9 ton-mile
Ship	0.7×10^{15} Btu	4%/yr growth	3%/yr growth

Table B–1. Level of Demand for Energy Services

Scenario 0—No New Initiatives

	Quantities 1985	2000
Electric Supply (GWe)		
• Coal	295	
• Nuclear—Moderate Growth—no LMFBR	185	720
• Hydroelectric—Moderate Growth	86	92
• Geothermal—Expansion of Geysers	5	10
• Oil and Gas	Remainder of demand	

	Quantities 1985	2000
Direct Fuels Production		
• Oil((MBD)	10.1	5.3
• Gas (TCF)	21.5	15.4
• Coal	as needed	
• Urban Waste (Quads)	0.1	0.1
Consumption Technologies		
• Automobile Efficiency (MPG)	17.5	20.0

Scenario I—Improved Efficiencies in End-Use

	Quantities 1985	2000
Electric Supply		
Same limits as in Scenario 0, but amounts used less in some cases		
Direct Fuel Supply		
• Oil—amount added for tertiary recovery (MBD)	1.5	3.6
• Gas—amount added for enhanced recovery (TCF)	5.0	7.4
• Solar heating and cooling (Quads)	0.25	3.5
• Geothermal heat (Quads)	0.2	1.0
• Waste material use (including re-cycling) (Quads)	2.0	7.5
Waste heat use for heat and power	0.4	3

	Quantities 1985	2000
Consumption	% Improvement	
• Buildings:		
—shell	10	15
—heating and cooling equipment	10	20
—other appliances and consumer products	10	25
• Industry:		
—process heat and electrical equip.	10	12
—petrochemicals	5	25
—primary metals	10	20
• Electric Power Transmission and Distribution	—	25
• Transportation		
—land transport other than autos	10	20
—aircraft	15	15
—autos (fleet average)	18.7	28

Table B–2. Inputs for Scenarios

Scenario II—Synthetics from Coal and Shale

	Quantities 1985	2000
Electric Supply		
Same as in Scenario O		
Direct Fuels Supply		
• Oil and gas: Same as in Scenario I		
• Synthetic crude and pipe line quality gas from coal (or equivalent barrels of oil)	0.7	7.0
• Oil from shale (above ground and in situ)	0.5	4.0
• Biomass conversion (oil equivalent)	0.025	0.75
• Solar and geothermal heat	........none........	
• Urban wastes: Same as Scenario I		
Waste heat use and electric transmission and distribution same as Scenario I		

	Quantities 1985	2000
Consumption		
All end-use efficiencies same as in Scenario O		

Scenario III—Intensive Electrification

	Quantities 1985	2000
Electric Supply		
• Coal electric (maximum in 1985)	295	not limited
• Hydroelectric (same as other scenarios)	86	92
• Nuclear converter reactors	225	720
• Breeder reactors	0	80
• Solar elec. power	1	50
• Fusion power	0	1
• Geothermal elec. power	10	40
• Oil and gas electric power	balance of total	
Direct Fuels		
Same as Scenario I, except waste materials use & recycling added at base level		

	Quantities 1985	2000
Consumption		
• Same as Scenario II Except: Electric autos	1	10

Scenario IV—Limited Nuclear Power

	Quantities 1985	2000
Electric Supply		
• Coal electlic (maximum level in 1985)	295	not limited
• Hydroelectric power (same)	86	92
• Nuclear converter reactors	185	200
• Solar electric power	5	100
• Fusion power	0	1
• Geothermal	20	100
• Oil and gas	Balance of demand	
Direct Fuels Supply		
• Same as Scenario II (Synthetic Fuels), plus:		
—Solar heating and cooling	0.25	3.5
—Geothermal Heat	0.20	1.0

	Quantities 1985	2000
Consumption		
• Same as Scenario, O, less the following efficiency improvements from Scenario I:		
—Process heat and electric equipment	10	12
—Petrochemicals	5	25
—Primary metals	10	20

Table B–2. Inputs for Scenarios—Continued

Scenario V—Combination of All Technologies

	Quantities 1985	Quantities 2000		Quantities 1985	Quantities 2000
Electric Supply • Same limits as in Scenario III (but supply level does not always reach limit)			**Consumption** • Same as Scenario I, plus: —Electric autos from Scenario III		
Direct Fuels Supply • Same as Scenario II					

Table B–2. Inputs for Scenarios—Continued

	Resources Consumed, Quads (10^{15}Btu) 0	I	II	III	IV	V
Hydroelectric (at 34% efficiency)	3.38	3.38	3.38	3.38	3.38	3.38
Geothermal	0.69	0.93	0.69	1.60	3.20	1.60
Solar	0.00	0.25	0.00	0.31	0.57	0.31
Fusion	0.00	0.00	0.00	0.00	0.00	0.00
Light Water Reactor (LWR)	10.61	10.61	10.61	12.97	10.60	12.97
Liquid Metal Fast Breeder (LMFBR)	0.00	0.00	0.00	0.00	0.00	0.00
High Temperature Gas Reactor (HTGR)	0.24	0.25	0.24	0.24	0.25	0.25
Oil Steam Electric	3.39	2.79	3.39	4.91	2.32	2.79
Gas Steam Electric	4.39	3.00	4.39	3.19	4.03	3.00
Oil, Domestic and Imports	47.14	34.59	41.43	41.57	41.52	31.95
Oil Imports	25.94	10.49	17.33	17.47	17.42	7.85
Oil Shale	0.00	0.00	1.00	0.00	1.00	1.00
Natural Gas, Domestic and Imports	24.00	26.50	26.50	26.50	26.50	26.50
Coal (including 1.5 Quads exports)	21.14	18.46	23.28	20.10	19.98	18.13
Coal (million tons per year)	1006	879	1108	957	951	863
Waste Materials	0.10	2.00	0.10	0.10	0.00	2.00
Biomass	0.00	0.00	0.05	0.00	0.05	0.05
Total Energy Resources (including exports)	107.30	96.97	107.28	106.77	107.05	98.14
Total Cost in Billions of Dollars per year	226.83	198.17	224.94	223.74	218.57	197.15
Average Cost in Dollars per Million Btu of Resources Used	2.11	2.05	2.10	2.10	2.05	2.01

Table B–3. Year 1985 Scenario Results—Resources

	0	I	II	III	IV	V
Centralized Air Pollutants						
Carbon Dioxide (CO_2) 10^{11} pounds	40.5	36.2	40.5	41.5	35.7	30.6
Carbon Monoxide (CO) 10^7 pounds	55.1	52.0	55.1	55.6	50.5	42.0
Nitrogen Oxides (NO_x) 10^9 pounds	12.2	11.1	12.2	12.5	10.8	9.3
Sulfur Dioxide (SO_2) 10^9 pounds	18.7	17.4	18.7	19.8	16.5	14.3
Particulates 10^8 pounds	68.5	64.7	68.5	69.2	62.3	52.2
Hydrocarbons (HC) 10^8 pounds	3.6	2.9	3.6	3.4	3.2	2.6
Decentralized Air Pollutants						
CO_2 10^{11} pounds	97.5	80.7	95.7	86.7	91.4	80.6
CO 10^7 pounds	6339.6	5818.9	6223.1	6129.5	6321.2	5573.7
NO_x 10^9 pounds	24.8	21.5	24.2	22.6	23.6	21.5
SO_2 10^9 pounds	16.0	9.6	13.2	11.3	12.5	9.7
Particulates 10^8 pounds	160.7	134.2	157.1	137.3	119.5	133.9
HC 10^8 pounds	133.8	119.8	132.2	129.8	133.3	117.1
Total Air Pollutants						
CO_2 10^{11} pounds	138.0	116.9	136.2	128.2	127.1	111.2
CO 10^7 pounds	6394.7	5870.9	6278.2	6185.1	6371.7	5615.7
NO_x 10^9 pounds	37.0	32.6	36.4	35.1	34.4	30.8
SO_2 10^9 pounds	34.7	27.0	31.9	31.1	29.0	24.0
Particulates 10^8 pounds	229.2	198.9	225.6	206.5	181.8	186.1
HC 10^8 pounds	137.4	122.7	135.8	133.2	136.5	119.7
Water Pollutants (all in 1000 tons)						
Bases	3.9	3.4	3.9	3.3	2.6	3.4
Nitrates	1.8	1.8	1.8	2.2	1.8	2.2
Other Dissolved Solids	552.8	481.7	533.1	521.7	471.9	438.1
Suspended Solids	98.2	86.2	94.2	93.9	88.3	71.8
Nondegradable Organics	26.6	19.5	23.4	23.3	23.5	17.7
Biological Oxygen Demand (BOD)	69.1	57.5	65.1	65.1	62.3	55.3
Aldehydes	192.1	146.0	170.2	170.9	168.8	131.1
Radioactive Effluents						
Solids, 1000 ft^3	13.1	13.1	13.1	15.9	13.1	15.9
Krypton-85, 10^6 curies	36.1	36.1	36.1	44.0	36.1	44.0
Tritium, 10^5 curies	22.2	22.2	22.2	27.1	22.2	27.1
Population Exposure, 1000 man-rem	64.3	64.3	64.3	78.2	64.3	78.2
Heat Dissipated						
Central Sources (Quads)	36.5	33.6	36.5	39.9	36.1	34.1
Decentralized "	69.9	61.1	69.9	65.5	69.3	62.0
Total "	106.4	94.7	106.4	105.4	105.4	96.1
Solid waste, million tons	2569.7	1961.9	2368.0	2304.9	2297.2	1831.1
Land use, million acres	17.2	15.4	17.1	17.5	16.7	15.3
Occupational Health & Safety						
Deaths	209.0	180.0	223.0	199.0	196.0	176.0
Injuries (1000s)	11.2	9.6	11.8	10.7	10.5	9.3
Man-Days Lost (1000s)	540.6	461.0	567.7	511.6	504.7	446.9

Table B–4. Year 1985 Scenario Results—Environmental Effects

	Resources Consumed, Quads (10^{15}Btu)					
	0	I	II	III	IV	V
Hydroelectric (at 34% efficiency)	3.65	3.65	3.65	3.65	3.65	3.65
Geothermal	1.40	2.40	1.40	6.60	14.93	6.60
Solar	0.00	3.50	0.00	6.59	9.59	4.82
Fusion	0.00	0.00	0.00	0.05	0.05	0.05
Light Water Reactor (LWR)	36.59	16.50	36.59	36.59	10.97	16.50
Liquid Metal Fast Breeder (LMFBR)	0.00	0.00	0.00	3.90	0.00	3.90
High Temperature Gas Reactor (HTGR)	3.90	3.90	3.90	3.90	0.40	3.90
Oil Steam Electric	4.07	2.18	3.77	4.08	2.44	1.88
Gas Steam Electric	2.00	0.00	2.00	2.00	2.00	0.00
Oil, Domestic and Imports	70.54	40.32	37.71	46.47	46.30	19.77
Oil Imports	58.34	20.62	18.01	26.77	20.55	(4.11)
Oil Shale	0.00	0.00	8.00	0.00	8.00	8.00
Natural Gas, Domestic and Imports	15.40	22.80	22.80	22.80	22.80	22.80
Coal (including 1.5 Quads exports)	33.89	22.91	49.77	30.51	45.87	39.11
Coal (million tons per year)	1614	1091	2370	1453	2184	1862
Waste Materials	0.10	6.50	0.10	0.10	0.00	6.50
Biomass	0.00	0.00	1.50	0.00	1.50	1.50
Total Energy Resources (including exports)	165.47	122.48	165.42	161.16	158.01	137.03
Total Cost in Billions of Dollars per year	498.94	325.64	460.52	469.54	396.96	328.74
Average Cost in Dollars per Million Btu of Resources Used	3.02	2.74	2.78	2.98	2.57	2.46

