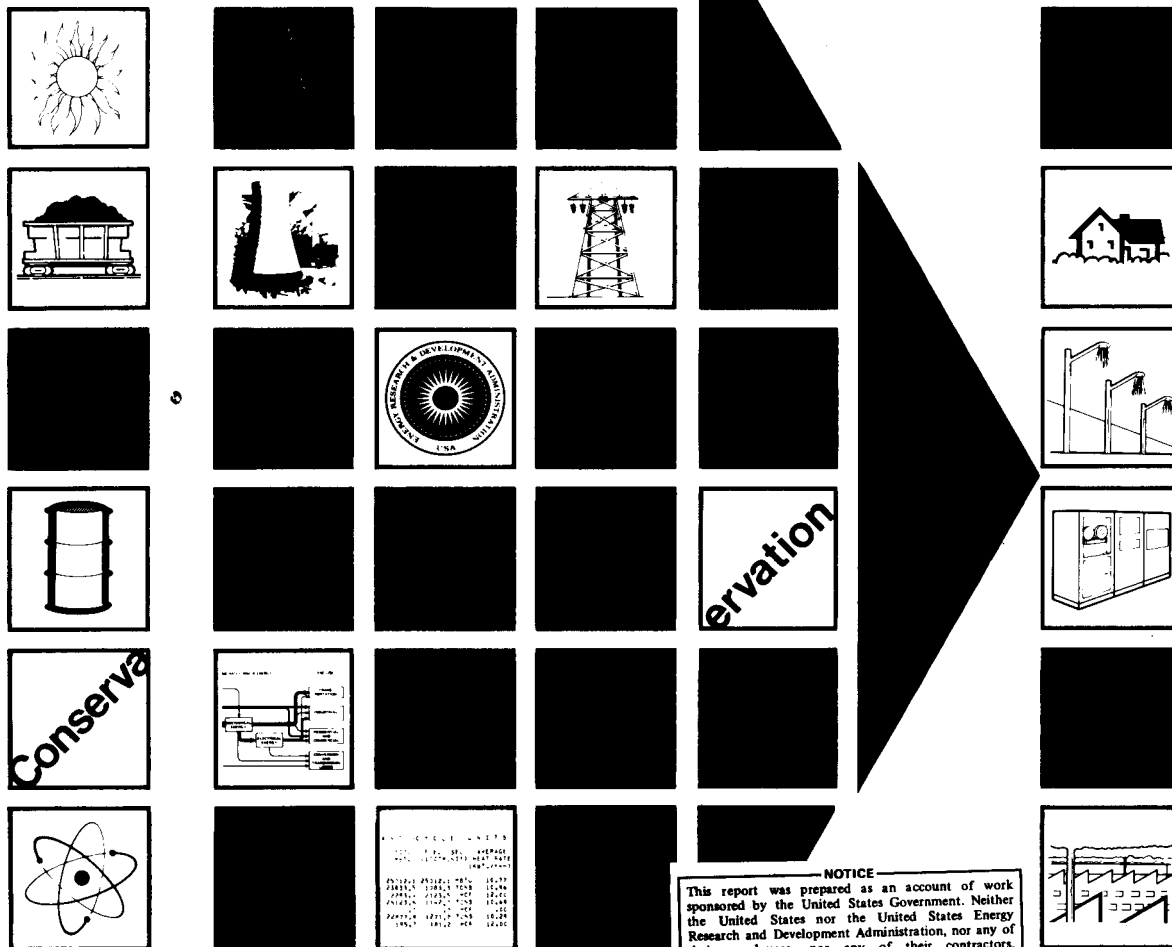




# Electric Energy Systems Program: Linking Sources and Uses.



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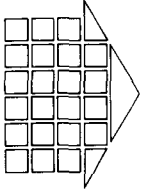
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# EXECUTIVE SUMMARY

It is generally accepted that the United States faces a serious, long-term energy crisis. A major key to the management and resolution of this problem is the operation of the U.S. electric energy system that links the sources of electrical energy to the various customer users. ERDA was created to provide a national focus on energy technology; within ERDA, the Electric Energy Systems Division (EES) is specifically concerned with the U.S. electric energy system. This document describes the EES Division, and its role in and program for electric energy systems R&D.

The U.S. electric energy network is vast, complex, and multi-faceted. It is a major part of the total energy system and, thus, its continued successful operation is critical to the future economic health and social well-being of this country. Moreover, most experts forecast a rapidly increasing dependence on electrical energy—a dependence which must inevitably require a higher level of performance from the electric energy network. At the same time, some potential new sources for the future—solar energy, for example—have inherent characteristics which will make the network even more complex than it is today.

To meet the challenges and opportunities presented by the requirements on the U.S. electric energy system, ERDA's EES Division is developing a broadly-based R&D program in associated technologies—one which addresses both near-term and longer-range needs. EES' systems approach has a somewhat special character within the ERDA organization, in that it cuts across and ties together the various energy source and end-use electric energy technologies. The specific elements of EES' program are:

- New Source Technology Integration,
- Advanced Systems Design Methods,
- Bulk Power Delivery,
- Conservation on the Electric Energy System,
- Load Management, and
- Major Demonstrations on Operating Systems.

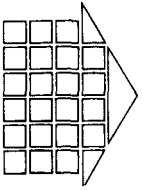
The broad objective of this program is to insure that the national electric energy system is capable of meeting future demands reliably, with minimum losses, and within environmental and other constraints.

By achieving its objective of an improved electric energy system, the EES program will provide direct social and economic benefits. Direct energy savings provide a substantial and easily quantified measure of this benefit. However, in a resource-limited society, the indirect benefits, although more difficult to quantify, may be the most important of all.

The magnitude, scope, and importance of these challenges and opportunities will require a long-range, broad-based, and co-operative national effort which focuses the respective activities of institutions such as the Federal Government (through ERDA/EES), the utilities, the Electric Power Research Institute, and the electric power equipment manufacturers. EES' program is

designed to encourage and complement this kind of joint effort, with the goal of having the necessary technological "products" for the electric utility system available when (or even before) they are needed.

No one can predict with certainty the evolution of the U.S. electric power system. However the need for EES' electric energy *systems* approach is not dependent on the specifics of any particular energy scenario; rather, it is required by the need to understand the impact of *any* scenario, and incorporate that understanding in national electric energy systems planning and decision-making. Because it is certain that the alternatives are several, their respective consequences significant, and the need to consider them imminent.



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# 1. INTRODUCTION

The gasoline lines of 1973-1974 and the harsh winter of 1976-1977 have underscored in the public mind a fact long known by energy planners—this nation faces a severe, long-term energy crisis. Because energy is one of the keystones of our national economy, and because our country's energy resources are not infinite, the management of the production, delivery, and use of energy has become a primary national concern. And, central to the entire energy picture is the delivery system for electrical energy—the U.S. electric energy system—that links the sources of that energy to the various customer users.

ERDA was created to provide a national focus on energy technology. Within ERDA, one group—the Electric Energy Systems (EES) Division—is specifically concerned with the U.S. electric energy system.

The purpose of this document is to describe the EES Division, and its role in and program for research, development, and demonstration. It begins with an overview of the challenges and opportunities presented by the requirements which must be met by the U.S. electric energy system, including the need for an R&D program in this area. The EES Division is described in terms of its current role, history, and technical capabilities. An overview of EES' R&D program is presented, including its focus and objectives, elements, organization, development, and implementation. The presentation concludes with a brief perspective on the future of the U.S. electric energy system.

The operative word throughout this presentation is 'systems'. Webster defines 'system' as:

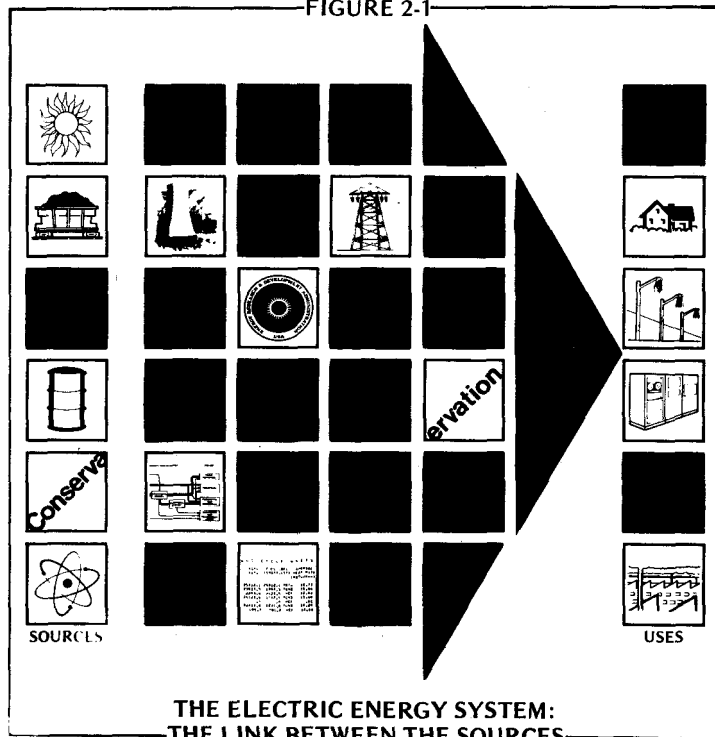
**SYSTEM** /'sis-təm/ n. [L. *systemat-*, *systema*. . . to combine,. . . ] 1: a regularly interacting or interdependent group of items forming a unified whole: as. . . (d) a group of devices or artificial objects or an organization forming a network esp. distributing something or serving a common purpose. . .

