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Thermal Power Systems
Small Power Systems Applications Project

Proceedings of Small Power Systems Solar Electric Workshop

Held at Aspen, Colorado
October 10-12, 1977

Volume II. Invited Papers

Prepared for
Department of Energy
by
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

(JPL PUBLICATION 78-10)

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Edited by
R. Ferber

February 1978

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FOREWORD

The Small Power Systems Solar Electric Workshop was held in Aspen, Colorado, on October 10 - 12, 1977. This meeting was sponsored by the U. S. Department of Energy (DOE) and Jet Propulsion Laboratory (JPL), Pasadena, California. JPL has the responsibility for developing the technology application scenarios, and hardware for small solar thermal electric power applications. The Small Power Systems Solar Electric Workshop was conducted to gain input from the utility community in identifying the important issues and requirements involved in the adoption of solar thermal power technology.

The program at the workshop consisted of presentations, panel discussions and small discussion groups on topics such as technology, financing, utility planning, public policy and environmental impact. All of the presentations are included in their entirety with discussions given in summary form.

ACKNOWLEDGEMENTS

The contributions of the people who attended the workshop and those who worked to make this workshop a success are gratefully acknowledged. More than eight Jet Propulsion Laboratory people were intimately involved during both the development and staging of the workshop. A similar number from Energy Services Consulting were involved. In addition, twelve people from other organizations prepared and presented material which was vital to the success of the workshop. These people are listed in the appendix (8.3).

This proceedings documents the workshop effort sponsored by the U. S. Department of Energy, Division of Solar Energy under the Interagency Agreement, EX-76-A-29-1060, with NASA.

ABSTRACT

The Jet Propulsion Laboratory (JPL) sponsored a solar power workshop in conjunction with their Small Power Systems Applications project, on October 10 through 12, 1977, in Aspen, Colorado. The project is managed by JPL for the U.S. Department of Energy (DOE). The workshop's primary purposes were: (1) to acquaint the utility community with JPL's Small Power Systems Applications project, and (2) to gain input from utilities regarding their needs as they affect the development of solar thermal electric technology.

The workshop presented the commitment of the DOE and JPL to the development of solar thermal power plants in the 1 to 50 MWe range for a variety of applications including utility applications, the focus of this workshop. Workshop activities included panel discussions, formal presentations, small group interactive discussions, question and answer periods, and informal gatherings. Effective interchange of ideas and information was gained by emphasis on participation and discussion. Discussion on topics included:

- Solar power technology options
- Solar thermal power programs currently underway at the DOE, JPL, Electric Power Research Institute (EPRI), and Solar Energy Research Institute (SERI)
- Power options competing with solar
- Institutional issues
- Environmental and siting issues
- Financial issues
- Energy storage
- Site requirements for experimental solar installations
- Utility planning

It was concluded that many of the problems associated with the implementation of any new technology, or the siting of new power plants, also apply to solar thermal power. However, several issues and conclusions were identified that are unique to solar power technology development. These issues and the results from the small group discussions are summarized in the proceedings.

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Introduction & Program 1.0

The availability of conventional fuels, which currently supply energy for the nation's industries and utilities, is declining. As a result, the nation is looking to alternative sources of energy. Solar energy is an alternative source that holds promise of supplementing conventional sources of energy before the end of this century. Oil and gas can be saved by developing and commercializing technology that can efficiently and economically use the solar energy resources that are abundantly available.

The electric utility industry depends heavily on conventional fossil fuels. Along with this dependence goes the reality of increasing fuel prices. Subsequently, as the cost of generating electricity by conventional means increases, the opportunity for new approaches using advanced technology also increases.

Thus, the major thrust of the Department of Energy's (DOE) plan is the development and commercialization of technologies that will supplement and eventually replace conventional fossil-fuel technology. The DOE is supporting a major program in developing solar thermal technology for generating electric power in the United States.

The Solar Thermal Power office of the Division of Solar Energy of the DOE is responsible for developing the technology for low-cost long-life reliable thermal power systems suitable for a wide range of applications. To accomplish this goal, programs have been established in three primary areas:

- Advanced technology
- Central power technology and applications
- Dispersed power technology and applications which includes Total Energy Systems and Irrigation Applications

One element of the dispersed power applications activity is being performed within the Small Power Systems Program, managed for the DOE by the Jet Propulsion Laboratory (JPL). Within this program, one of the first tasks in the Small Power Systems Applications (SPSA) project is the definition of the program requirements. JPL sponsored the Small Power Systems Solar Electric Workshop in order to accomplish four prime goals:

- Introduce electric utilities to small solar thermal power technology, its potential and the programs developing it
- Pinpoint the issues involved in the adoption of small solar thermal power which will influence its development
- Establish communication channels with utilities which will assist JPL in developing the technology in ways which will meet the needs of small utilities
- Gain input on how JPL's upcoming RFP for experimental projects can be made attractive to various types of utilities, particularly small ones.

The workshop was held in Aspen, Colorado, from October 10 to 12, 1977. The workshop was attended by more than 35 electric utility community representatives, who were given opportunities both to hear and be heard on a variety of pertinent issues.

The workshop presented the commitment of the DOE and JPL to the development of solar thermal power plants in the 1- to 50-MWe range, for a variety of applications including utility applications, which was the focus of the workshop. Workshop activities included panel discussions, formal presentations, small group interactive discussions, question-and-answer periods and informal gatherings. An effective interchange of ideas and information was gained by emphasis on participation and discussion. Discussion topics included:

- Solar power technology options
- Solar thermal power programs currently underway at the DOE, JPL, Electric Power Research Institute and Solar Energy Research Institute
- Power options competing with solar
- Institutional issues

- Environmental and siting issues
- Financial issues
- Energy storage
- Site requirements for experimental solar installations
- Utility planning.

The workshop was designed to identify and clarify the issues involved in the adoption of solar thermal power systems, rather than to obtain problem solutions. Some of these issues are listed in the next section under Summary and Conclusions.

WORKSHOP PROGRAM

MONDAY, OCTOBER 10, 1977

MORNING

Registration

Buffet Lunch

AFTERNOON

Technology and Program Overview

- Welcome and Introduction
  Robert R. Ferber, Workshop Chairman,
  Requirements Definition Task Manager, SPSA Project, JPL
- Orientation to Workshop Goals
  Doug Kruschke, Staff, Energy Services Consulting (ESC)
- DOE Solar Thermal Power Programs
  James Rannels, Program Manager, Division of Solar, DOE
- History and Overview of JPL
  Roger D. Bourke, Asst. Section Mgr. for Solar, JPL
- Solar Thermal Power Technologies
  John E. Bigger, Electric Power Research Institute (EPRI)

(Break)

- Small Power Systems Applications (SPSA) Project Overview
  Alan T. Marriott, Technical Mgr., SPSA Project, JPL
- Technologies for SPS Applications
  Robert R. Ferber, Requirements Defintiton Task Mgr.,
  SPSA Project, JPL
- Solar Power Research at EPRI
  John E. Bigger, Project Manager (Solar Thermal Technology),
  EPRI
- Solar Power Research at SERI
  Charles J. Bishop, Senior Staff, SERI

- The Southwest Project

  Kenneth Hogeland, Principal Engineer, Stone and Webster Engineering Corp.