Table B–5. Year 2000 Scenario Results—Resources

	0	I	II	III	IV	V
Centralized Air Pollutants						
Carbon Dioxide (CO_2) 10^{11} pounds	42.5	26.0	41.0	43.5	34.9	23.7
Carbon Monoxide (CO) 10^7 pounds	62.9	43.0	61.2	65.2	53.2	38.9
Nitrogen Oxides (NO_x) 10^9 pounds	13.0	8.2	12.6	13.3	10.8	7.5
Sulfur Dioxide (SO_2) 10^9 pounds	20.9	13.6	20.1	21.4	17.1	12.4
Particulates 10^8 pounds	76.6	51.3	74.3	78.8	65.1	46.9
Hydrocarbons (HC) 10^8 pounds	3.1	1.5	3.1	3.2	2.6	1.4
Decentralized Air Pollutants						
CO_2 10^{11} pounds	136.4	100.7	134.4	86.8	138.4	106.7
CO 10^7 pounds	9651.3	7677.7	9608.5	8875.6	9603.8	5438.7
NO_x 10^9 pounds	41.8	32.4	37.7	33.1	38.3	13.1
SO_2 10^9 pounds	30.7	16.0	17.5	13.6	20.0	13.3
Particulates 10^8 pounds	301.5	236.8	202.5	181.2	179.3	203.8
HC 10^8 pounds	201.7	163.7	171.8	185.1	173.1	75.2
Total Air Pollutants						
CO_2 10^{11} pounds	178.9	126.7	175.4	130.3	173.3	130.4
CO 10^7 pounds	9714.2	7720.7	9669.7	8940.8	9657.0	5477.6
NO_x 10^9 pounds	54.8	40.6	50.3	46.4	49.1	20.6
SO_2 10^9 pounds	51.6	29.6	37.6	35.0	37.1	25.7
Particulates 10^8 pounds	378.1	288.1	276.8	360.0	244.4	250.7
HC 10^8 pounds	204.8	165.2	174.9	188.3	175.7	76.6

Table B–6. Year 2000 Scenario Results—Environmental Effects

	0	I	II	III	IV	V
Water Pollutants (all in 1000 tons)						
Bases	9.2	7.4	6.5	5.8	5.2	6.7
Nitrates	6.9	3.5	7.0	7.6	1.9	4.1
Other Dissolved Solids	1005.5	705.2	796.3	889.1	611.8	525.3
Suspended Solids	139.7	100.2	113.2	139.6	104.7	58.2
Nondegradable Organics	39.8	22.8	21.3	26.3	22.7	8.9
Biological Oxygen Demand (BOD)	94.6	58.2	71.9	78.0	65.8	41.1
Aldehydes	281.0	159.6	154.4	188.3	162.6	64.0
Radioactive Effluents						
Solids, 1000 ft^3	51.5	26.8	52.3	57.1	14.3	31.6
Krypton—85, 10^6 curies	135.2	65.9	137.5	142.9	39.1	71.2
Tritium, 10^5 curies	82.2	39.5	83.6	97.8	24.0	53.7
Population Exposule, 1000 man-rem	250.1	128.0	250.1	277.9	69.3	155.8
Heat Dissipated						
Central Sources (Quads)	71.9	43.6	71.9	85.3	50.0	45.9
Decentralized "	93.3	71.3	93.2	68.2	97.0	77.9
Total "	165.2	114.9	165.1	153.5	147.0	123.8
Solid Waste, million tons	4001.8	2392.6	2972.4	2887.7	2974.0	1702.4
Land Use, million acres	27.5	18.0	26.7	28.9	21.7	18.0
Occupational Health & Safety						
Deaths	361.0	239.0	480.0	322.0	435.0	364.0
Injuries (1000s)	18.7	12.4	23.5	16.5	21.5	17.5
Man-Days Lost (1000s)	920.6	608.1	1169.8	808.0	1072.6	875.2