For which it follows that we can define an *electric energy system* as that interacting, but unified, group of devices, objects, organizations, et. al., required to form a network for transmitting and distributing electrical energy to serve the common purposes of the people of the United States.

Thus, a '*systems approach*' to electric energy is one which takes into account the interactions and interdependencies of the devices (power plants, control centers, transmission lines, etc.), 'objects' (loads, demands, resources, etc.), organizations (utilities, manufacturers, consumers, etc.), and other factors which are the constituent elements of that system. And, it then follows that '*systems solutions*' are those which provide a resolution of the problems, needs, demands, and other requirements of the system as an integrated whole.

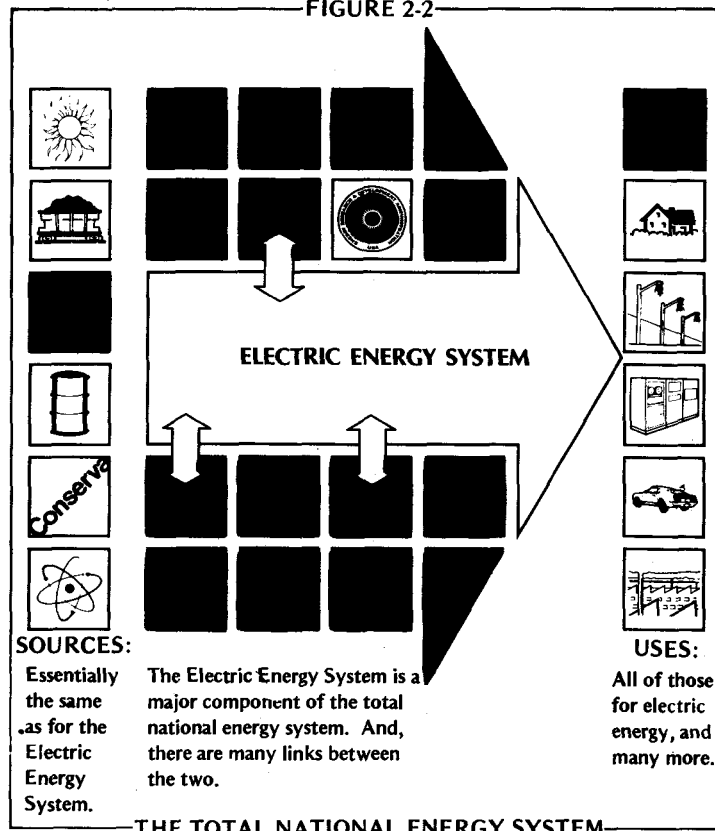
It is in the context of these definitions that this document presents EES' systems approach to, and systems solutions for, the requirements on U.S. electric energy network.

FIGURE 2-1



THE ELECTRIC ENERGY SYSTEM:  
THE LINK BETWEEN THE SOURCES  
AND USES OF ELECTRIC ENERGY.

FIGURE 2-2



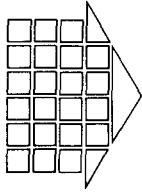
**SOURCES:**  
Essentially the same as for the Electric Energy System.

The Electric Energy System is a major component of the total national energy system. And, there are many links between the two.

**USES:**  
All of those for electric energy, and many more.

THE TOTAL NATIONAL ENERGY SYSTEM

# 2.



# THE U.S. ELECTRIC ENERGY SYSTEM— CHALLENGES AND OPPORTUNITIES

The U.S. electric energy system is a vast and complex linkage between the sources and uses of electric energy. This presents both a challenge and an opportunity. The nature of these challenges and opportunities is considered below, together with the need for ERDA's systems approach as directed through EES.

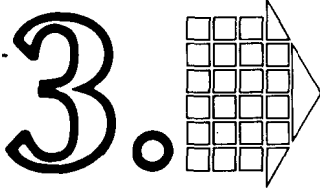
The cover graphic (Figure 2-1) which is used throughout this document as a symbol of the national electric energy system depicts the complex and multi-faceted nature of that system. It illustrates the fact that it is the electric energy system which connects the sources of electric energy (the sun, fossil and nuclear fuels, conservation, et. al.) to the uses of that energy (residential, commercial, industrial, transportation, et. al.). Moreover, the electric energy system is a major component of the larger and even more complex total U.S. energy system (Figure 2-2).

Each of those resources from which we derive our electric energy supply is, in some way, limited while, in a growing and healthy economy, the user demands on these resources are virtually open-ended. We have, in fact, reached a point where resource limitations are becoming one of the primary constraints on the growth and expansion of the national economy. Thus, the functioning of the total energy system is becoming, and will continue to be, an increasingly important determinant of the economic health of this country. And, it is a complex system. A variety of types and sizes of power plants (coal, oil, nuclear, hydroelectric) convert resources into electric power; this power then flows to the customer users through a transmission and distribution network that permits various components to function synergistically to meet demand fluctuations.

Currently, the electric energy system does a remarkably good job of meeting the demands placed upon it—so good, in fact, that we tend to take its performance for granted. However, the capability that has resulted in this performance record is more evolutionary than the result of a national electric energy systems planning effort. As we look to the future, most experts forecast a rapidly growing dependence on electrical energy—a dependence which must eventually require a higher level of performance and efficiency from the electric energy system. Clearly, it would be both risky and unwise to trust to evolution alone to develop an electric energy system for the future that will be able to meet these growing, changing, and complex requirements. This is particularly true when we note that some of the potential new sources for the future—solar energy chief among them—have inherent characteristics which will make the national energy equation even more complex.

If there is a missing factor in the larger electric energy picture, it is the need for a greater emphasis on a systems approach to electric energy systems development. This will require encouraging, defining, developing, testing, and implementing systems solutions concepts—concepts which will enhance and improve the linkage between source technologies, delivery systems, and user requirements. It is to these needs that the ERDA/EES program is specifically directed.



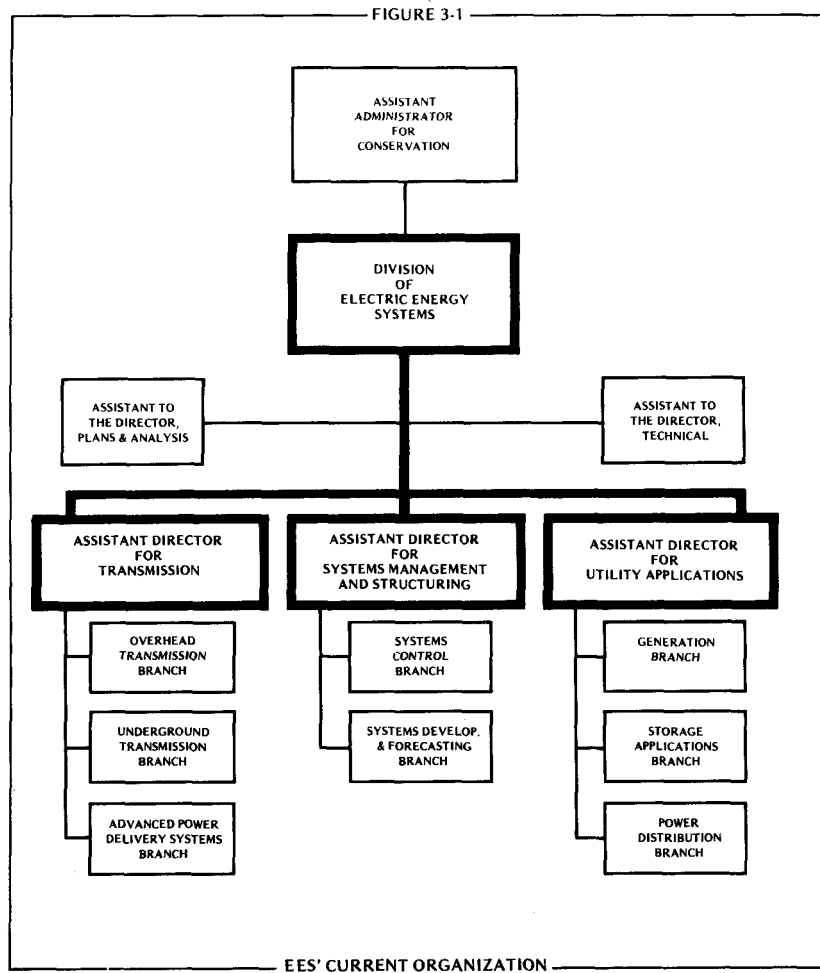


# ERDA'S ELECTRIC ENERGY SYSTEMS (EES) DIVISION

The Electric Energy Systems (EES) Division of ERDA has, as its primary concern, those technologies which are relevant and applicable to the *systems* aspects of U.S. electric energy systems. This section describes the current role of the EES Division, its history, and its capabilities.

## CURRENT ROLE OF EES

The EES Division is developing a broadly-based R&D program in electric energy system technologies—one which addresses both near-term and longer-range needs. The current EES program includes transmission and distribution, systems management and structuring, and utility applications. The organization of EES (Figure 3-1) reflects this range of activities and programs.