EVENING

Informal Social Hour

TUESDAY, OCTOBER 11, 1977

MORNING

Comparing Power Options (Panel Discussion)

MODERATOR:

Vincent C. Truscello, Manager, Solar Thermal Power Systems Projects, JPL

PANELISTS:

Merwin Brown, Manager of Research, Arizona Public Service Company

Frank Goodman, Resource Development Engineer, Los Angeles Department of Water and Power

Peter Steitz, Planning Engineer, Burns & McDonnell

(Break)

Orientation for Workshop Discussion Sessions

Mike Van Horn, Project Manager, ESC

Solar Thermal Power: Institutional Issues

Overview Presentation

Robert L. Mauro, Director of Energy Research, APPA

Small Group Discussions

Lunch

AFTERNOON

Environmental and Siting Issues

Overview Presentation

Edward J. McBride, Systems Engineer, Black & Veatch

Small Group Discussions

Financial Issues

Overview Presentation

Tifton Simmons, Jr., Vice President, Smith, Barney, Harris Upland & Company

Large Group Discussion

EVENING

Dinner Presentations

Solar Architecture in the Aspen Area

Gregory Franta, Architect, Sundesigns

Energy Storage

Thomas R. Schneider, Project Manager, EPRI

WEDNESDAY, OCTOBER 12, 1977

MORNING

Workshop Sessions Orientation

Doug Kruschke, Staff, ESC

Sites for Experimental Solar Thermal Systems

Overview Presentation

Herbert J. Holbeck, Field Test Integration and Management Task Mgr., SPSA Project, JPL

Small Group Discussion

Small Utility Planning

Overview Presentation

Peter Steitz, Planning Engineer, Burns & McDonnell

Thomas J. Kuehn, Commercialization Analysis Task Manager, SPSA Project, JPL

Large Group Discussion

Lunch

AFTERNOON

Workshop Wrap-Up

Peter Klock, Project Director, ESC

Dave Evans, Staff, ESC

Doug Kruschke, Staff, ESC

Final Remarks and Workshop Closing

Robert R. Ferber, Workshop Chairman,
Requirements Definition Task Manager, SPSA Project, JPL

EDITOR'S NOTE:

The speakers at the workshop made numerous references to federal solar projects. These projects are now all under the direction of the Department of Energy (DOE), though many were begun under the Energy Research and Development Administration (ERDA) or the Federal Energy Administration (FEA). Programs begun and completed under agencies such as ERDA or FEA are referred to as such. Future and ongoing programs, begun by extinct agencies, are understood now to be part of the activities of the DOE.

Summary & Conclusions 2.0

The Small Power Systems Solar Electric Workshop was conducted by JPL in order to gain input from the utility community in identifying the important issues and requirements involved in the adoption of solar thermal power technology. It was quickly observed that most of the problems typically encountered in the implementation of a new technology, or the siting of new power plants, also apply to solar thermal power. However, some issues and conclusions peculiar to solar did arise out of the workshop discussions:

- A need exists for clarification of the public image (or opinion) and expectations regarding solar energy utilization. This issue requires widespread information dissemination to the public regarding the real potential of solar power and its timing for commercial use
- Utilities must develop new methods of generation mix planning when considering solar equipment
- Successful commercialization will depend in part on the demonstration of the economic feasibility and market potential to reduce the degree of risk and uncertainty enough to stimulate private investment decisions
- Utility adoption of the new technology will also depend on the existence of a strong industrial system that can support the construction, operation and maintenance requirements of the utilities

- The utility planning process will require the timely availability of comparative technology assessments, including lifetime cost and performance, environmental impacts and utility expansion and dispatch models at least 10-15 years prior to commercial introduction of the SPS technology
- As solar technology is developed, utility companies along with public agencies must develop innovative planning

strategies if expansion of installed capacity through the purchase of solar electric generating equipment is to be accomplished

- New siting and licensing regulations and techniques must be created to deal with the safety and environmental considerations specific to focusing solar collector systems
- Experimental solar installations must be operated in a fashion that is attractive and inexpensive to the host utility/community
- Commercialization of solar thermal power systems may require special participation on the part of the government in providing incentives to industry
- Solar technology has a much higher public visibility than most conventional generating systems
- The siting problem for the first SPS experimental plant will require careful study prior to issuance of the site request for proposal, if some segments of the electric utility industry are not to be effectively excluded from the site competition
- Generally, solar power is an energy form requiring new types of financing, utility plant equipment planning and commercialization activities.

A more extensive list of observations made by the workshop participants on specific topics is included after each presentation in Section 5 of these proceedings.

The results from a written evaluation at the end of the workshop indicated that all of the attendees benefitted from their participation. The major benefits included the development of:

- An understanding of the goals and plans for Small Power Systems Applications program
- A better understanding of solar technology

- An opportunity to influence the future development of the program.

The workshop was viewed as successful and productive by virtually all of the individuals involved. It has opened a communication channel between JPL and the utility community, as well as aided in the initial definition of requirements. Nearly all of the participants indicated a desire to have further involvement with the Small Power Systems program through a variety of means, according to the needs of the program as it develops. As a first step, JPL has prepared and mailed a workshop summary to participants. Other planned communications and involvement activities include:

1. This Workshop Proceedings Document
2. Future workshops and seminars on programmatic topics
3. Individual meetings with utility industry representatives
4. Technical paper presentations on SPSA topics at electric energy-related technical meetings
5. Magazine and journal publications.

The workshop was an important step towards making the Small Power Systems Applications Project successful. The information gained by JPL will definitely be of use in program planning and implementation.

Overview Presentations 3.0

3.1 WELCOMING COMMENTS - ROBERT R. FERBER

Small Power Systems Solar Electric Workshop

Good afternoon. I'm Bob Ferber of JPL and I would like to welcome you to Aspen and the first Small Power Systems Solar Electric Workshop. Why should electric utilities be interested in a small solar power systems program or in this workshop? Each of you might want to think about that.

We hope that each of you can leave this meeting on Wednesday feeling that it has been of value to you to have attended. I'm sure the meeting will be of value to us if we meet any of our objectives:

- o Establish communication channels with utilities which might utilize small solar thermal power plants
- o Inform the electric utility representatives about the Small Solar Thermal Plant Project, its technology and potential
- o Identify the needs that might be served by small solar thermal electric power plants
- o Identify specific problems and limitations related to small utility applications of solar thermal electric power plants
- o Enlist the support of electric utility operators and provide effective communication channels through which the utility users can affect the direction of the project during the developmental stage.

To accomplish our objectives, we have planned a program and technology overview this afternoon, followed by interactive workshop sessions tomorrow and Wednesday on several specific small power systems areas of interest.

Solar research today consists of programs in:

- o Solar photovoltaics

- Solar thermal
- Wind
- Ocean thermal energy conversion
- Biomass.

We'll hear more about these technologies later today.

The Small Power Systems Program is a new solar thermal program which fits between the large central station program, exemplified by the pilot plant to go in at Barstow, and the user site-related total energy and irrigation programs managed by Sandia Laboratory. Both of these programs have been underway for years and the SPS program is officially less than three months underway at JPL.

Because of the recent program start, we are, in a sense, playing a catch-up ball game in comparison to the other, better established, solar programs. We need very quickly to develop a close working relationship with the ultimate customer, the electric utilities, and solicit information from them which can be used in the hardware engineering and development work.

This is an opportunity for the utilities to get actively involved in the shaping of this program and in influencing the hardware designs which may ultimately be used by them. This early feedback can best be initiated through a workshop-type of meeting.

JPL is looking for both general utility feedback which can be used in programmatic decision-making and for specific site-related feedback useful in planning the site procurement for the first experimental power plant. JPL also has a goal of using this workshop and its proceedings for information dissemination to the utility industry about the SPS program.

The workshop is structured in a way which should produce these results and be of significant value to everyone assembled here today. Principal topics to be covered are:

- SPS program/projects
- Solar thermal technologies
- EPRI R&D activities
- Power options
- Institutional issues
- Environmental and siting issues
- Financial issues
- Energy storage
- Small utility planning.

JPL has contracted with Energy Services Consulting for workshop management and to handle the mechanics of the workshop. They have a highly-qualified staff of persons here who are prepared to supervise the interactive program, provide workshop support services and prepare a volume of workshop proceedings which should be available for widespread distribution in a few weeks.

It is the ESC workshop discussion group leaders who can do most to facilitate these sessions. For complete success, however, each of you must endorse the methodology and participate actively in the sessions.

Before continuing with this afternoon's program, I will ask each of you to stand up now and give a brief introduction.

3.2 DEPARTMENT OF ENERGY SOLAR THERMAL POWER PROGRAMS - JAMES RANNELS

Program Manager, Solar Division, Department of Energy

I'm with the Department of Energy, and I'd like to talk a little with you about the DOE.