Table B–6. Year 2000 Scenario Results—Environmental Effects—Continued

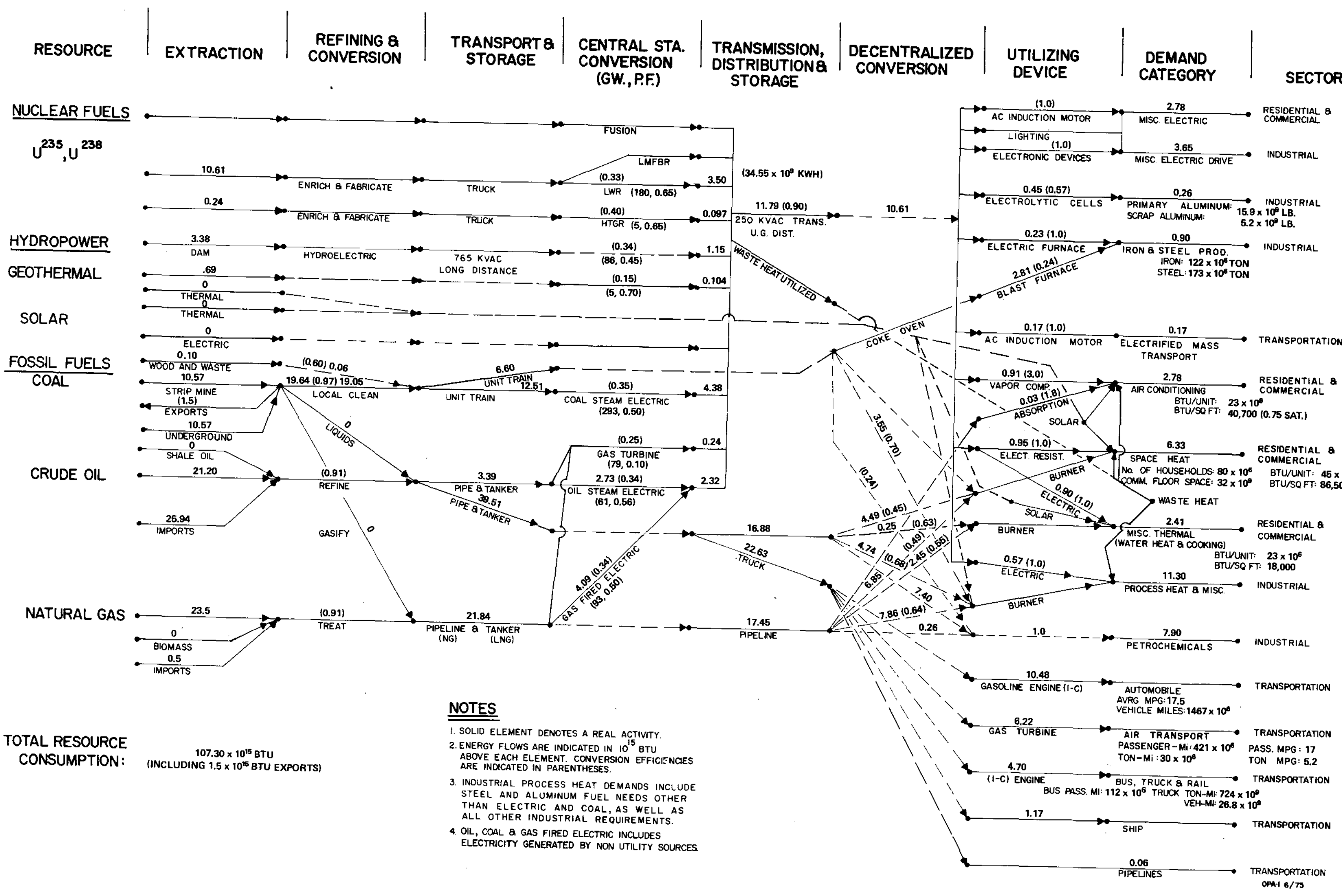

Figure B–1. Scenario O No New Initiatives, Year 1985

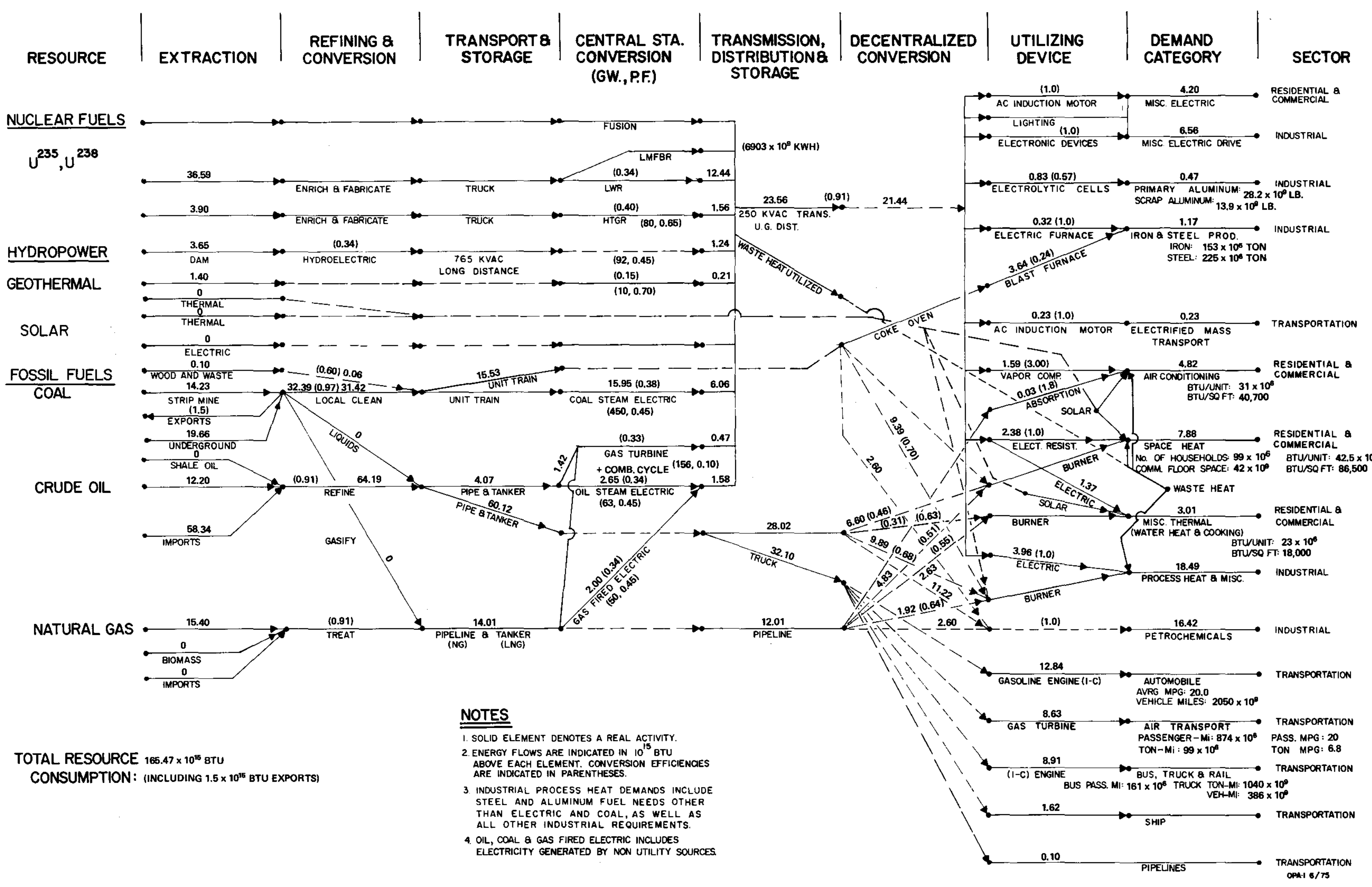

Figure B–2. Scenario O No New Initiatives, Year 2000

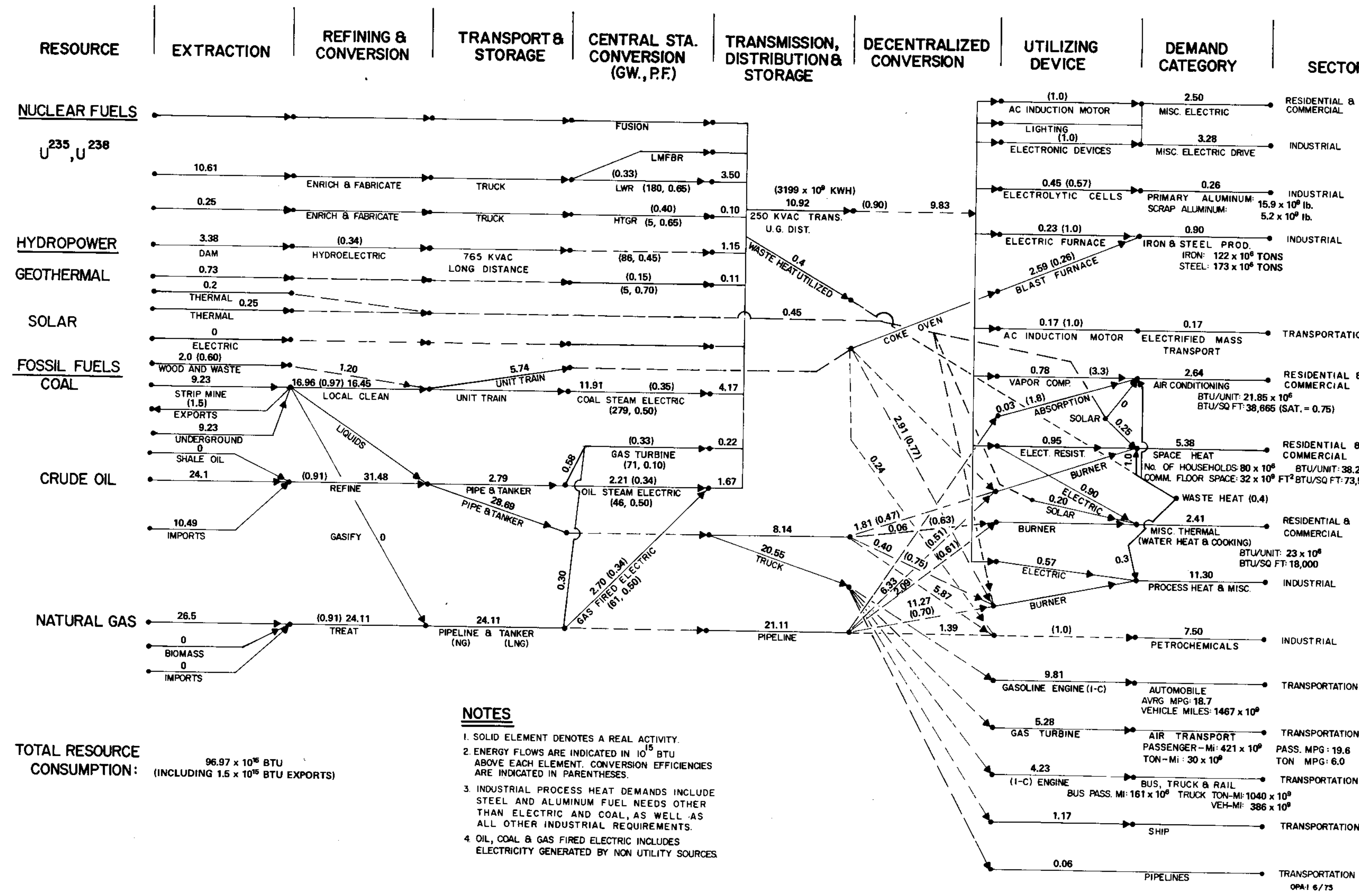

Figure B–3. Improved Efficiencies in End Use, Year 1985

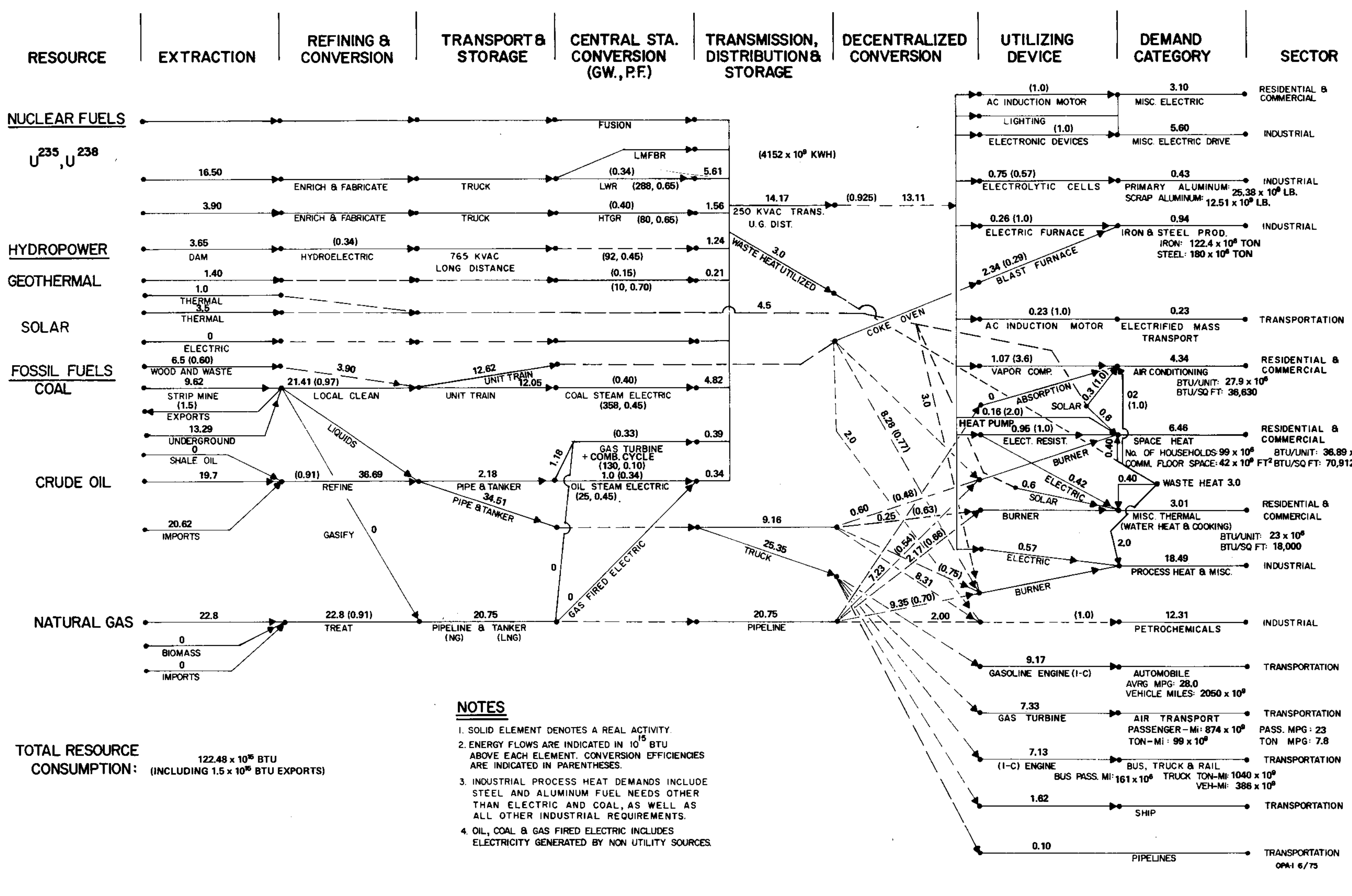

Figure B–4. Scenario I Improved Efficiencies in End Use, Year 2000

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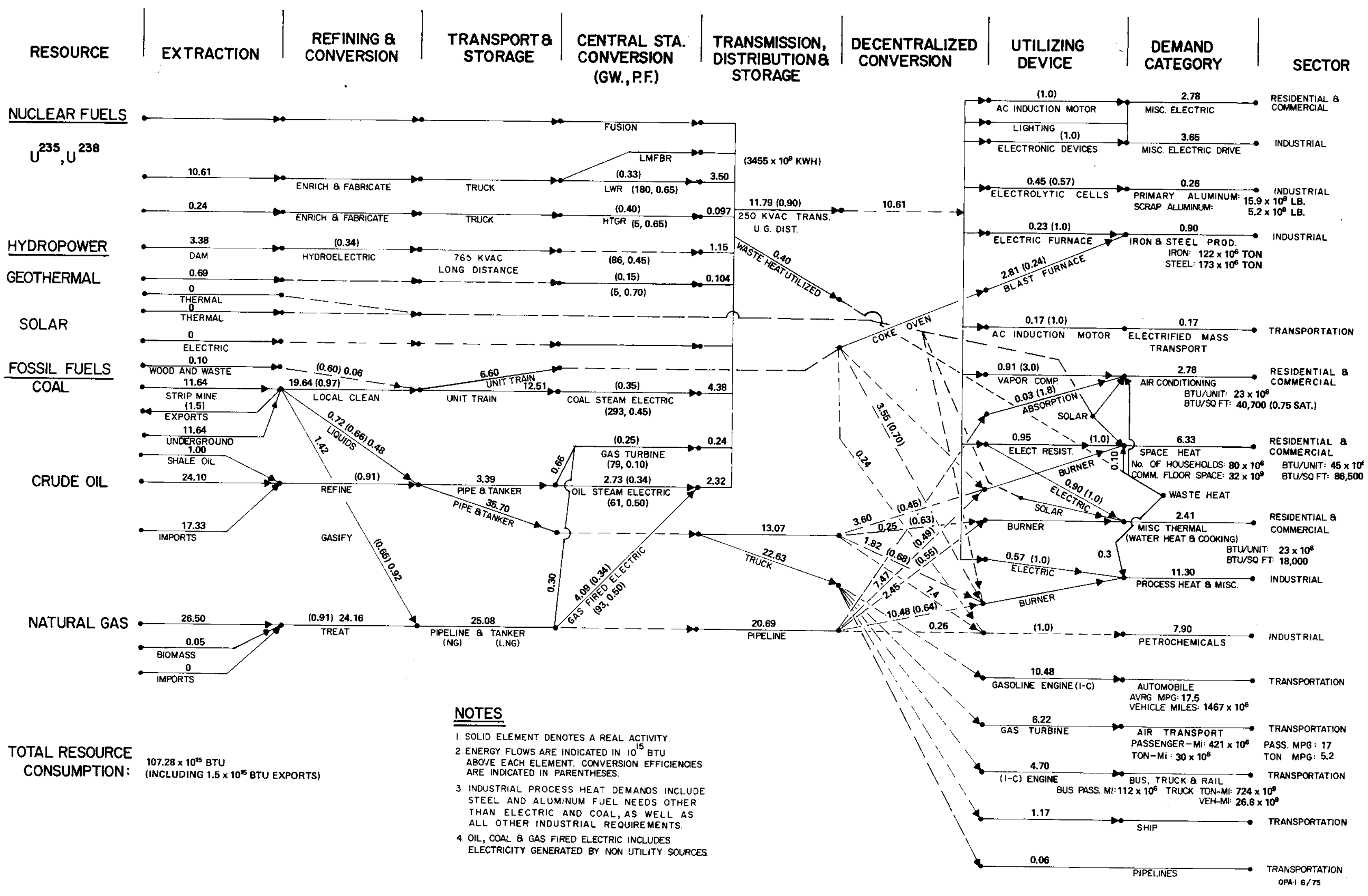