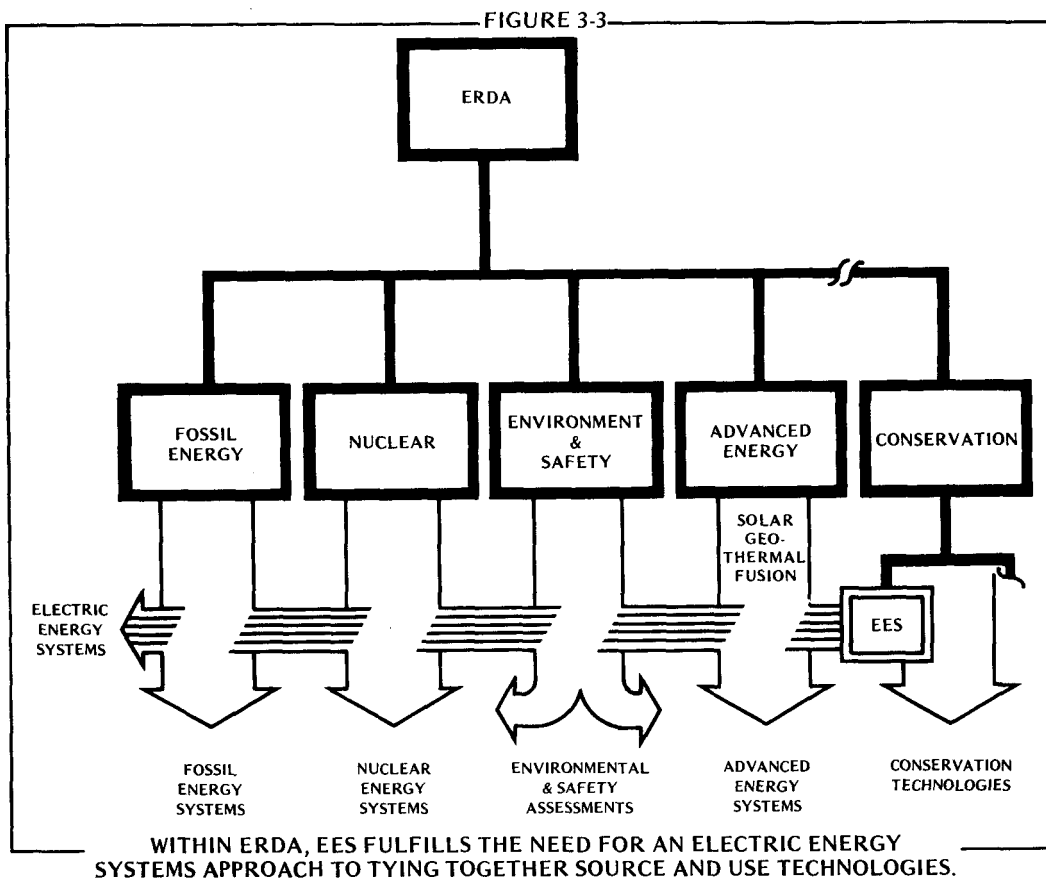


EES has a somewhat special character within the ERDA organization. It is the only ERDA program division which specifically takes the systems approach to the electric energy network. This is illustrated by Figure 3-3, which shows that EES fulfills an important need for a "horizontal" electric energy-systems approach to tying together the "vertical" energy source and end-use electric energy technologies. By specifically addressing this need for a systems-oriented R&D program focus, the EES Program meets the broad objective of insuring that the national electric energy system is capable of meeting future demands reliably, with greatest efficiency, and within environmental and other constraints.

The elements of EES' electric energy systems program are:

- New Source Technology Integration,
- Advanced Systems Design Methods,
- Bulk Power Delivery,
- Conservation on the Electric Energy System,
- Load Management, and
- Major Demonstrations on Operating Systems.

These elements are described in Section 4.



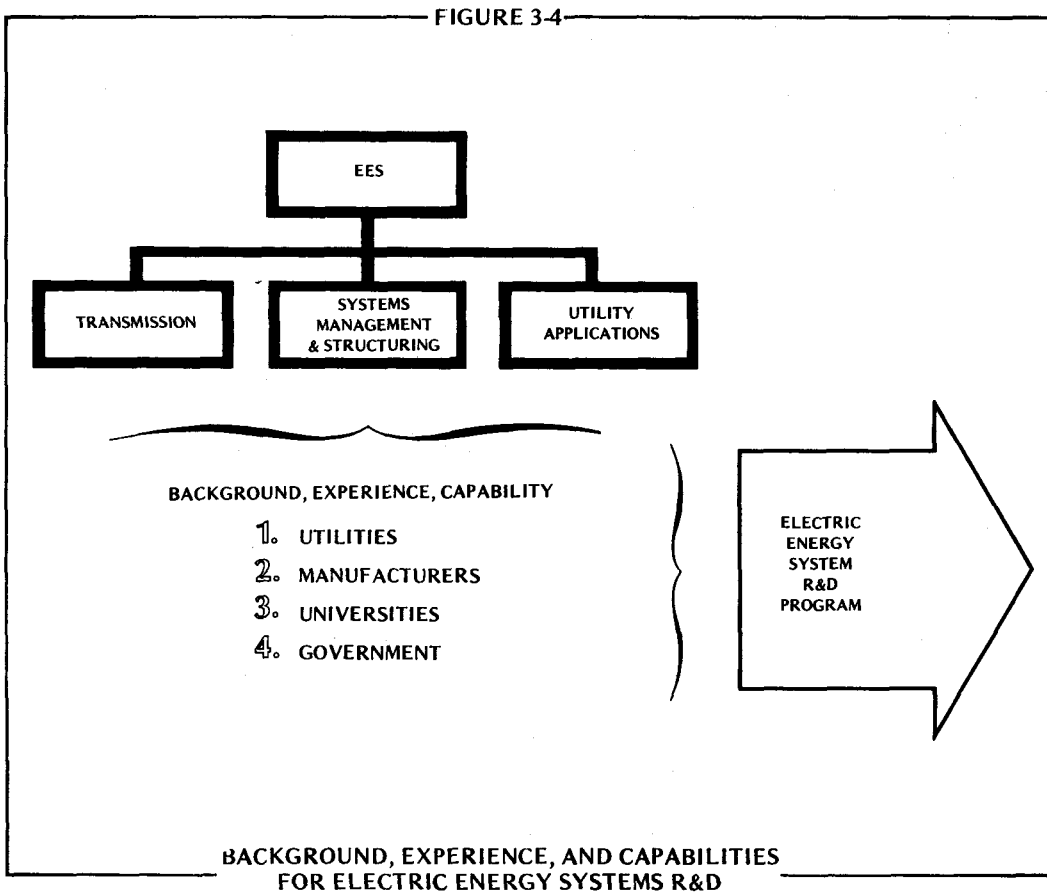
## EES HISTORY

The current EES program is an outgrowth of government and Electric Research Council (ERC) efforts to develop a viable R&D program in underground transmission. Beginning in 1970, the program was funded largely by the Edison Electric Institute (EEI) and the Department of the Interior (DOI). At one time, the program was the major effort of the ERC. Subsequently, pressure from the utilities and others moved the utilities to form the Electric Power Research Institute (EPRI). The emergence over the past decade of the energy crisis has underscored the need for an objective, national view of and approach to energy systems development. Out of this came the formation of ERDA, and within ERDA, EES. It is in the context of these institutional developments that the EES program has evolved from its beginnings in underground transmission to its present broadly-based electric energy *systems* scope.

## EES CAPABILITIES

The development of EES' technological capabilities has paralleled the Division's institutional evolution. EES' current professional staff has a broad electric energy systems capability drawn about equally from the utilities, equipment manufacturers, and government, with some representation from universities. As suggested by Figure 3-4, this range of background, experience, and capability is essential to an electric energy systems R&D program.

To avoid taking an "ivory tower" approach, EES has made and is making a concerted effort to continuously upgrade its capabilities and to maintain—through participation in professional societies, technical journals, seminars, and similar activities—broad general contact and information exchange with the energy systems community.



# 4. THE EES PROGRAM

The EES Division's program for electric energy systems research and development has six primary elements:

1. New Source Technology Integration,
2. Advanced System Design Methods,
3. Bulk Power Delivery,
4. Conservation on the Electric Energy System,
5. Load Management, and
6. Major Demonstrations on Operating Systems.