Dr. James Schlesinger, the Secretary of DOE, along with the President, has expressed a great deal of interest and support for the national solar program. Indeed, at the program level, the program managers, formerly with ERDA, are now in DOE and are continuing to implement the program.

The ERDA Division of Solar Energy has been divided into two portions. One is going to the Assistant Secretary of Conservation and Solar Applications. This portion primarily involves the heating and cooling of buildings and industrial process heating programs. The electric technology development program has been placed under the Assistant Secretary of Energy Technology. Bob Thorne has been nominated as our Assistant Secretary. He was formerly the manager of our San Francisco operations office. We're very encouraged to have Mr. Thorne nominated.

The DOE is also bringing together a lot of people from other energy organizations, such as the Federal Energy Administration, the Federal Power Commission, the Department of the Interior, the Energy Research and Development Administration (ERDA) and part of the Bonneville power operation. The small power systems program was initiated by ERDA which includes about 9,000 people. The Department of Energy is now 20,000 strong, so the aggregate number of employees has increased dramatically.

In the Energy Technology Group of the Division of Solar Energy, various power systems are being investigated. These include:

- Solar thermal systems
- Photovoltaic systems

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- Ocean thermal electric conversion
- Wind systems.

In the solar thermal program, there are four application areas:

- The central station program, which includes the 10-MWe project to be located in Barstow, California. This is an exciting project that holds out potential for significantly advancing the state of the art. The 5-MW thermal test facility in Albuquerque, New Mexico, is almost complete.
- The small power systems program
- The irrigation program -- for which there's a system constructed at Willard, New Mexico. That's a 25-hp mechanical energy system with direct drive of the pump. There will be a much larger unit, 200 hp, built in Coolidge, Arizona, which is currently under design. It will be an operating deep-well irrigation project in a few years.
- The total energy program is developing systems which produce electricity and thermal energy.

The five-megawatt solar thermal facility installed at Albuquerque, New Mexico, is a good test system for the central station technology. The system includes a field of heliostats and several receiver test positions for the flexible testing of our central receiver boilers. It's intended to be a flexible test facility that will allow us to test many of our components. This experimentation can apply both to the central station applications or large systems, as well as the smaller systems.

The irrigation program includes a shallow-well project that has been operating in Willard, New Mexico. The solar technology employed uses a system of distributed parabolic troughs. It has been operating since July, 1977, and is rated at 25 hp. The aperture area is approximately 600-square meters.

The agricultural experiments associated with the shallow-well irrigation project are being run for the DOE by the University of New Mexico. This installation is a center-pivot irrigation unit, which presently does not generate enough power to run both the center-pivot irrigation unit and to raise the water up from the shallow well. We will expand the system later this year, so that it will have the capability of performing both the pumping of water into the holding pond and provide sufficient pressure to operate the center-pivot irrigation unit. The deep-well irrigation project is currently under design.

The total energy program has two sites that have been selected for the construction of systems. One of these sites is in Fort Hood, Texas. It will be on the order of 500 kWe and about one to three megawatts thermal, depending on the final design. We have now completed the conceptual design and have initiated the hardware design. The other total energy-system site is at Shenandoah, Georgia.

However, we've come here today to talk about the Small Power Systems Program. It has a very simple objective:

> To provide an economic solar thermal power technology that will supplement and replace nonreplaceable energy sources, such as gas, oil, coal and, to some degree, nuclear, in the 1- to 50-MWe plant size range.

I would like to move now to the subject of cost. We've carried out a number of systems studies, as part of our program activities, that, in specific instances, indicated economic viability for the small power systems program. One study was carried out by the Aerospace Corporation. Obviously, the cost items that are of interest to you include both first cost and O&M cost. The precision with which we can address those items is primarily a function of the status of the technology. Right now, the technology is fairly uncertain; nevertheless, we know the general approach we'd like to take. We expect to get a better handle on first cost before we have figures on O&M and the last thing we'll obtain good data on is reliability.

We have a small power systems technology development activity that will be ongoing. We now have a solicitation for contractor selection for design of the first experimental small power system. Site selection has not yet been released, but we're looking forward to that in the near future.

3.3 HISTORY AND OVERVIEW OF JET PROPULSION LABORATORY.- ROGER BOURKE

Assistant Section Manager for Solar, Jet Propulsion Laboratory

INTRODUCTION

The Jet Propulsion Laboratory is a contractor-operated government laboratory, performing scientific and technical research and development and systems and project management in space exploration, energy and various other technical fields. It is staffed and operated by the California Institute of Technology, in Pasadena, California, under contract to the National Aeronautics and Space Administration. It has worked within the framework of federal programs for nearly four decades and, in recent years, has broadened its involvement with state and local governments and private institutions in the conduct of tasks in the civil sector.

The Laboratory is simultaneously a government laboratory, in working contact with other government facilities, and a university laboratory, maintaining close ties with the Caltech campus and other academic institutions. It associates with the scientific community in the conduct of space flight missions and with Caltech and other universities in studies and research and development on problems of the civil sector. In the latter field, it has close contacts with state and local governments and with appropriate industries, both as collaborators and as sponsors, and JPL makes extensive use of industrial firms and university laboratories as subcontractors for various tasks.

HISTORICAL DEVELOPMENT

The Jet Propulsion Laboratory began nearly 40 years ago as a small rocket-research project of the Guggenheim Aeronautical Laboratory, California Institute of Technology. In the early 1940's, the use of project objectives as a focus for the application of various engineering and scientific disciplines began with the development of several rocket systems. The addition of more sophisticated projects in the late 1940's and the 1950's broadened the technical-discipline base, resulting in greater testing emphasis and development of facilities, such as the supersonic

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wind tunnels and the White Sands Missile Range, and stimulated increased institutional collaboration with governmental sponsoring agencies and industries. JPL became the lead center for Army Ordnance surface-to-surface guided-missile development in this period, which culminated in the launch of Explorer I, the first U. S. earth satellite, developed by the Laboratory in 1957-58.

During the transition to space exploration as a prime mission and to NASA as a sponsor, the Laboratory's technical base and field of institutional interactions increased greatly. Their period of solar system exploration was one of growth in technical scope and depth to meet large scientific-exploration challenges, and the methodology of system analysis, engineering and management was well established. Creation of the worldwide Deep Space Network for tracking and data acquisition in planetary exploration was a large aspect of institutional growth in this phase.

A new class of activity in the application of Laboratory capabilities and systems methodology to problems of the civil sector developed in the late 1960's. New applications studies, research and development, and interdisciplinary system and project teams began to address a new diverse class of problems, each with social, environmental and economic implications, so that the new challenge was the analysis and integration of these powerful nontechnical factors in conjunction with technology development.

TECHNICAL CAPABILITIES

The Laboratory's technical strengths, developed over the years in the pursuit of its missions, cover several broad engineering and scientific disciplines. These include mission and system engineering, power-system technologies, applied mechanics, communications/command-and-control/data-handling and applied physics and chemistry. With the entry into civil applications of technology, JPL has recently augmented its predominantly engineering- and hard-science-oriented staff with professionals from social science fields, including economics, policy analysis and business management.

A major capability not represented as a technical area of expertise, but requiring special note, is project and systems management. This capability has been developed over many years and spans a breadth of activity, from preliminary planning and project design, to procurement, to dissemination of results. Personnel involved in these activities have had, for the most part, other initial training and career experience in a technical discipline. The project management tradition at JPL, however, has developed to include the total capability necessary to assure successful attainment of project goals and thus encompasses expertise in financial and contracts management, procurement, documentation and quality control.

The Laboratory's organization has evolved to provide rapid response to sponsor needs while retaining a broad spectrum of long term capability. The orientation toward goals and the maintenance of technical excellence constitute the two dimensions of the matrix organization which assures effective implementation of complex and difficult tasks, demanding both managerial and technical skills.

The matrix organization functions through a group of technical divisions, each centered upon a cluster of discipline capabilities, interacting with a group of program and project offices, each centered on a class or an explicit set of sponsor needs and requirements. The technical divisions employ and develop technical staff and develop and maintain special facilities in their discipline areas, while contributing to the advancement of their disciplines. The program/project offices are responsible for understanding sponsor requirements, negotiating scope of work, schedule and resources with the sponsor, interacting with the divisions to assemble project teams or assign special tasks and managing the efforts on behalf of and responsible to the sponsors.