Figure B–5. Scenario II Synthetics From Coal and Shale, Year 1985

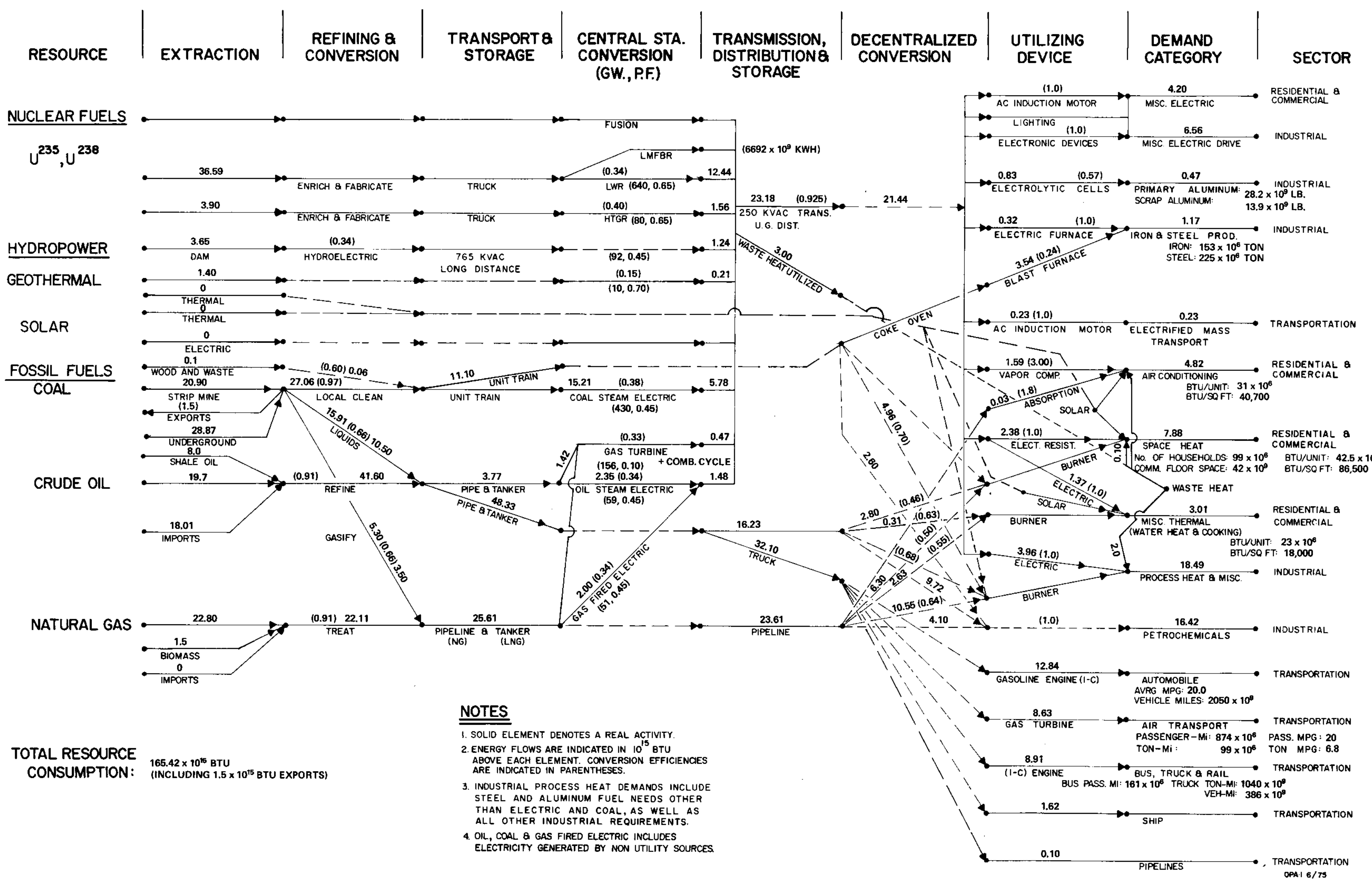

Figure B–6. Scenario II Synthetics From Coal and Shale, Year 2000

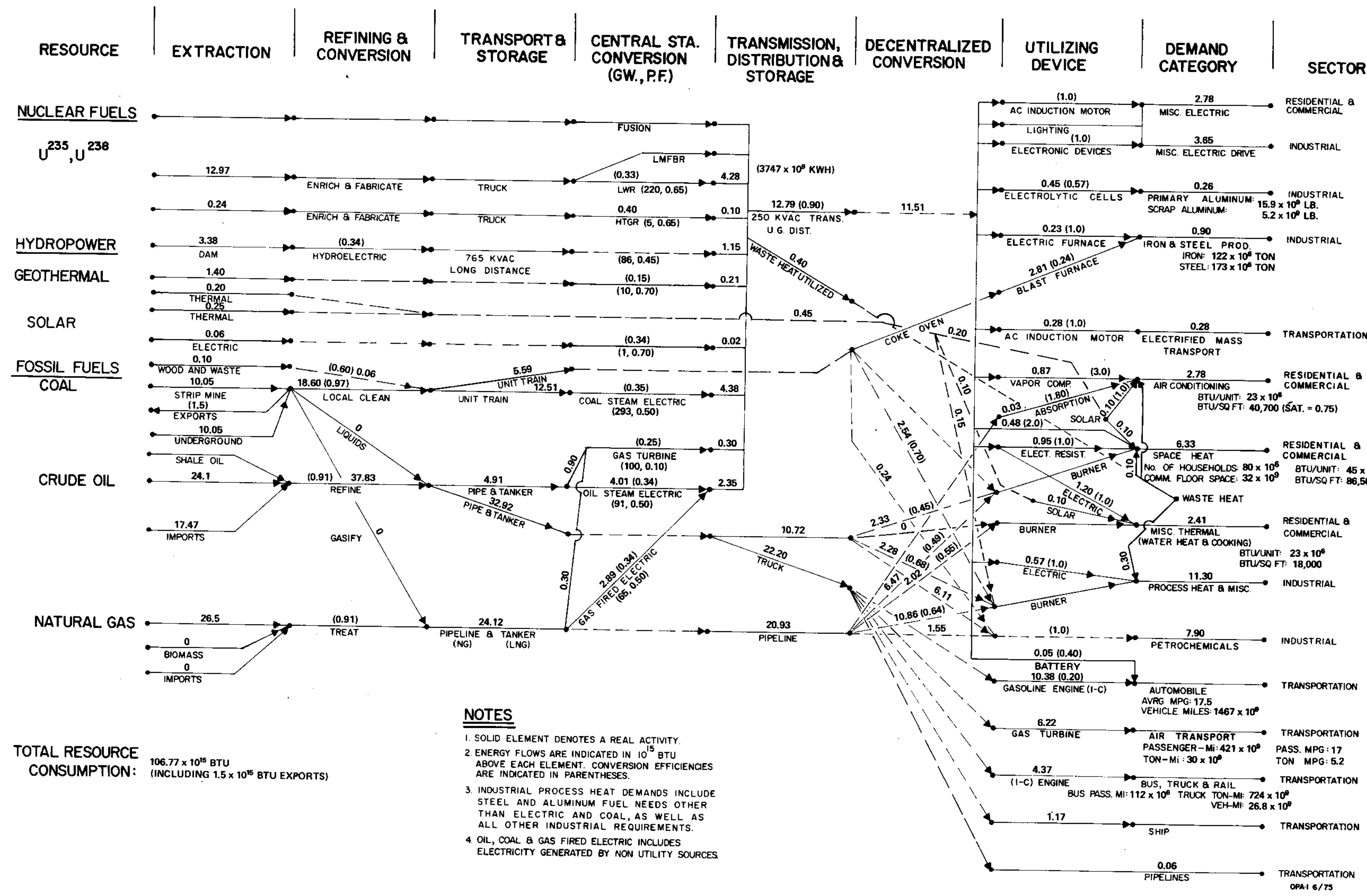

Figure B-7. Scenario III Intensive Electrification, Year 1985

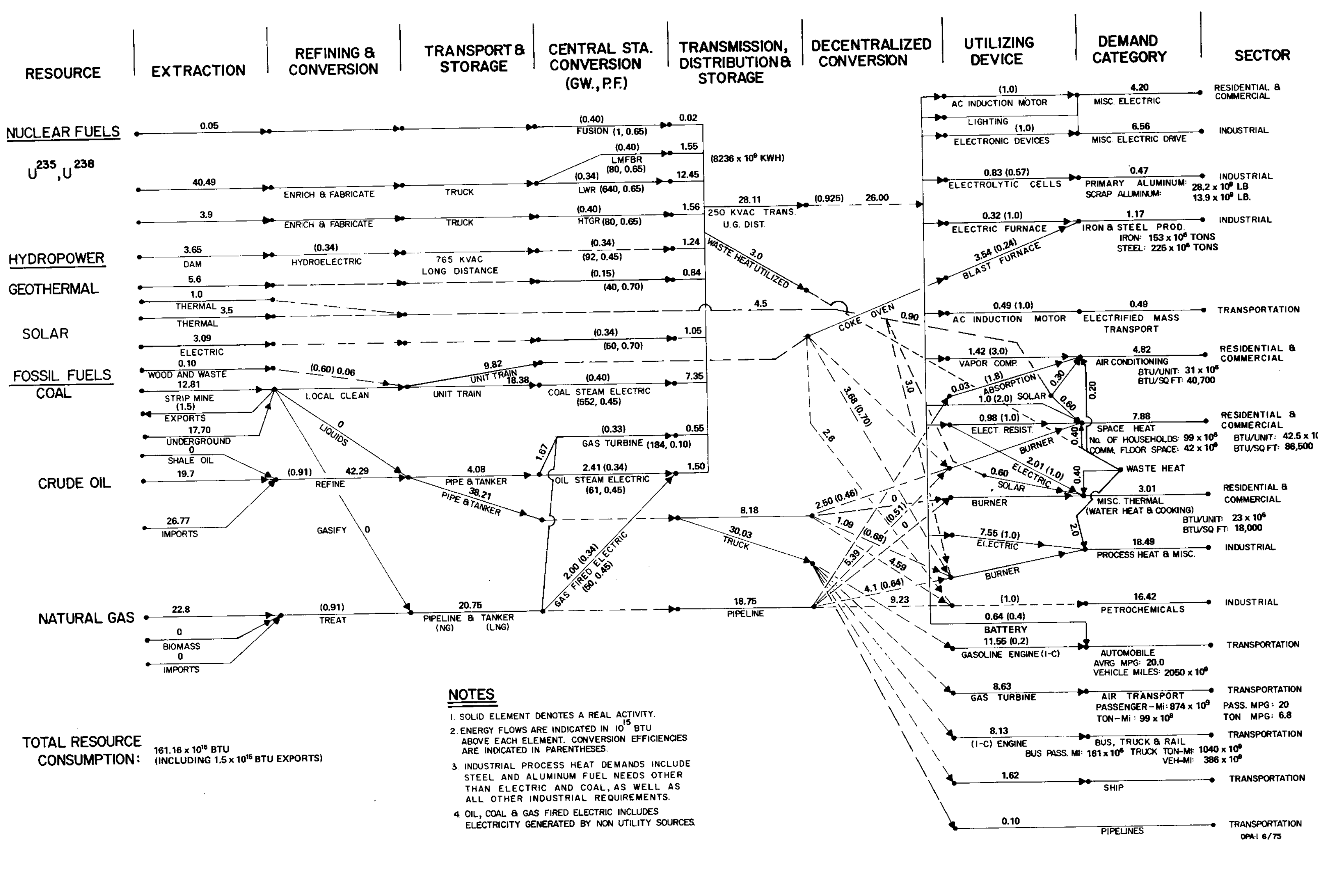

Figure B-8. Scenario III Intensive Electrification, Year 2000

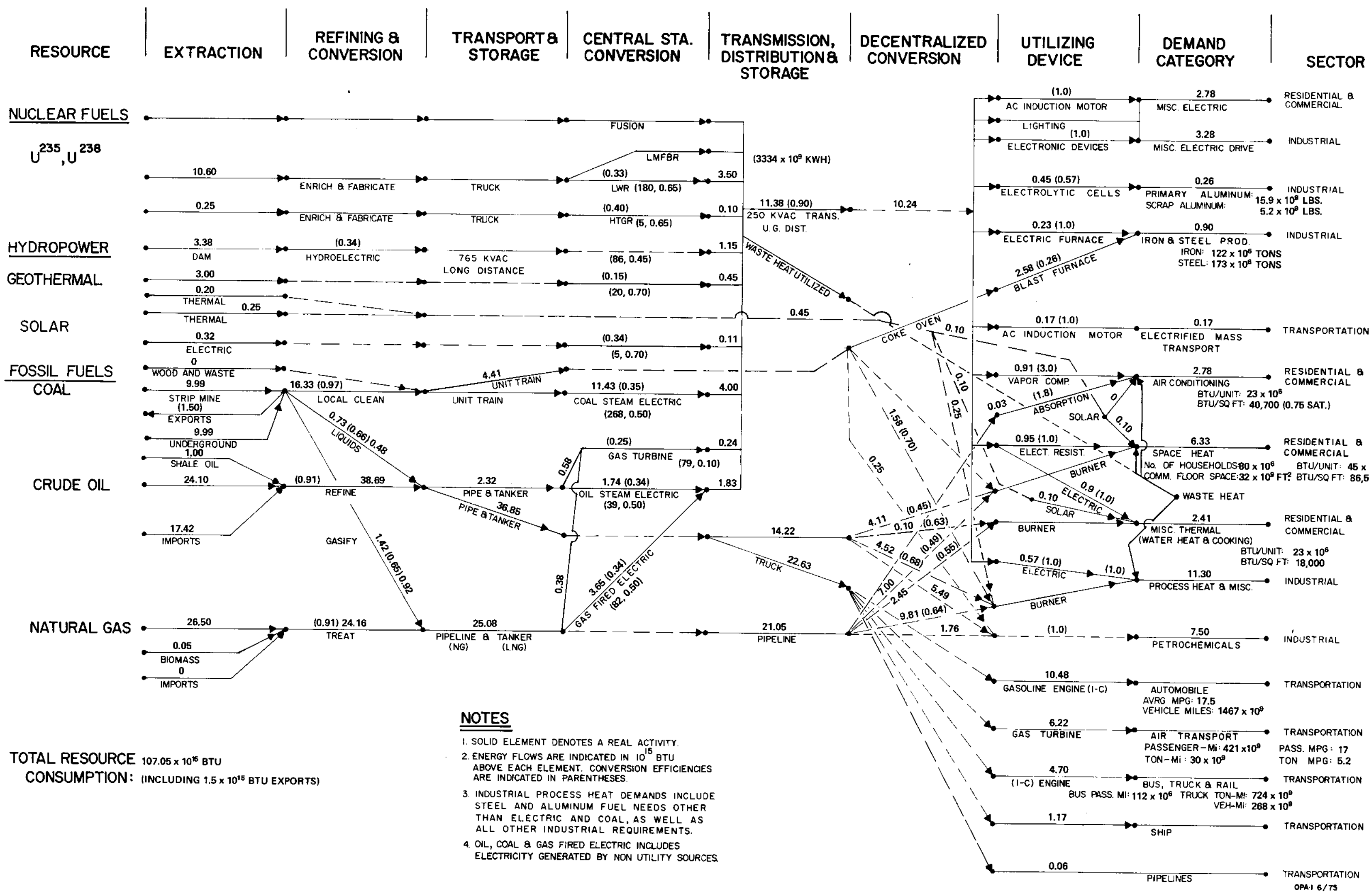

Figure B—9. Scenario IV Limited Nuclear Power, Year 1985

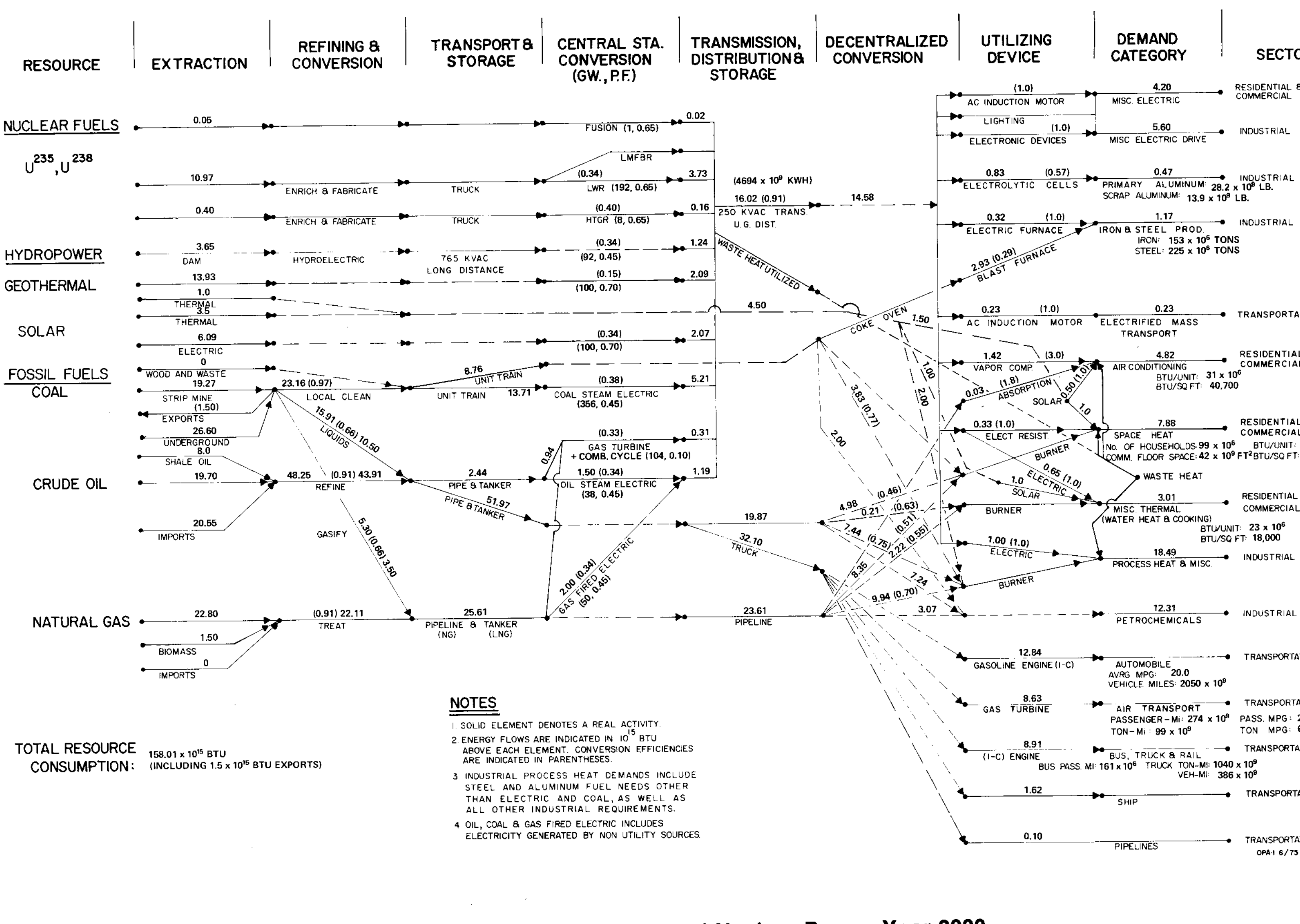

Figure B—10. Scenario IV Limited Nuclear Power, Year 2000

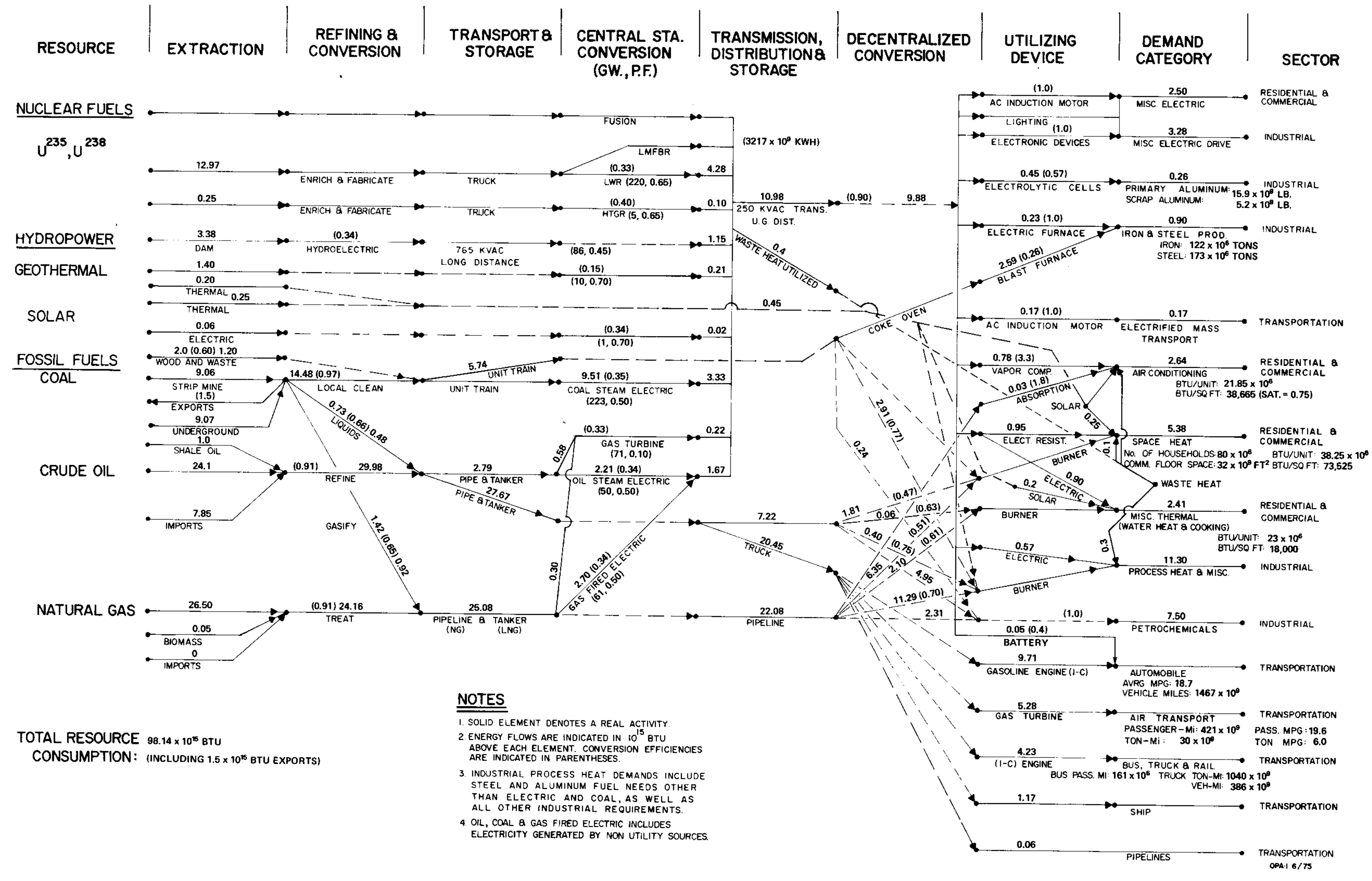

Figure B–11. Scenario V Combination of all Technologies, Year 1985

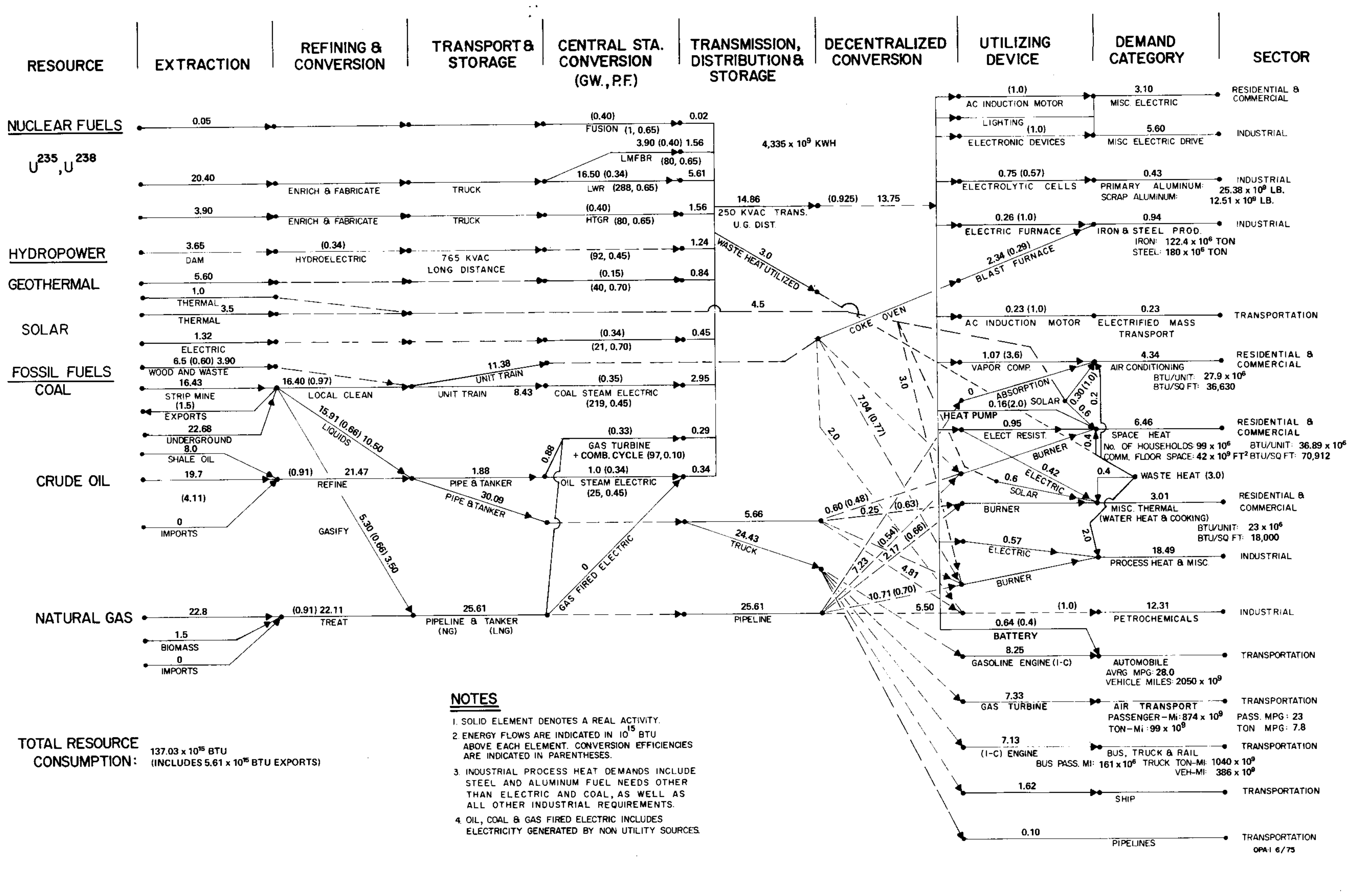

Figure B–12. Combination of all Technologies, Year 2000

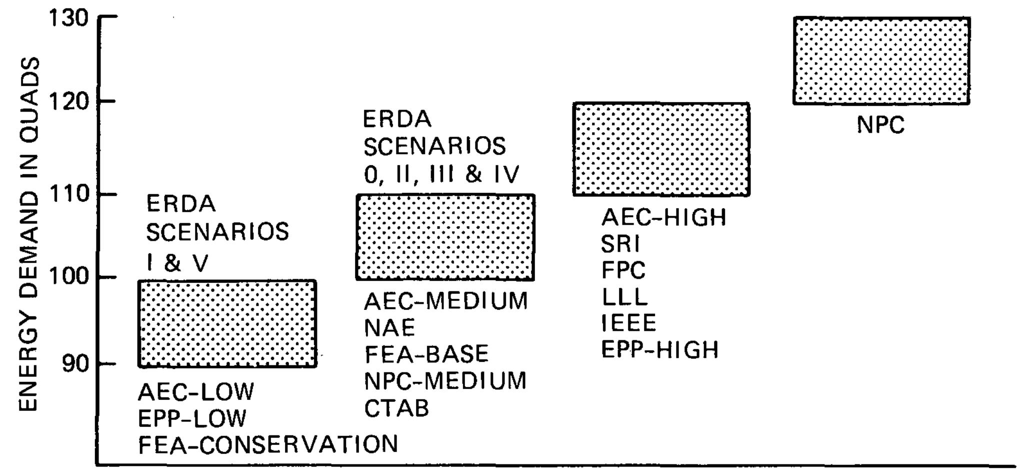

Figure B–13. Estimated U.S. Total Energy Demand, Year 1985

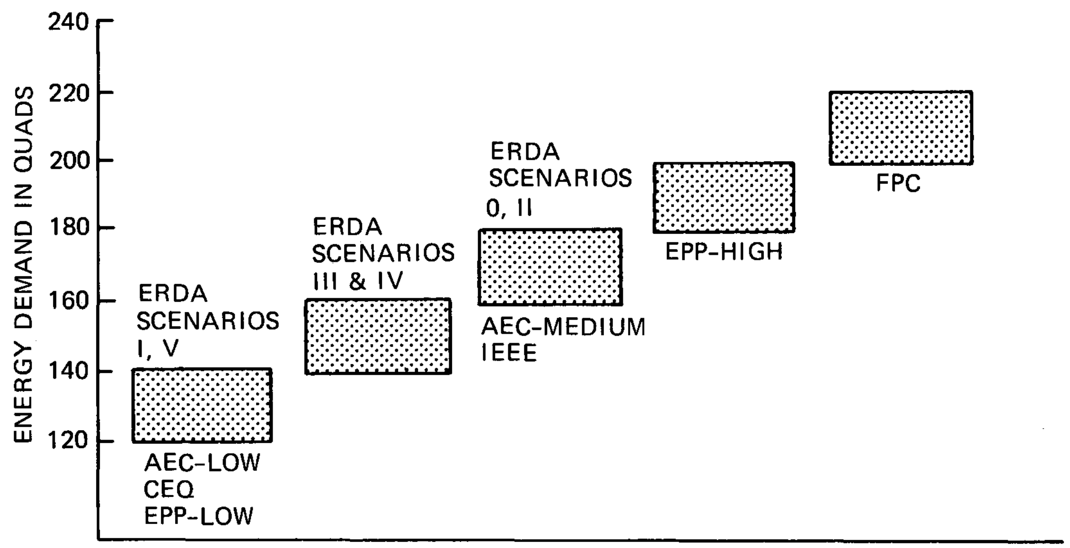

Figure B–14. Estimated U.S. Energy Demand, Year 2000

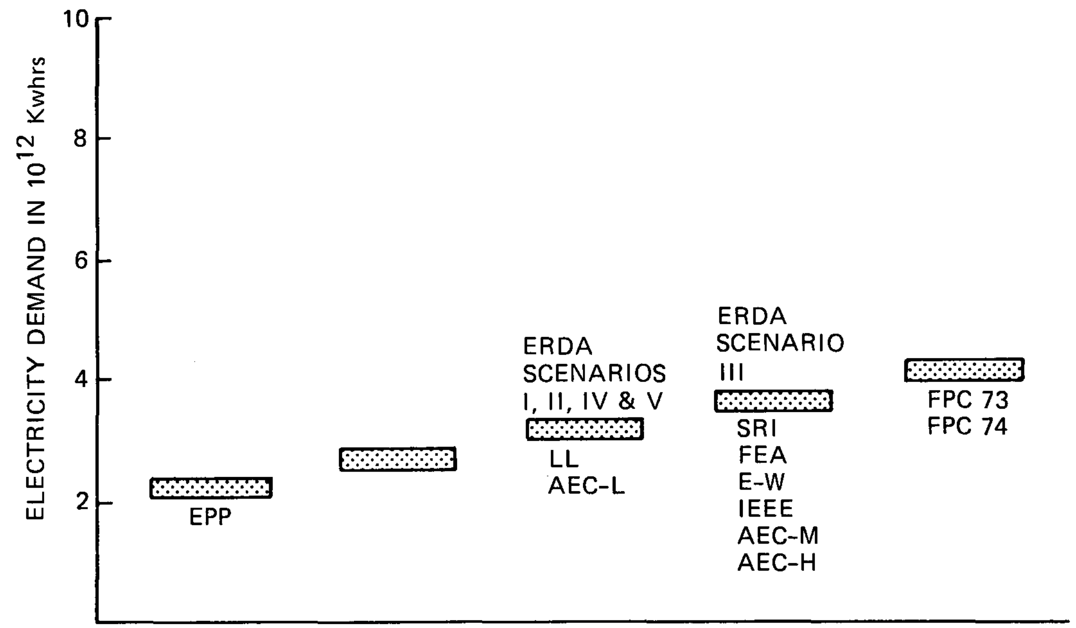

Figure B–15. Estimated U.S. Electricity Demand, Year 1985

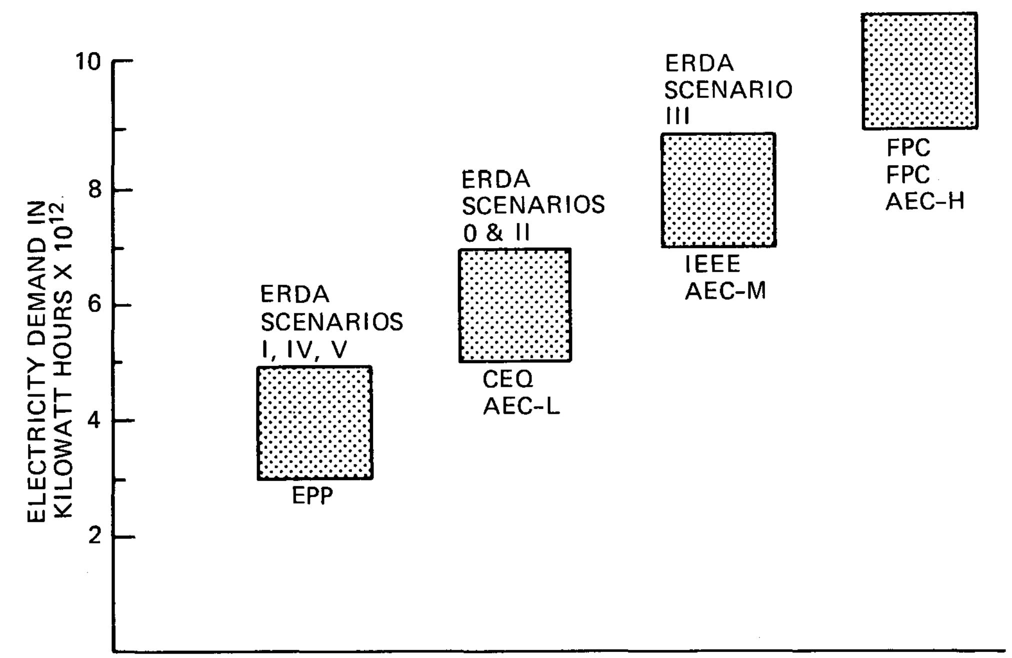

Figure B–16. Estimated U.S. Electricity Demand, Year 2000

Appendix C—Survey of Energy Activities Outside ERDA

Energy R,D&D activities are conducted by private industry, by various U.S. government agencies, and in foreign countries. Each of these sectors of activity will be discussed in the sections which follow.