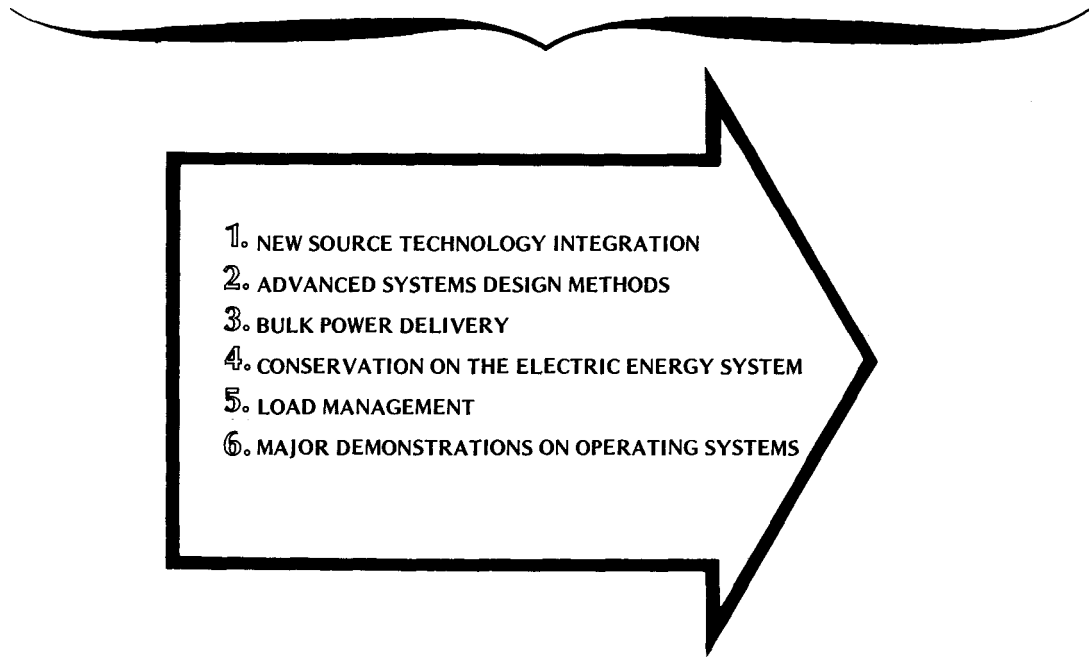
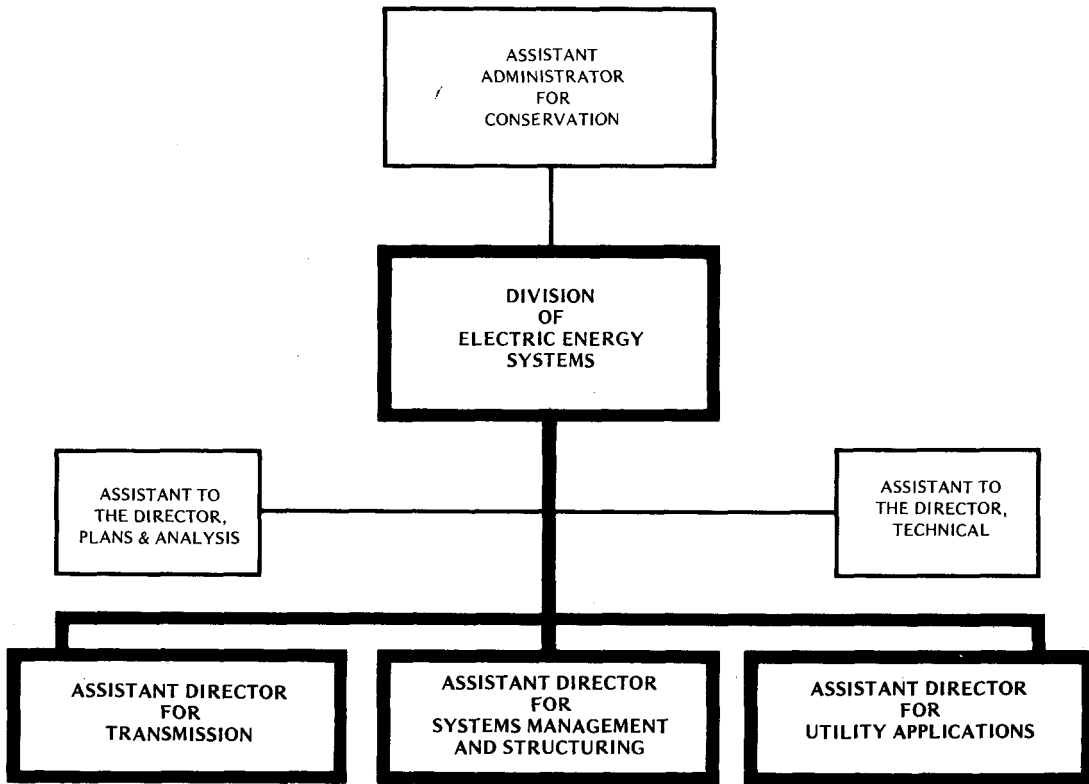
These elements are described below, together with the focus and objectives of the program and certain aspects of the program's development.

## FOCUS AND OBJECTIVES

The broad, overall objective of the EES program is to insure that the nation's electric energy system is capable of meeting future demands reliably, with the lowest practicable energy losses, with maximum energy conservation, and in accordance with environmental and other constraints. To this end, the EES program focuses on R&D designed to:

- Insure that all of the elements of future electric energy systems (oil, coal, nuclear, solar, storage, fuel cells, conservation, etc.) are integrated as required to achieve an overall energy-efficient system;
- Insure the continued availability of the system's capability of delivering electrical energy from source to user, as needed;
- Develop the system design and control techniques that will be required to maintain reliability as the system increases in size and complexity;
- Accelerate the commercialization of emerging technologies with significant near-term energy benefits; and
- Meet the need for electric energy systems input for national energy policy planning.

FIGURE 4-1



THE EES PROGRAM

Environmental and socioeconomic considerations are central to this R&D effort.

From a technical perspective, the national electric energy system will benefit from the EES program in many respects. Improved total system reliability (relative to the reliabilities of system components) is a principal anticipated benefit; reduced time for the introduction of new technologies is another. And, the program will provide independent, objective evaluation of the impacts of various technological alternatives.

By meeting its objective of an improved electric energy system, the EES program will provide direct social and economic benefits as a result of energy savings. The successful R&D and industry implementation of the EES program can be measured quantitatively in terms of direct energy savings—estimated to be 1.0 million barrels per day equivalent by 1985 and 5.0 million by the year 2000.

Beyond the direct energy savings, there are numerous second, and even third order, savings that will result from a more efficient electric energy system. These savings will be measured in both dollars and social benefit, and will include:

- Reduced capital investment requirements for energy development;
- Greater conservation of limited energy resources (coal, uranium, oil, and natural gas);
- Reduced use of raw materials (steel, aluminum, copper, etc.);
- Lowered electrical demand (because less energy will be required to extract and manufacture new energy sources);
- Reduced cooling water requirements (leaving more for agriculture and other non-energy uses);
- Minimization of public health and safety risks;
- Reduction of land requirements (for plant siting, transmission line rights-of-way, and mining of energy resources); and
- Minimization of environmental intrusion.

Some of these savings have large potential dollar values; others will provide more subjective or qualitative benefits. Some would come as a result of greater use of renewable resources. In any event, most represent complex socioeconomic interrelationships and are, as a result, very difficult to quantify. However, in a resource-limited society, they may be the most important savings of all.

## EES PROGRAM ELEMENTS

As symbolized by Figure 4-1, the six elements which comprise the current EES program are essential elements of the electric energy system which connects the sources and uses of electrical energy. And each of these elements is important to the achievement of the overall program objectives:

1. ***New Source Technology Intergration***— Each new electric energy source and storage technology creates a unique set of conditions and constraints which must be analyzed and understood from a systems perspective to insure their optimal integration into and usefulness to the national electric energy system. For example, solar generation will introduce a distributed source, the availability of which will largely be a function of conditions

(essentially, climatic) external to the demand on the electric energy system. While this technology, if properly integrated into the system, may help meet future requirements, it will also introduce a new dimension of complexity. Conversely, if not properly integrated it could actually bring about an increase in overall costs.

2. **Advanced Systems Design Methods**- Development of advanced methods and techniques for system planning, design, and control will be required to insure the reliability and efficient management of—and, thus, greater capital efficiency from—the complex and strongly interconnected electric energy systems of the future. The solar generation example is just one of those which will require new system design concepts and approaches. The electric energy systems of the future will need the flexibility to accommodate such a distributed source, or concentrated power generation, or, as is most likely, both in some combination with energy storage devices. They must also take into account new problems, such as the institutional questions related to the ownership and use of distributed sources.
3. **Bulk Power Delivery** — Even with a serious conservation effort, we can anticipate that bulk electric power demand loads will increase in the future. To this end, other ERDA divisions are actively pursuing the development of new sources of bulk power generation. The requirement to deliver more electrical power will, in turn, create an on-going need for development of higher capacity bulk power overhead and underground transmission/distribution systems. Moreover, independent of any growth pressures, expanding environmental concern and requirements will result in greater emphasis on underground transmission, more compact and aesthetic substations and overhead lines, and more power over a given right-of-way.
4. **Conservation on the Electric Energy System**- While it is necessary to plan for growth of the demand on and complexity of the electric energy system, it is also imperative that a concomitant effort be directed toward conservation on that system. Without appropriate means of conservation, system growth could outstrip available fuel supplies. Moreover, conservation is properly considered to be a major effective source of energy—one which has, as yet, only barely been tapped. Present-day losses in the electric energy system represent 7 to 10 percent of the total energy generated, or approximately 140 billion KW hours—any reduction in these losses will (because power plant efficiencies are less than 40 percent) translate into about three times that reduction measured in, for example, coal or oil.
5. **Load Management**— Load management is an important approach toward the development and demonstration of a more efficient electric energy system; this is the name given to the systems concept of altering, with energy storage and control, the apparent pattern of electricity use to:
  - Improve the efficiency of the electric energy system,
  - Shift fuel dependency from limited to more abundant energy sources,
  - Reduce reserve requirements for generation and transmission capacity, and
  - Improve reliability of service to essential loads.

Load Management is particularly attractive in terms of its potential for conserving energy and capital in the production and distribution of electric power—or shifting a significant

part of the fuel base from oil and natural gas to coal, nuclear, or renewable resources—and for holding down the cost of electricity. The concept of automated distribution systems also represents a significant possibility for achieving efficiency improvements, particularly when combined with other load management options such as energy storage, increased interconnections, load control, and new rate structuring.

6. **Major Demonstration on Operating Systems** – Testing and demonstration of full-scale prototypes on operating utility systems can, if successful, greatly accelerate the commercialization of near-term technologies offering potentially significant energy benefits. For example, demonstration of a 4.8 MW fuel cell power plant in a utility environment will accelerate the commercial introduction of this environmentally desirable form of dispersed generation.