LABORATORY STAFF PROFILE

More than half of the Laboratory staff of just over 4,000 consists of professionals in science and engineering, with the engineering disciplines dominating. The full-time staff is augmented to the extent of about 10 per cent by academic part-time employees, both student and faculty, representing Caltech and several other local universities and colleges. In addition, on-Lab contractor employees (engineers, technicians and support personnel) serve various short term needs.

Among degree-holders on the staff, Ph. D. and professional degrees constitute 20 per cent and Master, 35 per cent. Degrees in the sciences make up 32 per cent of the population, while engineering degrees consitute 63 per cent.

Organizationally, two-thrids of the Laboratory staff comprises the Technical Divisions, permanent staff of the program and project offices is approximately four per cent of the total and the balance is administrative and general management staff.

Over the years, the JPL staff has evolved from a mix which emphasized total in-house engineering and development to one in which industry is used more extensively. As industry has assumed more responsibility for fabrication, subsystem development and system integration, the engineer/scientist proportion increased from one-third to just over one-half, while the percentage of technicians, clerical and service employees has declined accordingly.

FACILITIES

The Laboratory's Pasadena site encompasses 175 acres (146 acres are government-owned, the remainder, leased). Here, 20 major modern buildings and many other structures provide 440,000-square feet of office space and 780,000-square feet of laboratory and other space. The total investment is some $200 million. Technical facilities include many specialized laboratories and test complexes, test ranges, a large Assembly Facility and an Isotope Thermoelectric Systems Applications Laboratory, as well as environmental test laboratories, which include large solar simulators of 10-foot and 25-foot diameters. Computing facilities include two owned Univac-1108 systems and two owned IBM-360-75 systems, additional leased systems and various smaller equipment.

Remote sites in Southern California include a test station at Edwards Air Force Base, in the Mojave Desert, used for propulsion-system and energy-related environmental testing; the Table Mountain planetary observatory and solar-array test site and the Goldstone Deep Space Station. The latter is the oldest and most fully-equipped tracking station of the Deep Space Network and is used for a variety of test and research activities, such as microwave power-transmission experiments. It operates in conjunction with similar stations in Australia and Spain and Mission Control at JPL, in Pasadena.

3.4 SOLAR THERMAL POWER TECHNOLOGIES - JOHN BIGGER

Solar Thermal Project Manager, Electric Power Research Institute

INTRODUCTION

Why should the utility industry be interested or involved in developing solar thermal technology? Things usually happen first in California, so let me relate something to you.

Pacific Gas and Electric Company, located in San Francisco, recently submitted Notice of Intent to file for an application for a nuclear plant to the California State Energy Commission. Part of the Energy Commission's responsibility is to license sites for power generation. Last week, this Notice of Intent was returned and the statement was made that Pacific Gas and Electric did not address the question of supplying this energy to its customers with alternative resources. Energy commissions, public utility commissions, city councils, various other organizations will be asking such questions. So, we need to acknowledge that it's very important for people in the utility industry to find out what the alternatives are.

The second reason why the utilities should be involved is that the federal government is spending a lot of money developing solar power systems and the electric utility industry is going to be the major market. The power generation facilities of the future and the advanced technology equipment will be purchased, built and operated by the electric utilities, themselves. So, I think it's important that the utility industry indicates its requirements and preferences for power generation equipment and finds out exactly what these new systems are all about.

STATE OF TECHNOLOGY

The development of new technology goes through a number of phases. The most important factors that have to be identified are the dollars required, the time required and the technical resources required for each phase.

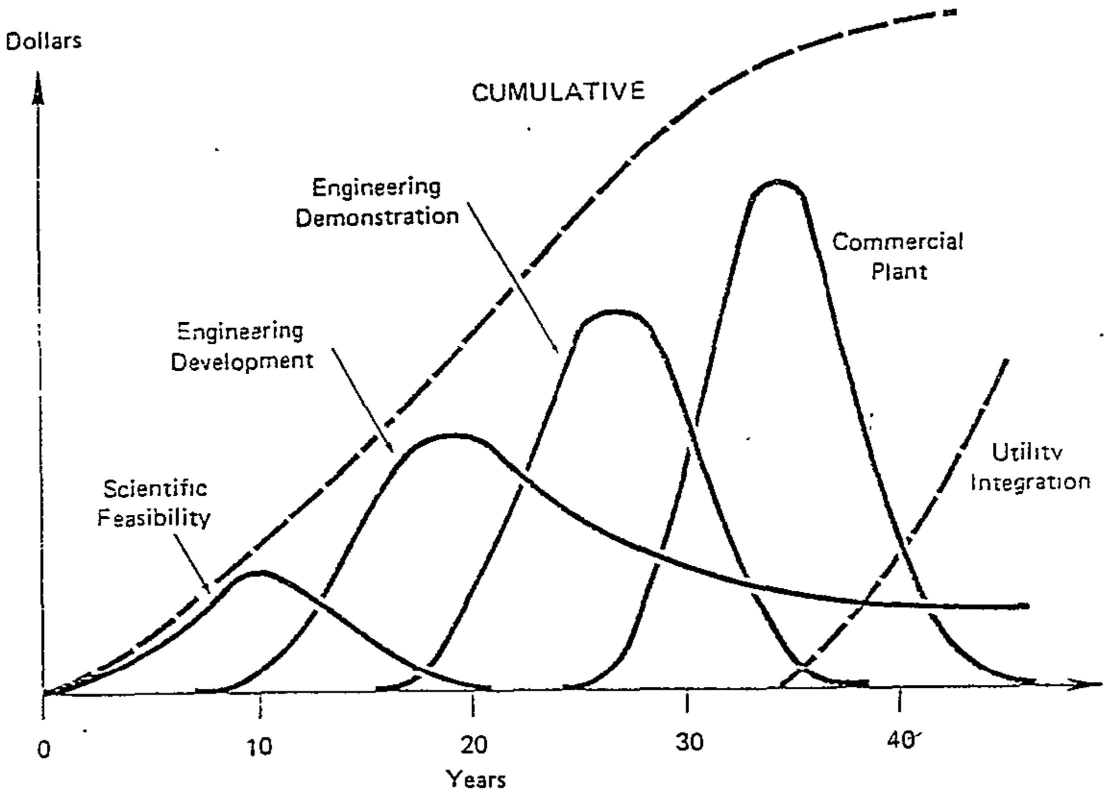

Figure 3.4-1 Phases of R&D

In developing a new technology for commercial application, there are a number of stages. The solar technology has the benefit of work in the early part of this century. We've had a number of water-heating and water-pumping projects throughout the world since the early 1900's. So, today, we're not really starting from scratch.

One of the factors in development is that each succeeding phase costs more money. When people see the price tag for moving from a laboratory model to a demonstration, or a demonstration model to a commercial plant, they want to sift and filter out some of the alternatives, since we don't have the money to bring all of these alternatives to some stage of development to compare them.

There is considerable overlap in projects. In some areas where we are doing development work, there's a lot of information that's really not available and we have to do basic research. But, the important thing to realize is that it takes quite a bit of time to bring this new technology to where it makes a big dent in the commercial market. I know this is true with solar thermal systems. A good example of a time line is the central station application. More money has been invested in this area than in the distributed systems. The solar thermal work started in the late 1960's and, since about 1971, larger and larger amounts of money have been going into these central receiver programs. The 10-MW pilot plant is planned to be operational in late 1981, in Barstow, California, with a water-steam system. The plant, which we are working on at EPRI, is the Brayton-cycle central receiver system. We are about a year behind the ERDA 10-MW project. In Europe, the International Energy Agency is planning a 500-kW project with liquid metal heat-transfer fluid. The French have a project on the way that is using a heat-transfer oil; this is also a central receiver project.