Energy R,D&D in Industry

Energy R,D&D within industry tends to be concentrated in those technological areas where the economic payoffs appear the highest in the short term (three to ten years).

Historically, industry emphasis (as measured by estimated dollar expenditures) has been on petroleum and natural gas and on electrical generation, with the former accounting for the largest percentage. Currently industry emphasis continues highest in these two areas although electrical generation has replaced petroleum and natural gas in expenditures.

These two technology areas have certain common attributes:

- They are consumer-preferred energy forms
- There are established industrial infrastructures to support commercial production facilities.

Thus, the market potential and delivery system that exist have not presented great risks to the private sector. Rather, economic payoffs have generally been visible, timely and relatively assured. However, in cases involving major technology change within these sectors, e.g., the shift to nuclear power, favorable market conditions and supporting infrastructure have not generally been available in initial stages, and significant private industry losses or deferral of return on investment has occurred.

In terms of the real buying power of the dollar, industry expenditures for energy R,D&D were about the same in 1963 as in 1973. Thus, relative to the Nation's output of goods and services (as measured by the gross national product), these energy expenditures have not kept pace with other sectors of the economy. Amounts invested in coal, geothermal, solar and other energy forms, however, did increase from insignificant amounts in 1963 to more sizeable amounts a decade later. Table C–1 summarizes the data on industrial energy R,D&D.

In 1973, comparable data for total (energy and non-energy) industrial R,D&D indicates almost $21 billion of expenditures. Energy (almost $900 million) accounted for four percent of this amount. In 1974, energy R,D&D expenditures rose to almost $1.1 billions.

Although not shown in Table C–1, two industry groups (both from the manufacturing sector) dominated energy R,D&D expenditures. The petroleum refining and extraction industry accounted for 37 percent of the almost $900 million spent in 1973. About one-half of this industry's energy expenditures is estimated to be spent on development, about 45 percent on applied research and the remaining 5 percent on basic research. The next highest expenditure was made by the electrical equipment and communication industry which accounted for another 28 percent. The remaining 35 percent was split among all other industries. Company funds (accounting for 70 percent of total expenditures) appear to dominate in all energy resource areas, with the exception of nuclear energy (shown in "Electricity") which is heavily funded by Federal monies.