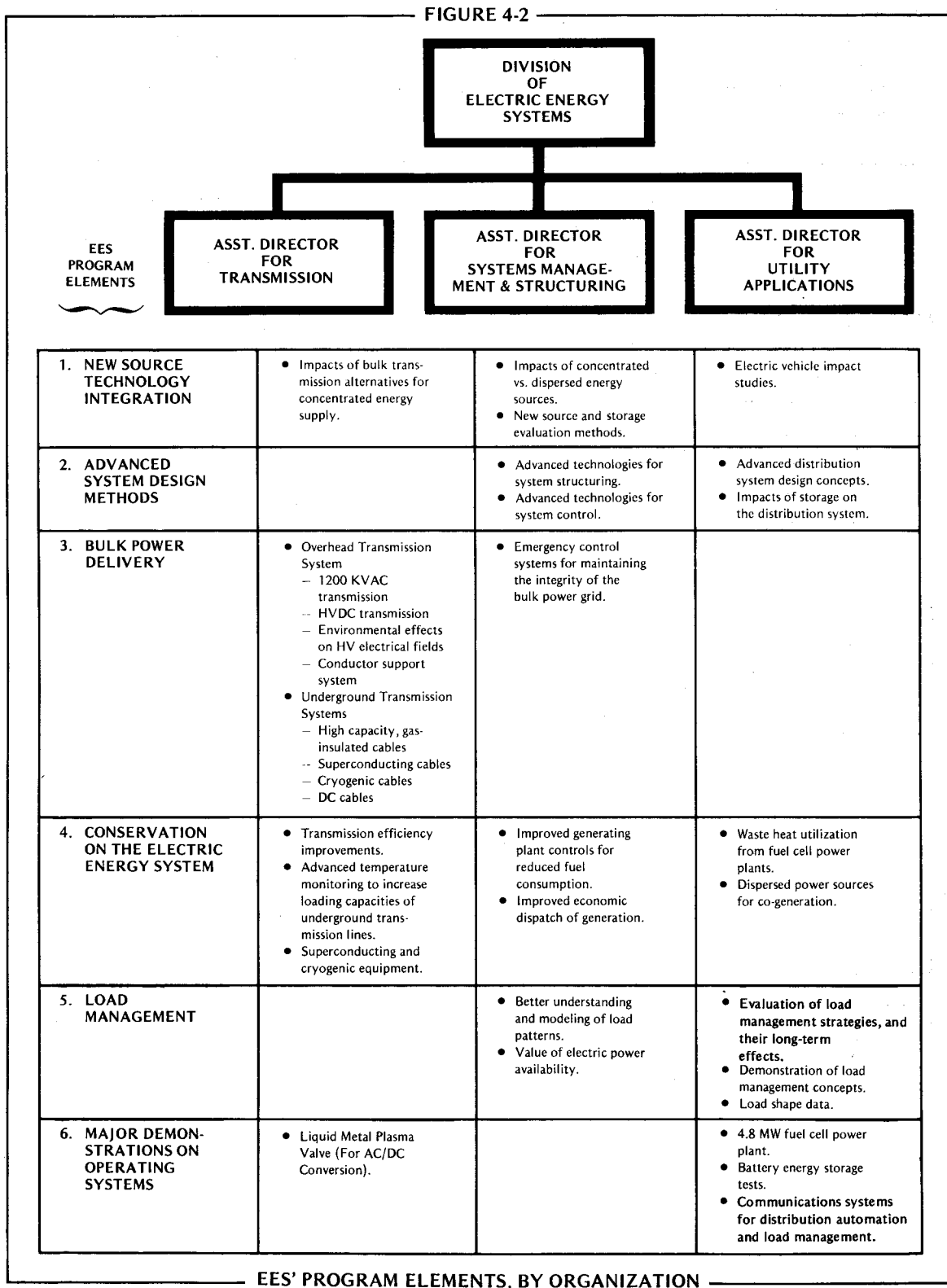
One important result from this program will be the generation of significant and highly useful data for utility and other energy system planners as they plan for the electric energy systems of the future.

## PROGRAM ORGANIZATION

The specific projects which are being and have been performed as part of the EES program include R&D work in areas such as:

- Advanced technologies for systems structuring;
- Advanced technologies for systems control;
- High voltage AC and DC overhead transmission systems;
- Environmental effects of high-voltage transmission lines;
- Advanced high capacity underground cables
- AC and DC superconducting transmission systems;
- Energy-efficient electrical equipment;
- Systems concepts and components for automated distribution;
- Load management, including storage;
- Integration of dispersed generation and storage technologies into utility systems;
- Fuel cell power plant demonstrations; and
- Battery energy storage tests.

Figure 4-2 illustrates the relationship between these projects and EES' organization and program elements.



The elements and individual projects which comprise the EES program cannot always be viewed discretely; they have many overlapping interrelationships. One characteristic they share is the goal of eventual implementation as part of the national electric energy system. As suggested by Figure 4-3, the scheduling of this implementation strategy varies by both program element and individual project. Future projects will add additional links to this strategy schedule, and extend it even further into the future. This is characteristic of R&D work in the area of systems technologies—both short and long range programs are required.

FIGURE 4-3

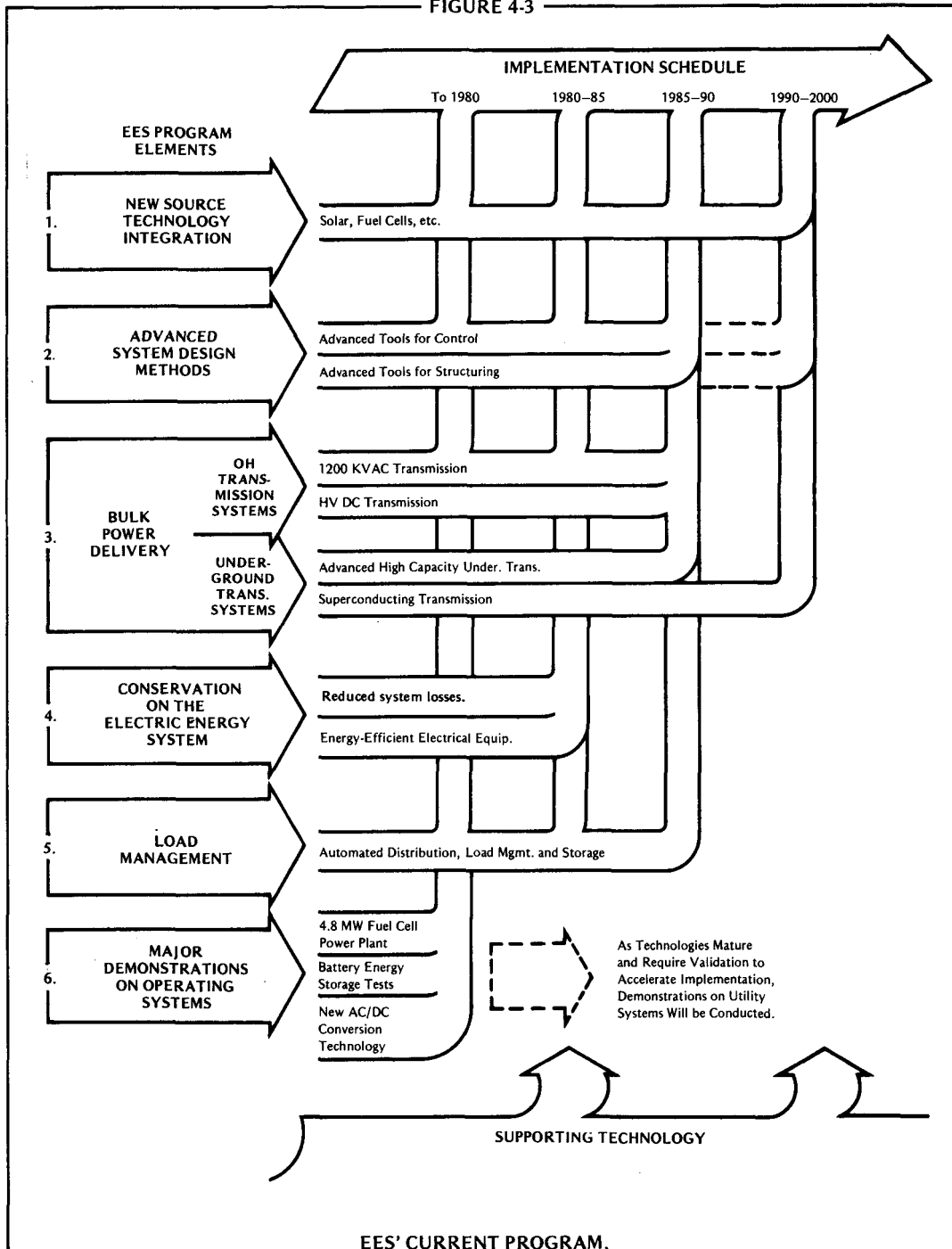
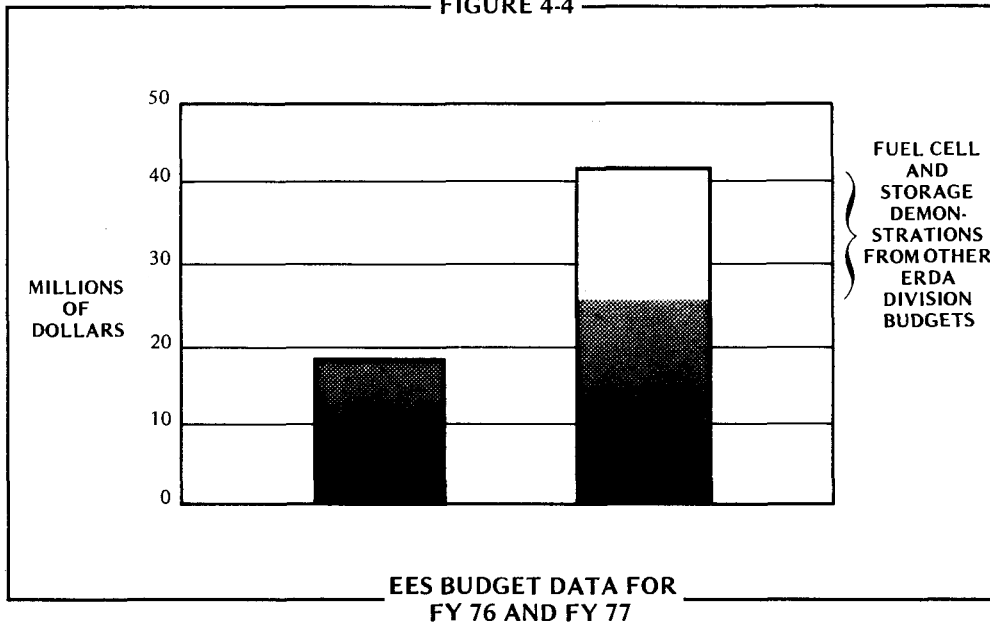