If we go down the time line to a fairly large demonstration model in the middle eighties, the commercial plants won't come on the line until well into the nineties. So, they really won't have much of an impact for another 20 years. The smaller solar thermal systems have a slightly shorter time line.

An overview of the generic types of systems show:

- o The central receiver system ($\approx 2000^{\circ}$F)
- o Trough systems ($\approx 1000^{\circ}$F)
- o Dish systems ($\approx 1500^{\circ}$F)
- o Flat plate ($< 350^{\circ}$F).

The name of the game is efficiency in electric power generation. If we have a low-efficiency system, first cost will be high. The geothermal people are struggling with this in some of their developments when they are looking at 500° and 600°F resources and wind up working with hydrocarbon turbines and binary cycles. You need at least 1000°F to achieve reasonable efficiencies. The central receiver, parabolic trough and dish systems are theoretically capable of reaching 1000°F. As for trough systems, there is a question, whether from an optical or thermal standpoint, they will achieve those temperatures. We believe the dish systems probably can achieve efficient operating temperatures.

We are supporting two Brayton-cycle central receiver systems at EPRI. One, a closed-cycle gas system, will have an operating gas temperature in the 1500°F range; and the second one, an open-cycle air system, will have an operating gas temperature in the 1900° to 2000°F range. So, we are pushing to get the temperature up to increase the efficiency in these systems.

EPRI is funding the development of a trough concept by General Atomics. Some of these units will be installed at Albuquerque during the first part of 1978 under an ERDA contract. This design has demonstrated capability to operate at about 600°F. We hope the capability of this unit will be 1000°F.

Previously, EPRI funded the development of a spherical dish solar thermal system. The commercial-size dish is approximately 100 meters in diameter. This can be scaled down, we believe, to smaller size so it could be applicable for a wide range of applications of various size.

To go back to the central receiver systems, an idea of the magnitude of land area would be that a 100-MWe pilot plant with about six hours of storage, would take up one square kilometer. So, we are talking about large land areas.

SUMMARY

You may ask, "Where are we today?" Both the Federal Government and EPRI have done a great deal of work with the central receiver concept, so we have some fairly good cost estimates. But, some of the costs are high and seem unfavorable, when compared with today's energy system economics.

Both the Federal Government and EPRI have spent considerably less on distributed receiver systems. Recently, we have seen some figures being spread around that show smaller distributed systems are lower in cost. You must be aware that with many designs we aren't at the same point of development as with the central receiver concepts.

Let me leave you with this thought: Based on considerable experience in developing high technology energy systems, Dr. John E. Cummings, the EPRI Solar Program Manager, has come up with his "Inverse Law for the Value of Ignorance:"

$$\text{Capital Cost} = \frac{1}{\text{Level of Ignorance}}$$

The closer we come to building a system, the higher its cost becomes.

3.5 SMALL POWER SYSTEMS APPLICATIONS - ALAN MARRIOTT

Technical Manager, Small Power Systems Applications Project, Jet Propulsion Laboratory

One of the main purposes of this workshop is to introduce the solar thermal program to the utility industry, which is a potential user of the systems developed in these programs. Of particular interest at this meeting is the Department of Energy Small Power Systems Program. I will describe one element of that program, the Small Power Systems Applications Project, which is being managed by Jet Propulsion Laboratory (JPL).

I will define small power systems and discuss the issues related to them and the goals of the program. I'll also comment on how we have organized to meet those goals and will give you a brief summary of near term plans and current activities. My talk will be followed by a discussion of the technologies that presently are candidates for the Small Power Systems Program.

JPL has established three projects in support of DOE's Thermal Power Systems Office, Division of Solar Energy:

- Research and development project
- Point-focusing distributed receiver technology project
- Small Power Systems Applications Project.

The first of these was established about a year ago and is concerned with the definition and planning of research and development activities for the solar thermal program. As such, it covers all technologies currently being considered in this program. The other two projects are part of the Small Power Systems Program.

The point-focusing distributed receiver project will develop that specific type of solar thermal system in support of application projects. Bob Ferber will discuss this approach in more detail.

In the Small Power Systems Applications Project, we are examining various uses for a variety of technologies that fall within the SPS range of interest. It is within this project that we are seeking to establish an interface with the using industries, the first of which is the utility industry that serves the small communities of this country.

In order to give you some idea of what we mean by small power systems, I have written down a few characteristics which will help define them:

- Solar thermal conversion technologies
- 1- to 50-MWe size range
- Technology options include:
    - Point-focusing distributed receiver systems
    - Line-focusing distributed receiver systems
    - Small central receiver systems
    - Rankine, Brayton, Stirling conversion

First, we are concerned only with solar thermal technologies; i.e., not photovoltaics, wind, ocean thermal, or any other means of generating electrical power from solar energy. We are looking at applications and systems that generally fall within a 1- to 50-MWe range. This, then, distinguishes the small power systems from the larger central receiver systems being developed for central power applications.

We will consider all solar thermal technologies for a given application until one emerges as the most appropriate. Therefore, point-focusing, line-focusing and central receiver systems employing Rankine, Brayton or Stirling conversion are all candidates.

Finally, to some extent, the small power systems are defined by their applications. These are some examples of potential applications:

- Small community electric power
- Remote load centers, such as Department of Defense installations
- Rural electric power, such as large feedlots
- Industrial loads
- Other countries; we may consider the foreign market for these systems as a means of bringing them to the point of commercial acceptance at an earlier date than might otherwise be possible by restricting ourselves to the domestic market.

The Small Power Systems programs fill a gap in the DOE's technology and applications programs:

- For power requirements less than one MWe, there are two programs. The solar irrigation and total energy systems programs being managed by Sandia, Albuquerque, have this capacity
- The central receiver program is aimed at requirements that generally fall above 50 MWe.

The SPS Program also provides a dispersed power capability. The inherent modularity of small systems allows the possibility of small scale testing, lower initial capital investments and the potential for earlier commercialization.

Another reason for the program lies in the fact that there appear to be several potential applications for these systems. An example is electric power for small utilities. Figure 3.5.1 shows a representative distribution of small utility loads and it is clear that there are many utilities that have requirements below 50 MWe.

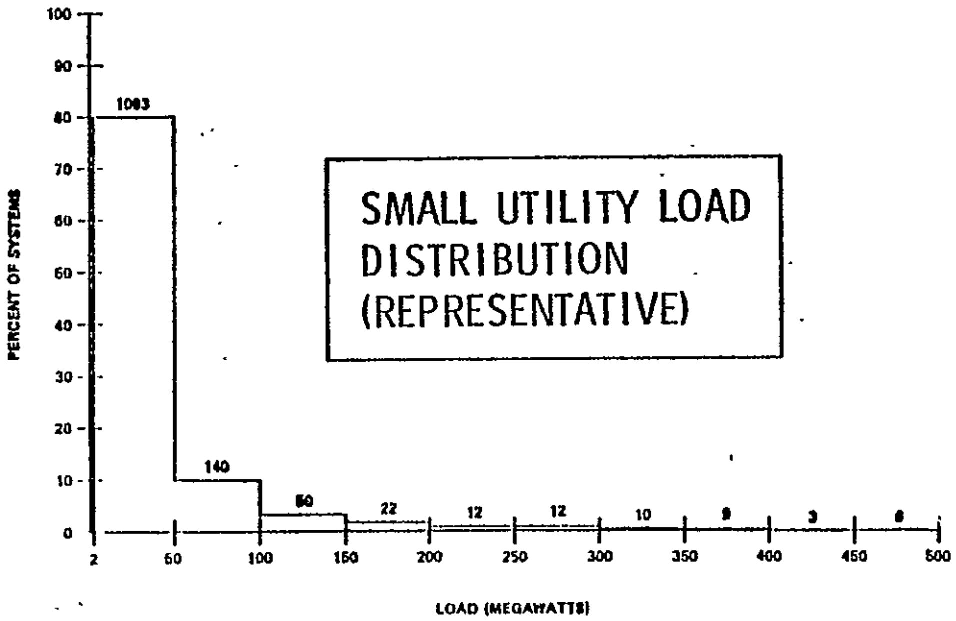

Figure 3.5-1 Small electric power systems
Source: EPRI Workshop on the R&D Requirements of Small (Municipal) Electric Utilities, December 1-3, 1976.