Also not shown in the table is the extent to which industry associations contribute to the national energy R,D&D effort. This is particularly true in the electric sector, where expenditures on electrical energy are exemplified by the activities of the Electric Power Research Institute (EPRI). Funded by the Nation's electric utilities, EPRI's 1975 expenditures are estimated at $133 million. Conservation programs appear to account for the major portion (about 40 percent) with derived fuels and environmental control technology efforts next in order of emphasis (at about 10 percent each).

Another example of industry effort is the Institute of Gas Technology (IGT) with a 1975 budget of $23 million. Partially funded by Government and partially by private money, the Institute has a $15 million effort aimed at coal gasification. This effort is jointly funded by ERDA and the American Gas Association (AGA). AGA has a 1975 research program amounting to over $21 million including support to IGT.

	1963			1973			
Energy Sources	**In 1963 Dollars**	**In 1973 Dollars**	**Percent of Total**	**Percent of Total**	**Total**	**Federal Funds**	**Company Funds**
Oil and Gas	$336	$483	(55%)	(35%)	$303	$ 7	$296
Coal	11	16	(2)	(7)	66	5	61
Other Fossil	not indicated	not indicated	—	(6)	53	0	53
Electricity	267	384	(43)	(45)	392	263	129
Geothermal, solar and all other	<1	1	(<1)	(7)	61	10	51
Total	$614	$884	(100%)	(100%)	$875	$285	$590

SOURCES: **Energy R&D and National Progress,** prepared by the Interdepartmental Energy Study under the chairmanship of the Director of the Office of Science and Technology, 1964.
Science Resources' Studies Highlights, National Science Foundation, NSF 74-319, December 4, 1974.

NOTES: 1. The yearly data are not strictly comparable because of differences in sources, definitions and data aggregation into the energy source grouping.
2. 1963 data are order-of-magnitude estimates and may include research or other commodities. The Implicit Price Deflator was used to put 1963 expenditures into 1973 dollars. "Electricity" includes nuclear fission and fusion plus generation and distribution R&D expenditures plus other electrical related projects.
3. 1973 data have been grouped using the NSF source material. "Electricity" includes nuclear fission and fusion expenditures only. Some portion of "Other Fossil" and/or "All Other" should probably be included in "Electricity". The funds are for operating expenses incurred by a company in conduct of R&D in its own facilities. Federal funds are receipts for work performed. Company funds are for internal company-sponsored R&D. Some arbitrary assignments of funding source have been made in the grouping. "Other Fossil" includes $11 million in shale and $42 million in unidentified energy sources.

Table C–1. Estimated Industrial Expenditures for Energy R,D&D—1963 and 1973
Expenditures in millions of dollars

While the available data summarized here provide some interesting insights, substantially greater efforts are necessary to understand and categorize industry R,D&D efforts in energy in view of the importance of the technological approach to the energy problem as established in this National Plan.

Energy R,D&D in Other Government Agencies

As the agency recently charged with the primary responsibility for the Federal energy R,D&D effort, ERDA will sponsor research in its own facilities and in contractor facilities and will also be responsible for coordinating Federal programs. In this regard other Government agencies continue to provide a significant contribution to the overall Federal effort, as shown in Table C-2.

Also, the Department of Defense has an industrial energy R,D&D budget of $300 million with activities in more than an dozen technological areas. Primary emphasis is on basic research and conservation in transportation.

In addition to the examples above, nine other agencies reported detailed plans in response to the survey undertaken by ERDA. These agencies have energy R,D&D budgets which range from $1 million to $36 million. Some indicate highly concentrated efforts in specific programs areas (e.g., Department of Transportation/conservation in transportation and General Services Administration/conservation in buildings) while other agencies have programs which are more dispersed (e.g., National Aeronautics and Space Administration/solar electric, conservation, advanced electric generation, and other high technology areas).

Agency	**Indicated FY 76 Energy, R,D&D Budget (millions)**	**Major Thrusts**
Department of the Interior	$160	Oil and gas recovery, resource assessment and mining and extractive technology
National Science Foundation	$155	Basic research
Environmental Protection Agency	$140	Alleviation of environmental damage to energy systems and measurement and monitoring of health effects and pollutants
Nuclear Regulatory Commission	$90	Confirmatory nuclear safety R,D&D and studies on safeguards, safety systems and siting guides.

* A survey of current energy R,D&D in other Government agencies was conducted early in the study. The survey was initiated by letter dated March 13, 1975, from the Administrator of ERDA. The heads of twenty Federal agencies were asked for material to incorporate into the ERDA National Energy Plan. The call requested information on each agency's program activities and objectives. the strategy and rationale for chosen program approaches, and the specifics of programs used to implement the strategy. Survey results (shown in Table C-2) were used as a basis for indicating general agency interest. The nature of the budget data, difference in interpretations of requirements and definitions, etc., preclude exacting reliance on the statistical data.

Table C–2. Selected Examples of Other Agency Energy R,D&D Efforts*

Other agencies are also making unique contributions to the Federal energy R,D&D effort:

- Housing and Urban Development, in designing thermal standards for buildings and promoting building conservation via the Modular Integrated Utility Systems (MIUS) program
- Federal Energy Administration efforts in systems analysis and energy conservation

- Department of Agriculture in conservation, with projects aimed at understanding energy consumption on the farm, developing improved tillage systems, processing food through new techniques, and using technology to develop more efficient utilization of nitrogen fertilizers
- Department of Commerce, in conservation of energy in buildings, in transportation and in industry.

Again, a substantial effort to resolve definitional questions, improve the quality of the data, and assure effective intergovernmental coordination appears appropriate.

Energy R,D&D in Other Countries

Energy R,D&D in foreign countries tends to be aimed at alleviating near-term energy problems. The primary program emphasis is directed at electrical generation with nuclear power. Research associated with oil and gas exploration and recovery and fuel conversion technology is also receiving attention.

The foreign effort is concentrated in six countries each with energy R,D&D budgets of over $100 million. These programs are shown in Table C-3.

Foreign nations are, of course, experiencing the same energy problems and challenges as this country's and will be conducting many energy R,D&D programs comparable to those in the United States. Thus, the potential exists for international cooperation and the avoidance of unnecessary duplication. Several examples of bilateral programs now underway are the US/USSR Joint Fusion Power Coordinating Committee and cooperative efforts to develop magnetohydrodynamics systems for thermal conversion, the US/Japanese program on geothermal and solar applications, the US/French Science and Technology Agreement for solar applications, and the Science and Technology Agreement with New Zealand which covers geothermal activities.

Country	**Estimated Current Budget**	**Major Thrust**
France	$700 million	Sixty percent of budget devoted to current and future nuclear technology. Also coal mining technology and oil and gas exploration, storage and transport.
West Germany	$450 million	Sixty-five percent devoted to nuclear and twenty-five percent to coal extraction and utilization.
United Kingdom	$350 million	Sixty percent devoted to nuclear power.
Canada	$220 million	Fifty percent devoted to derived fuels mainly in situ conversion of coal and tar sands. Thirty percent devoted to nuclear technology.
Japan	$200 million	Eighty percent devoted to the nuclear option.
USSR	Unknown	All aspects of technology believed receiving emphasis in a broadly based program.

Table C–3. Major Energy R,D&D in Other Nations

The primary focus for U.S. multilateral cooperation is the International Energy Agency (IEA). Through the IEA an extensive program of cooperation is under way in nine technical areas such as: coal technology; radioactive waste management; and hydrogen. Cooperative programs in nuclear energy have been conducted for several years with Euratom and the International Atomic Energy Agency.

U. S. GOVERNMENT PRINTING OFFICE : 1975 O - 579-905

FOR IMMEDIATE RELEASE JUNE 30, 1975

OFFICE OF THE WHITE HOUSE PRESS SECRETARY

THE WHITE HOUSE

PRESS CONFERENCE
OF
FRANK ZARB
ADMINISTRATOR OF THE
FEDERAL ENERGY ADMINISTRATION
ROBERT SEAMANS
ADMINISTRATOR OF THE
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
AND
ROBERT FRI
DEPUTY ADMINISTRATOR OF THE
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

THE BRIEFING ROOM

10:33 A.M. EDT

MR. GREENER: The Energy Research and Development Administration is today transmitting to Congress, as required by law, a comprehensive plan for energy research, development and demonstration dealing with the Nation's near-term, mid-term and long-term energy needs.

I believe all of you have an ERDA press kit which contains Volume I of the report which lays out the energy plan. Volume II, which is a more detailed analysis of the energy programs themselves, will be forwarded to Congress in a few weeks.

Here today to review the highlights of the report with you and to answer your questions are Frank Zarb, the Administrator of the Federal Energy Administration; Dr. Robert Seamans, the Administrator of the Energy Research and Development Administration; and Bob Fri, the Deputy Administrator of ERDA.

Frank?

MR. ZARB: Last fall, when ERDA was in the process of being legislated into being, the President reviewed -- in looking at a total energy program -- really three dimensions. He looked at the near-term conservation necessities, he looked at the general mid-term bringing on of additional resources, or that which we could do within sight, and then examined the overall research, development and demonstration program that we had within Government.

MORE

His analysis led to the conslusion that we were dispursed throughout Government, and the enactment of ERDA was essential. As you know, he supported that, and Congress did enact it. It became effective January 1.

At that time, the President directed the Energy Resources Council and the Administrator of ERDA, particularly, to develop a revised and comprehensive energy research, development and demonstration program taking from AEC, from the various elements of EPA, the Department of Interior and so on, all of the various principles and coming back with a recommendation for a balanced program.

Bob Seamans and his staff have completed that, the first cut, within the six months allotted to them. The Congress' simultaneous enactment of ERDA asked for a six month-report. Dr. Seamans has briefed the President right along.

He did last week, and this morning presented him with Volume I of a balanced energy research and development program. Dr. Seamans will go over it with you this morning. I gather he has had some backgrounders during the course of last week, and he will make available other technical people for subsequent background during the course of today on some of the more technical elements.

Bob?

MR. SEAMANS: Thank you, Frank.

This will just be a brief summary of what is in the report using charts that we used to brief the President. Some of the charts are in the report itself. This shows you what the problem is.

We have been increasing our use of oil and gas so that now it is up to around 75 percent of the total energy that we use. You can see right about in here, in 1970, our domestic supply started going down. This is our domestic production.

The question is, what is going to happen in the future. We know there is going to be increasing demands at the very same time that our domestic supplies, which are limited, will be going down.

There will be some increase, of course, as we come in from the Alaskan north slope, and there can be some additional increase through advanced technology, giving us better techniques for recovery from our existing fields.

MORE

The same problem with gas. Take a look at what the alternatives are. On this chart, you see -- depending on the size of the square -- the amount of energy that either we are using or that is available.

This square here is the amount that we are using annually. This is shown in quads. It happens to be 73, but divide by two to get millions of barrels a day so it comes out to 36 and one-half million barrels a day.

Here, using the same scale, is the amount of gas and oil that we have available. The little cross-hatched area shows what we might develop with these new recovery methods. From oil shale, we can get more energy than we can from either the oil or the gas, if we really learn how to retort it properly. Again, it is a technical problem.

With coal, we have ten times as much again that is available, maybe even more than that, if we learn how to get the energy out without actually hauling the coal to the surface so we can mine thin seams and things of that sort.

Our present type of light water reactors have tremendous amounts of energy compared to petroleum, about two and one-half times as much remaining. And we certainly ought to avail ourselves of that possibility. If we go to the breeder, which means using a great deal more of the uranium ore than we currently use with our light water systems, why, we can go to just a tremendous resource that could take this country 300 or 400 or 500 years into the future.

MORE

You say what are the alternatives to the breeder. The answer is solar, just a tremendous amount of energy falling on the United States each year. But there are some tricks in gathering in that energy and converting it to electricity. Again, we get into the technology and ultimately there is fusion and there are a variety of ways of extracting the energy in the fusion process, and we are working on several.

Either of these two, essentially, give you limitless supply. The breeder takes you, as I say, for hundreds of years.

Now you get into the question of time. We don't have much time. You notice from the first chart that our present domestic supply of oil and gas is going to run out in 35 years or so.

If you look at this chart you can see that back in the 1850s, we were using essentially nothing but wood. Sixty years later we were using essentially coal as 80 percent of our energy.