FIGURE 4-4



**PROGRAM DEVELOPMENT**

The growth of the EES program is described in Figure 4-4, which presents EES budget data for FY76 and FY77. Figure 4-5 breaks down EES' FY77 program funding three ways:

- By EES Directorate,
- By funding recipient (industrial contractors, universities, ERDA laboratories, and others), and
- By type of R&D work (engineering development, technology development, applied research, basic research, and demonstrations).

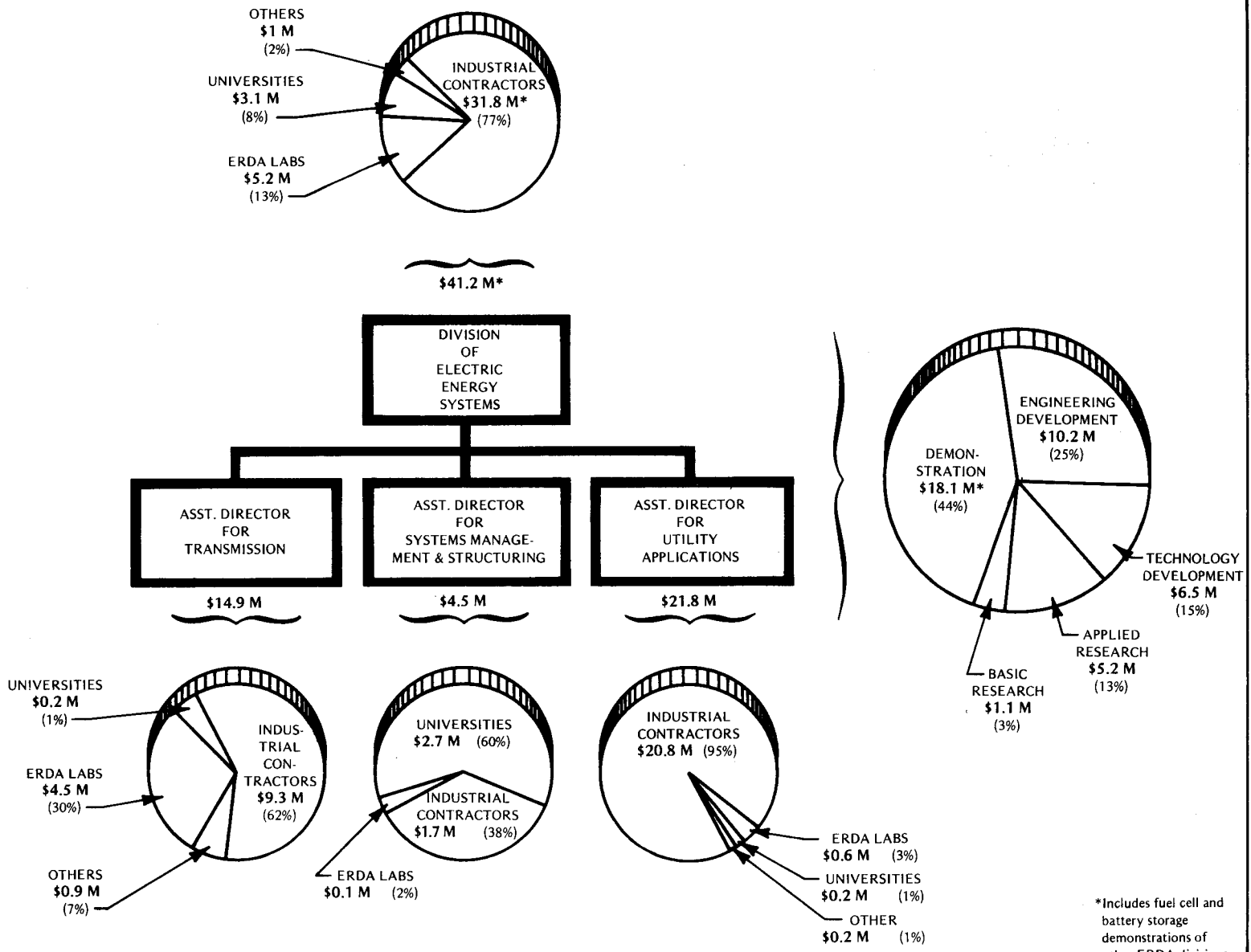
The bulk of EES' \$41.2 million FY77 budget went to industrial contractors, and the majority of EES' R&D effort was directed toward demonstrations and engineering development. However, sufficient budget has been allocated to universities and for basic or applied research, to achieve a balance between applied and theoretical technical work.

Program implementation has been designed to facilitate technology transfer to the private sector—a result of: (1) utility and other industry involvement in the conceptual planning, and project performance stages; (2) industry performance of R&D; (3) participation of utilities as hosts for field tests; and (4) the exchange of technical information in technical journals and professional organizations. The program also interfaces with Federal (FEA, EPA, DOI, NRC, REA, FPC) as well as with other national and state agencies. National and state regulatory agencies and councils are playing an increasingly significant role relative to the institutional aspects of new technologies under development. Intensification of interconnection, load management, environmental impacts, reliability, economics etc.—all are of interest to these groups, which now have a responsibility for, and a considerable voice in, the eventual incorporation of new technologies in the system.

The strategy diagram (Figure 4-3) suggests a timetable by which the various EES Program elements are expected to impact electric energy systems development. Such a timetable is, of course, a function of current and future technical, economic, political, and social developments.

FIGURE 4-5

17



EES FY 77 PROGRAM

Thus, a part of the program is, and must be, an on-going consideration and evaluation of such alternative developments and their consequences. However, the need for EES' electric energy *systems* approach is not dependent on the specifics of any given energy scenario; rather, it is *required* by the need to understand the impact of any scenario and incorporate that understanding in national electric energy systems planning and decision-making.

## PROGRAM IMPLEMENTATION

Implementation of the EES Program is built around a cycle which begins with the development of a better understanding of current electric energy systems and their requirements, and ends with an R&D "product" that is available, as needed, to the electric energy systems of the near and more distant future. The steps in this cyclic process are:

1. **Development of Program Concepts** Conceptualization of the EES Program evolves from two necessary and important initial steps:

- Development of a better understanding of present electric energy systems; and
- Forecasting of future developments, needs, and technology requirements.

The present U.S. electric energy system is already highly complex and not as well understood as needed to make decisions for the future; moreover, it can reasonably be expected that the evolution of the system will be in the direction of increased complexity. Thus, to develop R&D program concepts that will have useful results for both present and future systems, it is indeed necessary to expand upon current understanding of those systems and their evolution.

2. **Program Initiation**— The initiation of specific programs has two essential steps:

- Assignment of specific R&D priorities; and then
- Initiation of logical, sequenced R&D programs designed to meet these priorities.