These are the principal issues that we see as we start the Small Power Systems Application Project:

- What is the need for small solar power systems?
- What solar energy technology best meets the need?
- Are the economics of the solar alternative attractive?
- What are the institutional, societal and environmental considerations important to commercial success of small power systems applications?
- Is there a sufficient overall benefit to warrant acceleration of commercialization by government involvement?
- What is the appropriate commercialization strategy?

We will deal with all of these issues in the course of this project.

To summarize: The overall program goal is to develop the technology and to promote the commercialization of small solar power systems in the 1- to 50-MWe range, providing the concept is shown to be of sufficient benefit.

To accomplish this goal, JPL has put together the organization shown in Figure 3.5-2. Activities have been broken into four major task areas, each headed by a task manager. Bob Ferber is responsible for the requirements definition area. It is here that potential applications are defined and their requirements determined. We will rely on the Aerospace Corporation in this area, since they have the responsibility for supporting the DOE in the applications analysis area in this and several other programs. It is also in this area in which we will seek to establish the interface with the utility industry.

The systems definition area is headed by Randy Womack. This area is concerned with the development of the technologies to meet the needs of the various applications.

Tom Kuehn is in charge of the commercialization task area. This task is a broad umbrella over the project. Here we will identify the factors that will affect the eventual commercialization of the small power system technology for given applications. Institutional, environmental and social issues will be examined. If an accelerated commercialization program appears to be warranted, this task area will consider strategy for incentives and the government role in such a course of action.

The Field Test Integration Task Area is headed by Herb Holbeck. This area is concerned with site-specific issues associated with the experimental power plants or other experimental systems that will be a part of this project. The first task in this regard is the selection of a site for the first experimental power plant. Currently, JPL is in the process of developing site factors which will be important for this first experiment.

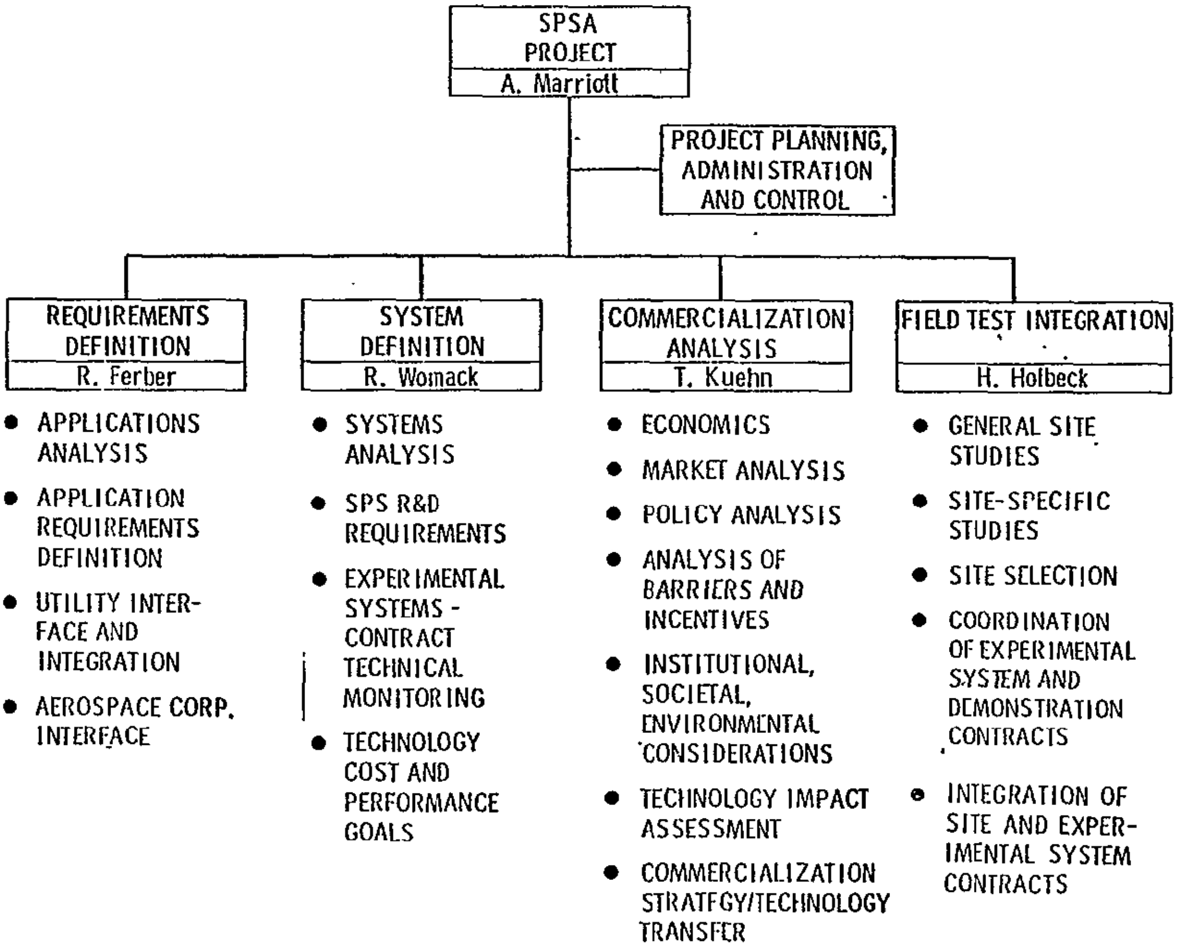

Figure 3.5-2 Organization chart of the Small Power Systems Applications Project

So, that's the organization. We have just started and we see many challenges ahead.

Figure 3.5-3 shows an overview of the Small Power Systems Program Schedule. Project management of the Small Power Systems Applications Project by JPL was initiated late in 1977. The applications analysis effort was started earlier by the Aerospace Corporation, who will continue to support the project under a contract with the Department of Energy.

Technology development refers to the Point-Focusing Distributed Receiver Technology Project, initiated later in fiscal year 1977, under the management of JPL. Other technology development programs, such as those being conducted by Sandia Laboratory, relative to the central receiver and total energy programs will, of course, also support the needs of the Small Power Systems Applications Project.

Three experimental systems (sometimes referred to as large scale experiments) are planned. The first is now underway with the release of the RFP for the first phase in mid-September. The first experiment will nominally be a one-MWe power plant, located in an as-yet-unspecified small community. The site will be selected as a result of a separate procurement during Phase I.(1) The other experiments are not defined yet and will depend on the results of application analyses conducted both at Aerospace and JPL. These experiments are roughly at two-year intervals and will continue until a decision can be made with regard to the potential for commercial success of selected technologies in conjunction with appropriate applications. The goal is to reach a full-scale commercial demonstration sometime after 1985.