Now here we were with our oil and gas up around 75 to 80 percent. But we have not got 60 years to convert to something else. As a matter of fact, I don't think we should convert to just one other possibility. I think in the future we should have a number of options and that is the part of the theme of this report.

Now, I won't take you through this in detail, but this is part of a detailed analytical study we carried out. We looked ahead the next 25 years and we projected how many passenger miles would be needed each year and how much floor space and how much you would have to heat and cool and all the rest of it.

If we take no new initiatives we are going to have to import increasing amounts of oil and gas and these amounts will be clearly not satisfactory. If we decide we want to conserve, which we certainly must do, but do nothing else, we find we help ourselves out the first 10 years but then again we start running out of resources.

We can do things like come in with synthetic fuels or electrify and we find that when we do that we use too much coal. We could not mine all the coal that would be required. We also find we have energy in the wrong form.

MORE

We can't drive cars today with anything but gasoline or diesel fuel. We can't drive with electricity.

Some time in the future we believe we may very well have electric cars and that is something we are working on. But to bring the imports down, we find we must have a comprehensive program where we are bringing in lots of new technology, both the conservation side, heating and cooling buildings or more efficient automobiles, more efficient methods for industrial processing, using our waste, our municipal waste, and so on.

On the resource side, we have to get moving with our nuclear program. You can see it is just getting started down in this bottom chart, and use it to generate electricity, use our coal in part to increase our electrical output, but use the coal primarily for synthetic fuels and for processed heat for industry, and bring on our geothermal and obviously do what we can to recover from our oil and gas fields what is there.

For the long-term, when you get out here and beyond, we want to be in a position to use some combination of the breeder, fusion and solar electric. We are going up to the Congress with a budget amendment that calls for increased effort in fossil fuel, the work I described -- in solar electric, geothermal, in advanced energy systems and conservation, both of which are getting at using our energy more efficiently as well as with the fusion program.

In the nuclear area, we are reducing our effort somewhat on the breeder this coming year and using some of those funds to work on the fuel cycle. This, as you know, takes you all the way from mining to enrichment, to use, to taking care of the spent fuel, recycling and waste management.

So out of this exercise we are coming in with quite specific recommendations to the Congress, and I am sure they will have lots of questions when we get into it. But I think this does improve the balance of the program and will get us on the road to an effort that will give us more energy options in the future than certainly we have today.

That completes my remarks, and if there are any questions I would be glad to try and answer them.

MORE

Q Dr. Seamans, this appears to be a very elegant framework for a policy that has been evolving for some time. From a policy point of view, is there anything significantly new in what you are sending to the Congress?

MR. SEAMANS: Well, I think what you say is true, that there has been a lot of discussion on what we ought to do, and I think we have quantified the need for conservation. I think the most immediate gain we can get is to conserve and only part of it -- what I am talking about here -- is to conserve by being more efficient, using our technology. Obviously, there is a lot more to it than that.

It involves all the citizens in the country. I think we now see clearly what the balance should be between coal and the nuclear. We see the importance of using our solar energy for heating and cooling of buildings. I think we see more clearly the long-range -- that we have got to come in in a 25-year period with some form of energy that is going to be available for a long, long period of time.

MORE

Q Dr. Seamans, it looks like, based on this chart, imports of oil and gas, with your different scenarios -- and also they are outlined in the booklet -- that no matter how you slice it, we are not going to be able to achieve the President's Project Independence goal of no longer relying on foreign oil by 1985. Is this right?

MR. SEAMANS: I think one thing that has to be recognized -- and I perhaps did not make that clear enough in this brief discussion -- that this is only showing what you can do with your technology and it assumes that you are going to keep our lifestyle and our growth pattern the way it has been.

The President's program calls for doing a lot more than bringing in new technology. There are other ways of minimizing our imports. As a matter of fact, if I am not mistaken, the President's plan still has some imports in 1985. I believe the number is in the order 3.5 million barrels a day.

Q And you think that is a realistic goal?

MR. SEAMANS: Yes, I believe that is definitely a realistic goal and one we should be working as hard as we can toward for obvious reasons.

Q Why does your report not show an equalization or reduction or disappearance of imports until 1995?

MR. SEAMANS: What I show here are a number of possible ways of proceeding with the technology. The purpose of doing this is to show the trade-offs between different technical efforts so that this should be viewed that way, not in sort of absolute terms.

But the other part of the answer is that we did not get into any econometric studies. We did not get into what happens in the marketplace. We did not get into market elasticity, and so on. That was all contained in the independent study, and is really more in the purview of the Federal Energy Administration.

Q Is it more realistic to assume we are going to be independent in 1995 or in 1985?

MR. SEAMANS: I think we can definitely achieve the President's goal, as I just stated in 1985, and we should be working toward it.

Q Dr. Seamans, can you detail what is happening to the fast breeder reactor, how much you are going to cut it and the direction it takes you into.

MR. SEAMANS: When you get into the details of this, we cut the budget in 1976 $71.4 million in the breeder program. This is to get a better handle, take the time to get a much better fix on the organization, to assemble a hard hitting project team for Clinch River, definitely a review of the environmental impact statement thoroughly and come up with my finding on that which I will be announcing later today, incidentally, and take the time to really put that on solid ground and move out with the development which we must carry out.

The purpose of the breeder is not to have a commercialization by 1987 or 1989. The important thing is to have an option in the 1900s -- 1990 and thereafter -- as to whether we go ahead and commercialize with the breeder or commercialize with fusion or commercialize with solar electricity or some combination of the three.

Q I missed the nature of your announcement later. What are you going to announce?

MR. SEAMANS: There is an environmental impact statement required by law before we do any construction work at Clinch River. This was filed by the Atomic Energy Commission back in December as a final proposed environmental impact statement.

We have set up a team to review this, a review team for me. They are coming in with their findings, and I am about to make a determination and the determination in effect will say we believe that the environmental impact statement serves as a basis for going ahead with the research and development, but it does not serve, in its present form, as a basis for making a determination as to whether we should commercialize the breeder.

More information will be required, and that information will come out of the research and development program.

Q So, in part, your cutback is due to the environmental impact statement?

MR. SEAMANS: It is due to a variety of reasons. That is part of it. Part of it is management. Part of it is our need to be moving more aggressively with the whole fuel cycle.

Q Now you leave us up in the air. Does that mean you are adopting as final the proposed final statement or you are not?

MORE

MR. SEAMANS: It means I am accepting it as a basis for determining whether to go ahead with the research and development.

Q Does that mean the drafting of that statement is complete and it is a final statement?

MR. SEAMANS: There will be a requirement for some additions to the environmental impact statement. I will be calling on the Nuclear Program Office for more specific details on how the research and development is going to provide the information that will, in the future, permit an adequate determination to be made on commercialization.

Q So that is not a final statement?

Q In the past, though, you have talked about 1987 as a target date for introduction of commercialization of the fast breeder reactor. You do now seem to have abandoned that as far as being a firm target date.

MR. SEAMANS: That is correct. It is not a firm target.

Q How does your figure of $131 million additional authorization compare with what the House passed a week or so ago?

MR. SEAMANS: The House figures were roughly $200 million over our request, and the Senate so far appears to be about $300 million over our request.

Q Does the plutonium have anything to do with your decision to get away from this firm date on the breeder and put it off?

MR. SEAMANS: Yes, we believe more medical information is required.

Q Are you going to go into that in detail in discussing this later?

MR. SEAMANS: Yes, I think perhaps on another occasion than this it will be more appropriate to go into those details.

Q Are you planning a public announcement this afternoon on your breeder decision?

MR. SEAMANS: Yes, I am.

Q What time?

Q Where?

MORE

MR. SEAMANS: It will be over at ERDA headquarters, about four o'clock this afternoon.

Q Can you tell us from this how much would you expect -- are we going to be paying more for energy wherever it comes from and how much more in the year 2000 and how much is this program going to cost to develop?

MR. SEAMANS: I don't have all the run-out costs for the year 2000 so I can't give that to you. Our experiences so far in this country is that there have been substantial reductions in the cost of energy when going to nuclear.

When we go to solar, the energy itself, or the geothermal comes free but obviously there are capital costs involved. I don't think anybody can really answer that question of yours.

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Q Dr. Seamans, a moment ago you said that one thing this plan does is that you now see more clearly the balance that has to be struck between coal and nuclear. Would you tell us more about that? What is it you see now that was not seen in this Government a few months ago?

MR. SEAMANS: The thing that was not seen is how you interconnect the sources to the end use. One of the problems we have is our supplies of oil and gas are depleted and there are certain uses that are very, very dependent on energy in that form, as for example, the automobile and the airplane and the truck.

So this means we have to get moving aggressively with a synthetic fuel program, a program that the President had in his message, of getting to one million barrels a day in the year 1985. That is the start.

We have to move beyond that and in our plan we talk about 8 to 10 million barrels a day, synthetic, in the year 2000. This is to get energy in the right form for certain of our end uses.

This means a tremendous load on our coal mining industry, and that being the case, we can see the need for electrification, using other than coal to the extent that we can, and this is where the nuclear program comes in, because it is a natural for generation of electricity.

Q Dr. Seamans, ERDA seems to be carrying out a systemmatic campaign to convince us that you are de-emphasizing and slowing down the breeder and this report talks about how solar is taking on all these dramatic new proportions and yet the budget figures really don't reflect that, and your report -- when you point as specifically as it gets to where energy will come from in the year 2000 -- you predict far greater output from the breeder than from solar or fusion, either one, so is this really a cosmetic change or a real change?

MR. SEAMANS: It is a very real change, and it seems to me that $19 million increase over $70 million that we originally had in there, or about a 25 or 30 percent increase, is really very substantial.

When programs are just starting you really have to look at percentage increases because it takes time to build up the research capability in this country.

MORE

You really spend the money wisely, it takes time to build up the project teams, it takes time to really put the project together, so I consider that we are going in the direction of substantially increasing our solar and our geothermal effort even though the numbers, absolute numbers, are still small compared to absolute numbers for nuclear.

The nuclear program has been around a lot longer. We can't turn these programs around in just a matter of months. It takes years to build up a good, sound program and that is what we are doing in the non-nuclear area.

Q Have you given any concern to environmental matters in putting together your various options?

MR. SEAMANS: We have given a great deal of thought to the environmental area and actually you will notice in this report in the appendices we have worked out not only data on supply and demand but also on the environment itself, and the impact of these various programs on the environment.

It is still preliminary but it appears that the program that permits us to reduce our imports to a maximum extent, it also looks to be the best from an environmental standpoint.

Q Dr. Seamans, the budget amendment requests $26 million for fossil energy. What is that, specifically?

MR. SEAMANS: Fossil energy, of course, includes work and coal. This particular item also includes advanced recovery methods. If you want to get the specifics on it, Bob Fri is here and he is in charge of our budget task force and he can tell you about that after the session.

THE PRESS: Thank you very much, Dr. Seamans.

END (AT 11:00 A.M. EDT)

FOR IMMEDIATE RELEASE MAY 12, 1976

Office of the White House Press Secretary

THE WHITE HOUSE

TO THE CONGRESS OF THE UNITED STATES:

In response to the requirements of Section 307(b) of the Energy Reorganization Act of 1974, I am pleased to transmit a comprehensive report concerning the desirability and feasibility of transferring ERDA's defense-related programs to the Department of Defense or other federal agencies. The recommendations of the Secretary of Defense and the Administrator of the Energy Research and Development Administration are also included with the report.

I agree with the judgments of the Administrator and the Secretary and support their recommendations that ERDA retain its current responsibilities for funding and management of the defense-related programs. I have noted the recommendations with respect to the establishment of separate budget planning ceilings for ERDA energy and defense-related activities. I will consider these recommendations in developing my future budgets.

I agree with the recommendations of the Administrator and the Secretary that the Department of Defense should revise its nuclear weapons budget and cost reporting submissions to Congress to specify separately the ERDA costs associated with each new nuclear weapon or nuclear weapons system.

This segregation of costs will make clear to the Congress and to the public the total requirements for national defense purposes. I also agree that it is desirable to review the funding and management arrangements for the ERDA defense-related programs after two or three years of experience to see whether additional changes should be considered.

GERALD R. FORD

THE WHITE HOUSE,
May 12, 1976

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