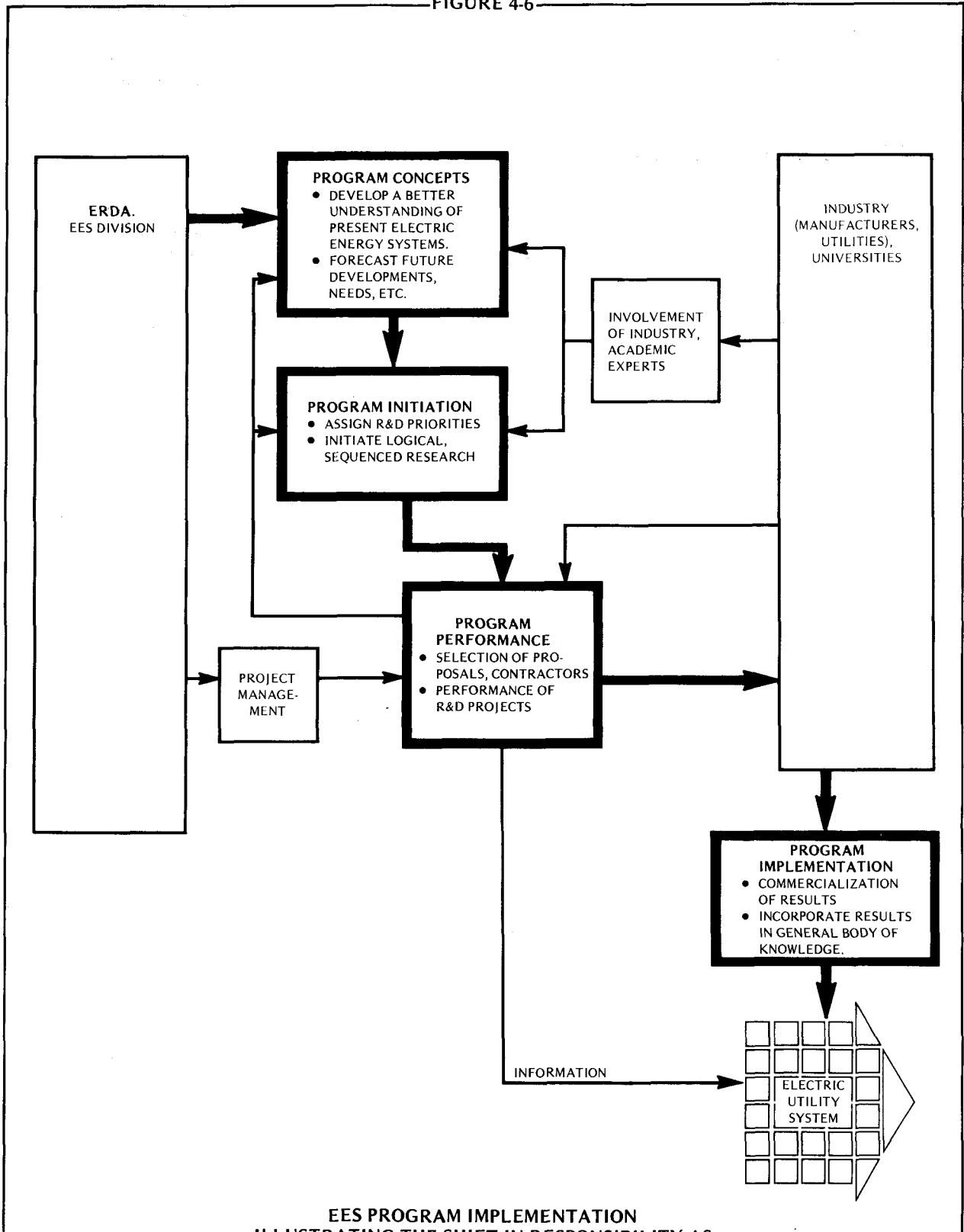
An essential input to EES' program conceptualization and initiation efforts will be provided by industrial and academic experts. The combined expertise of these industrial/academic sources and EES' staff are the key to insuring program relevance and subsequent utilization.

3. **Program Performance**— The steps in EES' R&D program effort are typical of those in most government contracting:

- Selection of specific proposals and contractors, and
- Performance of the specified R&D projects under the overall direction of the EES staff.

The results of current R&D programs will provide feedback for subsequent generations of program conceptualization and initiation; they will also provide a flow of information for application to current electric energy systems.

FIGURE 4-6



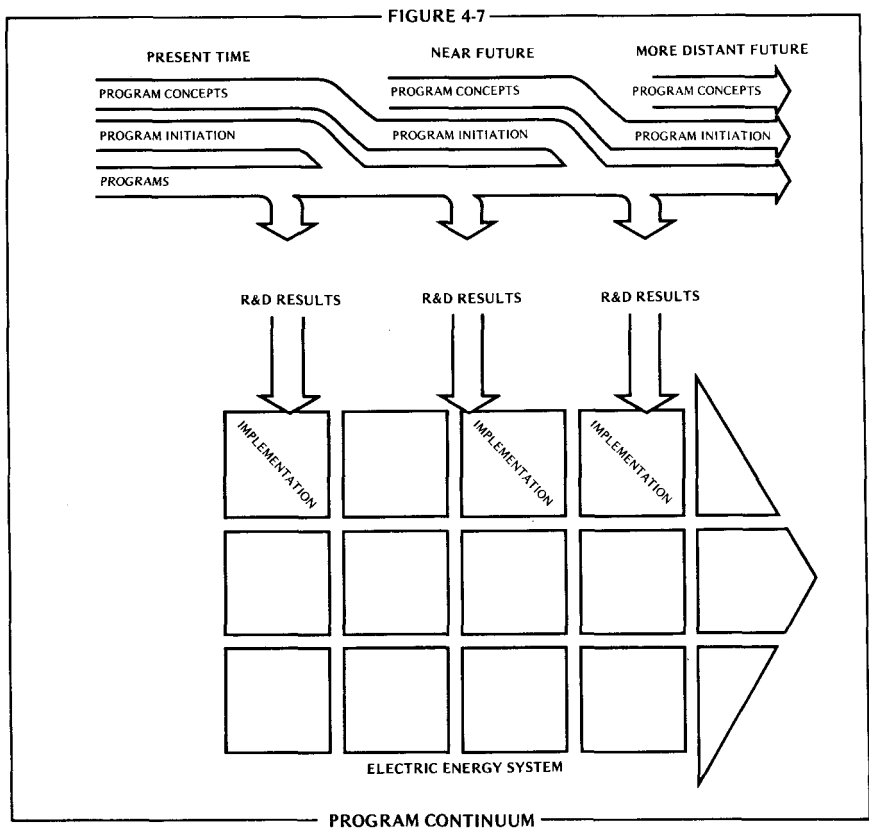
EES PROGRAM IMPLEMENTATION  
ILLUSTRATING THE SHIFT IN RESPONSIBILITY AS  
PROGRAMS PROCEED FROM CONCEPT TO COMMERCIALIZATION

4. **Program Implementation** — Perhaps the most significant “product” of EES’ R&D programs will be the implementation of their technological results as part of the electric energy systems. This implementation will, essentially, be in two forms:
- Direct commercialization of the results, and
  - The incorporation of these results in the general body of knowledge.

Once a technology has been proven to be technically and economically feasible, the responsibility for commercialization properly shifts to the private sector, which has historically provided this function. (It should be noted that the cost to carry a concept through to a final product has historically been from 5 to 20 times the cost of R&D.)

The relationship between these steps is illustrated by Figure 4-6. This figure also characterizes the planned shift in responsibility from the Government to the private sector as the programs proceed from conceptual to implementation phases. This program cycle is an on-going process. At any given time, new R&D needs are developing while the results from previous R&D efforts are being implemented as part of the current electric energy system. Between these endpoints, there must be a continuum of R&D programs. This on-going cyclic process is illustrated by Figure 4-7.

This EES Program Implementation Plan has been designed to provide a focus for and some integration of those ERDA activities that bear upon the systems aspects of the U.S. electric power system, and to encourage private sector institutions to utilize new technology, and carry it forward to commercialization. It is a flexible and dynamic plan which can be adjusted and modified to meet changing requirements. The goal of this process of program implementation is to have the necessary technological “products” for the electric utility system available when (or even before) they are needed.



# 5. PERSPECTIVES

The U.S. electric energy system, and EES' program relative to it, involve issues of the broadest national scope. To provide some perspective on these issues, the following takes a forward look at the potential evolution of U.S. electric power systems and at the roles of various institutions in developing that future. This section concludes with an example of new technology implementation.

## A FORWARD LOOK AT THE EVOLUTION OF U.S. ELECTRIC POWER SYSTEMS

Electricity use will be a primary determinant in the evolution of U.S. electric power systems. Forecasting experts disagree over the rate at which electricity use will rise, with estimates ranging from 2 to 7 percent compounded annually, but most agree that there will be a clear trend toward greater reliance on electric energy.

Supplying this electric energy will, however, not occur without the resolution of some major technical, institutional, and/or public acceptance problems. Although currently much of our electric power is supplied by oil and gas-fired plants, a shift to other resources will be required to "save" oil and gas for those uses where substitution is less readily achieved. Our coal resources are plentiful, and could potentially provide a long-range fuel for the electric power industry—assuming that environmental, transportation, and economic problems can be overcome. Nuclear power has considerable potential, particularly if breeder reactor technology can be implemented, but its wider use is currently being delayed by questions related to safety and nuclear proliferation. Alternative energy sources, ranging from solar to fusion power, offer many possibilities, but most are regarded as very long term options only. Thus, the future may bring a gap between electricity supply and demand. This will, in turn, place new and greater pressures on the power producers; it will also put pressure on society to make some difficult choices between the material benefits that result from energy, and the economic, social, and environmental cost of that energy.

With energy becoming more and more a national issue, the electric power producers may be drawn more deeply into the public arena. In the process, they will increasingly be viewed—both by themselves and by the public—as a critical link in the national resource-transformation-consumption chain. This will affect their relationships with the energy consumer and that, in turn, could impact upon their future generation mix. They may, for example, be induced to take a more aggressive role in encouraging new power generation options, or in pursuing nonconventional solutions to certain non-technical aspects (financing, rate structuring, regulation, interactions with consumer groups) of their operations.