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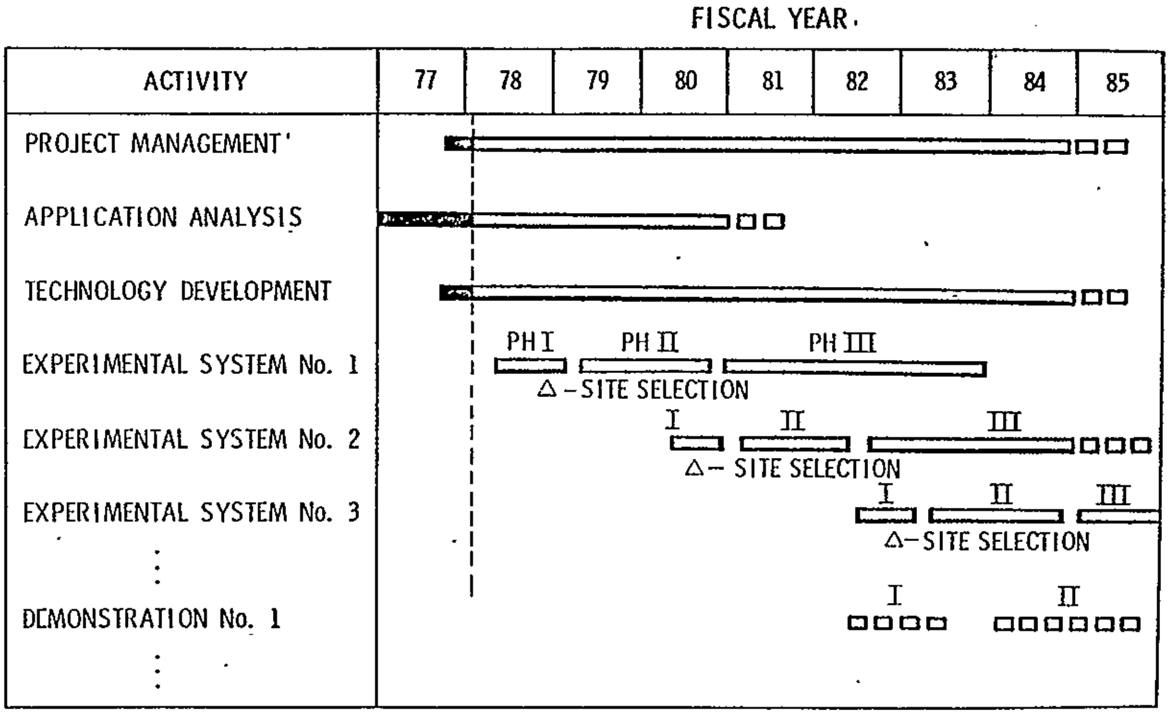
(1) A subsequent decision has delayed site selection to occur after Phase I.



* ONLY EXPERIMENTAL SYSTEM No. 1 IS DEFINED AT PRESENT TIME

Figure 3.5-3 Small power systems plan

Thus, the Small Power Systems Applications Project is proceeding on several fronts. We will explore the viability of various potential applications through market potential surveys, economic analyses and a definition of requirements for technology matching. Technologies will be analyzed and those exhibiting an attractive potential will be tested through the experimental program illustrated. Throughout the SPSA Project, a broadly based commercialization analysis will be conducted to consider barriers and incentives to successful adoption of small solar power systems for selected applications. The first application to be addressed and the subject of this workshop is electric power for small communities.

I would like to spend the last few minutes going into a little more detail concerning the first experiment.

We are in a sensitive stage of the procurement for the first phase of this experimental system and, therefore, no information not already in the RFP will be discussed. I want also to point out that JPL representatives at this meeting will not discuss the RFP, nor details of the first experiment beyond those given here.

The objectives of the first experiment are to:

- Investigate performance, functional, operational and institutional aspects of the selected system in a field test environment -- a small community, in this case
- Obtain a first order examination of economic factors associated with the technology and application
- Identify additional research and development used for small power systems
- Provide a means for involving the user community in the Small Power Systems Program.

Here are the main characteristics of the first experiment. It will be concerned strictly with solar thermal conversion technology:

- Solar thermal conversion technology
- Electric power only
- Not hybrid
- Integrated with existing utility in a small community
- One MWe -- nominal rated power output(1)
- Approximately three hours storage
- Nominal plant startup time ~4.5 years
- Schedule goal: operational by 1982 (RFP for Phase I issued September 16, 1977.

A three-phase program has been defined:

- I, System definition ~10 months
- II, Preliminary Design: component, subsystem and module testing ~1.5 years (nominal)
- III, Final design, fabrication, construction, test and evaluation ~3.0 years

Phase I will consider all potentially attractive solar thermal technologies. Thus, point-focusing, linear focusing, central receiver and other possible approaches will be examined either as a result of contracts awarded for Phase I or by independent studies conducted at government laboratories. Phase I will parametrically study rated power, storage and plant start-up time for each technology selected. On the basis of this information the system showing the most potential for eventual commercialization will be selected for Phase II.

There is a desire to emphasize near-term technologies for the first experiment; although, if necessary, some development of subsystems may occur in Phase II.

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(1) A range of power output from 0.5 MWe to 5.0 MWe will be studied in Phase I and the plant size selected on the basis of the results.

The site for the first experiment will be selected by the Department of Energy on the basis of a procurement to take place during Phase I. JPL will advise DOE in this regard.

That completes my presentation and I will be glad to answer any questions. Thank you.

3.6 TECHNOLOGIES FOR SPS APPLICATIONS - ROBERT R. FERBER

Task Manager, Requirements Definition, SPSA Project, Jet Propulsion Laboratory

There are two projects at JPL related to the Small Power Systems Applications (SPSA) Project. One is a technology project aimed at developing point-focusing systems; The other applications project, which will consider all of the appropriate solar systems technologies suitable for applications in the 1 to 5 MWe range.

We've all seen various pictures of solar power towers, or central receiver plants, as shown in Figure 3.6-1, where a field of two-axis tracking heliostats focus the sun's energy on a boiler or receiver. This technology is potentially applicable to our program, though in much smaller plant sizes than are now being contemplated. In the most commonly described conversion system, and the one to be used for the 10-MW pilot plant near Barstow, California, the receiver is a steam boiler, using 950- to 1000-degree steam which will go directly to a turbine or to a storage system. The storage is, in this case, thermal storage. Heat can be extracted from the storage and run through the turbine at a later time, as needed. The remainder of the system is a conventional steam-Rankine system (Figure 3.6-2).

Turning to distributed-collector technologies, Figure 3.6-3 shows an artist's sketch of a parabolic trough one-axis tracking system. There are several concepts that are applicable to the SPSA project that use only single-axis tracking and this system is one of them. In this case, of course, the heat is focused on a receiver tube, where it heats a working fluid, which is transported to a central point for conversion in a cycle similar to that used for the central receiver plant (Figure 3.6-4). Again, storage is thermal, with a conventional steam turbine-generator conversion system. Note, though, that the practical operating temperature

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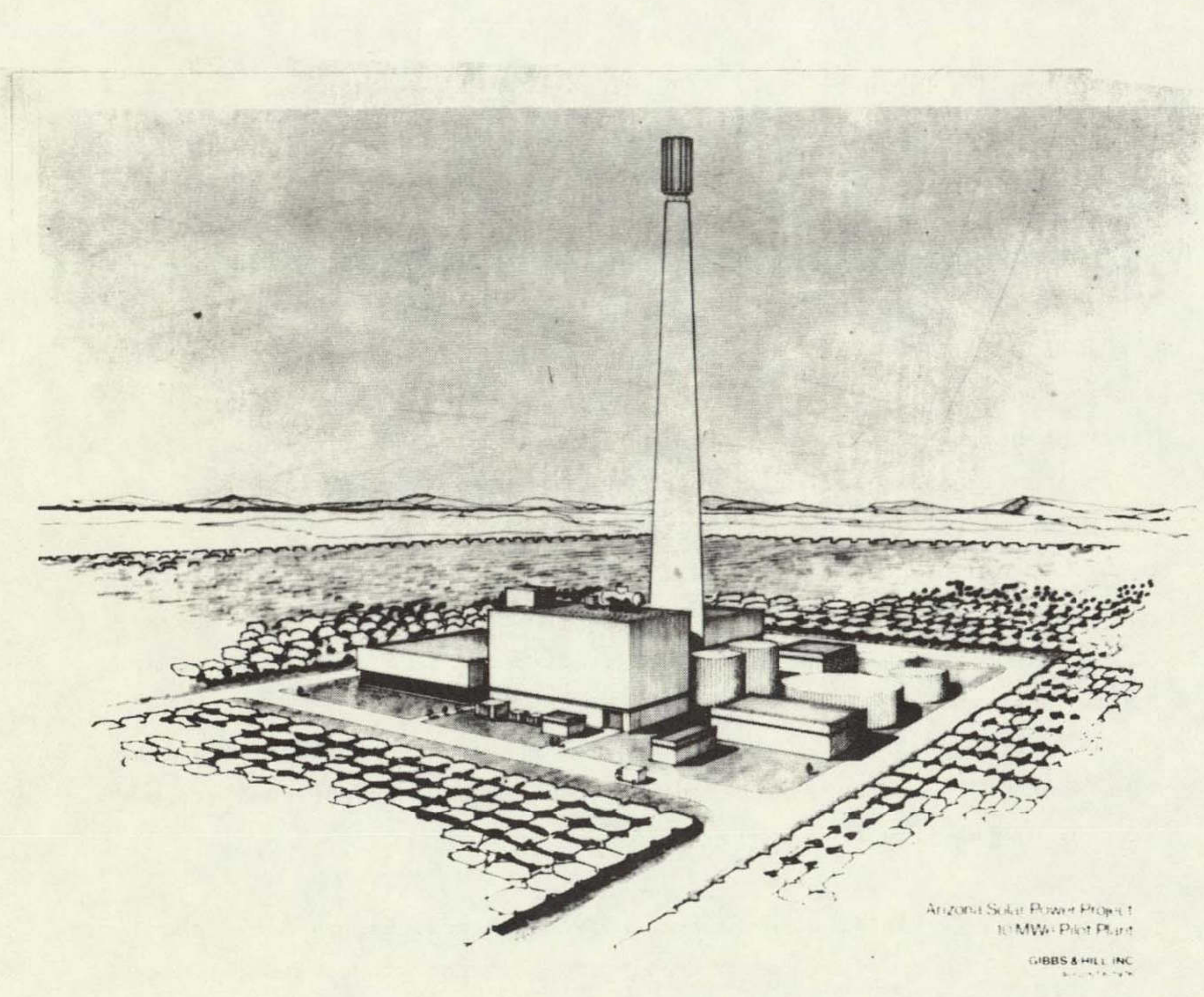