The evolution of the U.S. electric power system could take many different directions. Some of the factors that will influence this evolution are shown by Figure 5-1. One reasonably likely scenario is the following:

- The cost of fuels will continue to rise in real terms (conditional, to a degree, on OPEC actions and the extent of the U.S. pursuit of energy independence);

FIGURE 5-1

<p style="text-align: center;"><b>ELECTRICITY USE</b></p> <ul style="list-style-type: none"> <li>● Anticipated growth in electricity use.</li> <li>● Substitution of electricity for other energy sources.</li> <li>● Changes in distribution/load factors.</li> <li>● Conservation effects.</li> </ul>	<p style="text-align: center;"><b>ELECTRICAL SYSTEMS</b></p> <ul style="list-style-type: none"> <li>● Development/implementation of automated distribution systems.</li> <li>● Development/implementation of systems concepts for maximizing rate predictability.</li> <li>● Development/implementation of new normal/emergency theory/control.</li> </ul>
<p style="text-align: center;"><b>ELECTRICAL SUPPLY</b></p> <ul style="list-style-type: none"> <li>● Development/implementation of energy parks, or dispersed generation, or both.</li> <li>● Development/implementation of new sources.</li> <li>● Development/implementation of energy storage techniques.</li> <li>● Development/implementation of multi-purpose plants, or co-generation.</li> <li>● Development/implementation of HV/high capacity transmission.</li> </ul>	<p style="text-align: center;"><b>ENVIRONMENTAL CONSTRAINTS</b></p> <ul style="list-style-type: none"> <li>● Changing regulations.</li> <li>● Remote location of coal/nuclear plants.</li> <li>● Transmission line restrictions.</li> </ul>
<p style="text-align: center;"><b>RELIABILITY REQUIREMENTS</b></p> <ul style="list-style-type: none"> <li>● Public desire to maintain current standards.</li> <li>● Cost-benefit of meeting peak demand periods.</li> <li>● Economic/social trade-offs.</li> </ul>	<p style="text-align: center;"><b>PUBLIC POLICY</b></p> <ul style="list-style-type: none"> <li>● Development/implementation of a national energy policy.</li> <li>● Development/implementation of new rate structures/regulatory approaches.</li> <li>● Interaction of consumer/public interest groups.</li> </ul>

FACTORS AFFECTING THE EVOLUTION OF  
U.S. ELECTRIC POWER SYSTEMS

- Actions of various fuel producers and regulatory agencies will tend to guarantee that there will be no surplus of fuel supplies—with the result that the price of all fuels will be roughly equivalent and equal to the most expensive fuel source;
- Increasing fuel costs will put strong pressures on the utilities to increase the efficiency of their system and plant operations;
- While initially, efficiency improvements may be achievable at relatively low cost, eventually these improvements will come at the expense of increased capital outlays;
- The other major source of system development—new generation technologies—will have little impact on the short-to-mid range time period; and
- As a result, significant interest and activity will shift toward electric energy end-uses.

Thus EES has an additional objective of working to assure the coordination and integration of developments such as these with the utility network, with the goal of achieving maximum overall public benefit.

The preceding suggests one scenario. However, no one can predict with certainty the evolution of the U.S. electric power system. What can be done is to recognize that the alternatives are several, their respective consequences significant, and the need to consider them imminent.

## EXISTING INSTITUTIONS – THEIR ROLES AND ACTIVITIES

The magnitude, scope, and importance of the challenges and opportunities presented by the U.S. electric energy system suggest a strong need for a coordinated national effort to focus the disparate public and private institutions capable of and involved in addressing related R&D requirements. The major institutions with this capability and interest are:

- The Federal Government (through ERDA/EES),
- The utilities,
- The Electric Power Research Institute (EPRI), and
- The electric power equipment manufacturers.

In addition, there are numerous other institutions, ranging from state and local governments to small manufacturers.

Figure 5-2 compares the roles and characteristics of extant institutions involved in the field of electric energy systems. These roles and characteristics can be seen to be largely complementary, with the manufacturers, EPRI, the utilities, and ERDA/EES each filling a distinct and important role in the overall picture. Federal activities are, fundamentally, directed toward representing the public-at-large. They are characterized by a broad, long-range, national perspective, and are implemented in many ways, ranging from extensive R&D activity to various institutional actions (for example, regulation of wholesale power rates, safety requirements, environmental standards, etc.).

A primary determinant between the respective roles of these institutions is risk. Industry and the utilities are financially constrained from undertaking technological developments that do not provide at least the hope of some relatively near-term economic payback. By comparison, ERDA is necessarily more concerned with finding ways to meet national goals and needs and, thus, supports R&D in higher-risk, longer payback areas. From this it follows that utilities and equipment manufacturers—i.e., the private sector—are usually more directed toward commercialization and problem solving, which are relatively short range concerns, with ERDA more likely to look further into the future. EPRI fits neatly between these areas of emphasis, extending the more immediate reach of the utilities while strongly reinforcing ERDA's broader R&D efforts.

It is important to note that, while there are some hard distinctions, the manufacturers, EPRI, the utilities, and ERDA/EES have overlapping involvements in the broad task of electric energy systems development. It is suggested that this is both necessary and desirable for the achievement of the broad-based, long-range, and cooperative effort that is needed.

## AN EXAMPLE OF NEW TECHNOLOGY IMPLEMENTATION

The U.S. electric utility system began as a series of relatively discrete operations. Interconnections were few, with the result that the associated decision-making and control hierarchy was both simple and local. As the system developed and grew to meet expanding demands, it necessarily become more complex, particularly in the hierarchy of decision-making and control.

The current U.S. electric energy system is interconnected, interdependent, and complex to a very high degree. This system draws the bulk of its power from large, base-loaded, central station power plants. This power is, essentially, available on demand—a characteristic which greatly influenced the evolution of the existing decision-making and control hierarchy.

Now assume the successful development of a new technology—solar electric power—and consider some of the complexities involved in its implementation as part of the U.S. electric energy system. Solar electric plants could be large central station installations, or small distributed

FIGURE 5-2

	GOALS	RESPONSIBLE TO	CHARACTERISTICS	EMPHASIS IN TIME
<b>EQUIPMENT MANUFACTURERS</b>	<ul style="list-style-type: none"> <li>• To meet business competition</li> <li>• To grow and expand as a business</li> <li>• To make a profit</li> <li>• Risk avoidance</li> </ul>	<ul style="list-style-type: none"> <li>• Stockholders</li> </ul>	<ul style="list-style-type: none"> <li>• Product-oriented</li> <li>• Independent</li> <li>• Responsive to market demand</li> <li>• National &amp; regional scope</li> </ul>	<ul style="list-style-type: none"> <li>• Almost entirely near-term product improvements.</li> </ul>
<b>EPRI</b> <ul style="list-style-type: none"> <li>• Electrical Systems Div.</li> <li>• Advanced Systems Div.</li> </ul>	<ul style="list-style-type: none"> <li>• To satisfy utilities' R&amp;D needs</li> </ul>	<ul style="list-style-type: none"> <li>• Contributing Utilities</li> </ul>	<ul style="list-style-type: none"> <li>• Hardware/subsystem/study-oriented</li> <li>• Complements ERDA</li> <li>• Responsive to utility needs</li> <li>• National scope</li> </ul>	<ul style="list-style-type: none"> <li>• Responsive to current problems, but with significant mid-term and minor long-term effort.</li> </ul>
<b>UTILITIES</b>	<ul style="list-style-type: none"> <li>• To meet consumer demand</li> <li>• To improve systems' reliability/environmental acceptability</li> <li>• To achieve a fair rate of return</li> <li>• Risk avoidance</li> </ul>	<ul style="list-style-type: none"> <li>• Consumers</li> <li>• Owners/stockholders</li> <li>• Regulators/government</li> </ul>	<ul style="list-style-type: none"> <li>• Engineering/operations oriented</li> <li>• Public regulation</li> <li>• Conservative</li> <li>• Regional/subregional scope</li> <li>• Highly capital intensive</li> </ul>	<ul style="list-style-type: none"> <li>• Near-term engineering/operational problem-solving</li> </ul>
<b>ERDA</b> <ul style="list-style-type: none"> <li>• EES Division</li> </ul>	<ul style="list-style-type: none"> <li>• To satisfy national needs</li> <li>• To develop "high risk, high payoff" technologies</li> <li>• To insure reliable, safe, future systems</li> <li>• Conservation</li> </ul>	<ul style="list-style-type: none"> <li>• Public</li> </ul>	<ul style="list-style-type: none"> <li>• National systems-oriented</li> <li>• Emphasis on developing long-range hardware with no present market</li> <li>• Complements EPRI</li> <li>• National scope</li> <li>• Accelerates commercialization of energy-effective systems/equipment</li> </ul>	<ul style="list-style-type: none"> <li>• Balanced, to meet national needs</li> </ul>

COMPARING THE ROLES/CHARACTERISTICS OF EXISTING INSTITUTIONS

units, or both. In either event, their power will be available when the sun shines, and not necessarily when demand naturally occurs.

Although ameliorated somewhat by energy storage techniques (which themselves add new elements to the equation), the characteristics of this new technology are fundamentally different from the 'power-on-demand' quality upon which the present electric energy system is based. It would seem to follow that systems operations will have to be modified or changed in comparably fundamental ways.

Clearly, old and new technologies must be made to work together as reliably, efficiently, and economically as possible. Yet the system has matured to a point where such a union cannot be assumed to naturally result. Thus, the development of new source technologies will require the concomitant development of new systems technologies.



# 6. CONCLUSION— LOOKING TO THE FUTURE

Throughout this presentation, the U.S. electric energy system has been depicted as a multi-element connection between the sources and uses of electric energy. It has been noted that there is a need to completely understand these elements and their interrelationships if we are to effectively deal with present and future electric energy systems requirements. Moreover, it has been anticipated that future institutional, political, economic, and energy technology developments will cause these elements, and the system they comprise, to change and evolve over time. And every indication suggests that this evolution will be in the direction of a far more complex electric energy system.

To date, EES has provided an electric energy systems focus to ERDA's R&D goals. Looking to the future, EES is building the technical capability and supporting R&D program necessary to meet the imminent and growing need for an on-going electric energy systems technology development effort. The success of this effort will help assure tomorrow's linkage between the sources and uses of electric energy.