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Figure 3.6-1 Arizona solar power project 10-MWe pilot plant
(Gibbs & Hill, 1976)

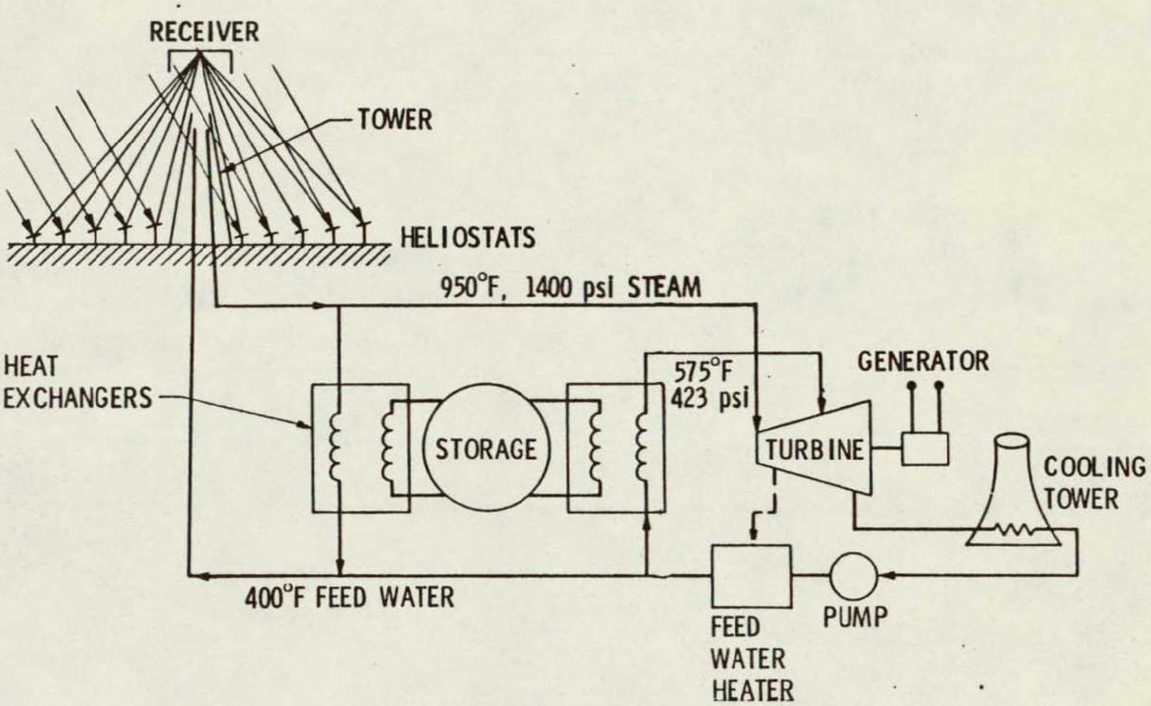

Figure 3.6-2 Central receiver solar thermal electric power plant

Figure 3.6-3 Parabolic trough one-axis tracking system

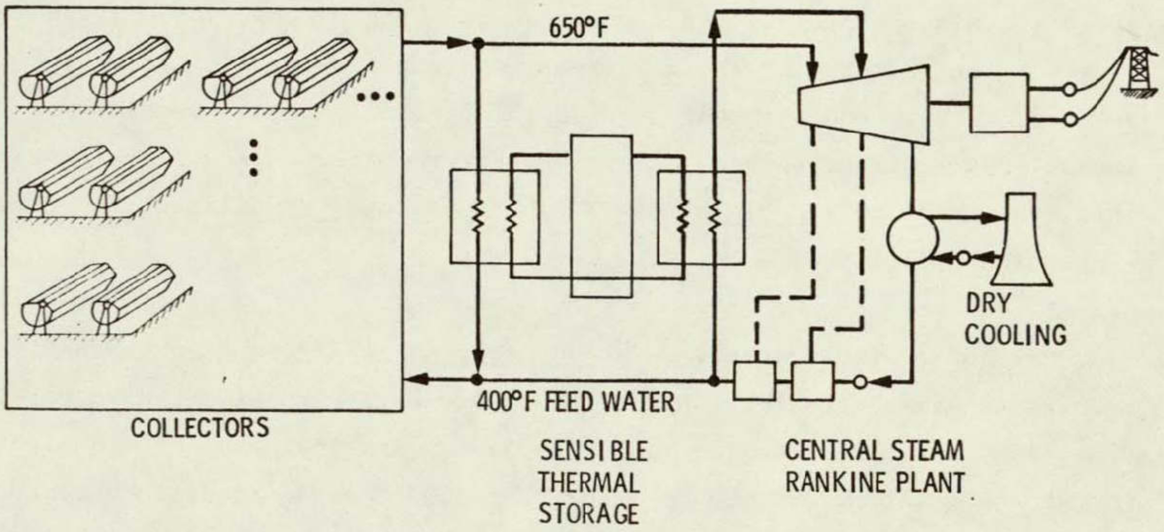

Figure 3.6-4 Parabolic trough steam transport

attainable by a trough system, approximately 650°F, is quite a bit lower that that for the central receiver. This limits the efficiency of this concept and requires that a larger collector area be installed for a given power output. This collector area increase generally means higher capital costs.

Another collection subsystem, using similar Rankine conversion system and thermal storage, is called a "variable slat" collector (Figure 3.6-5). The slats move to focus the sun's energy on a receiver mounted above the slats. Again, it's a one-axis tracking system, but now, because of the geometry of these systems, a linear cavity-type receiver may be used, rather than the tube used in the parabolic trough mechanism. This allows a higher working fluid temperature without excessive losses. This system may be capable of 850°F, which produces significantly better conversion efficiency.

Parabolic dish systems, as shown diagramatically in Figure 3.6-6, require two-axis tracking. Again, there are cavity receivers mounted at each dish, with steam collection to a central Rankine conversion and thermal storage system. Notice, though, that 1000°F steam conditions can be obtained from this system, which means still better conversion efficiency.

Another approach to parabolic dish systems is shown in Figure 3.6-7. Here, the dish focuses the energy on a heat engine and generator, which is mounted in the receiver area. The energy transport is then by means of electric power lines (Figure 3.6-8). This energy collection to a central point has lower losses associated with it. This approach requires the construction of small heat-engine units which are cost-effective, when compared to the large central units. Figure 3.6-8 shows that this approach is somewhat simpler than the central heat collection and conversion approaches. The only element missing from the main power plant using this conversion approach is the storage capacity, which can be located anywhere

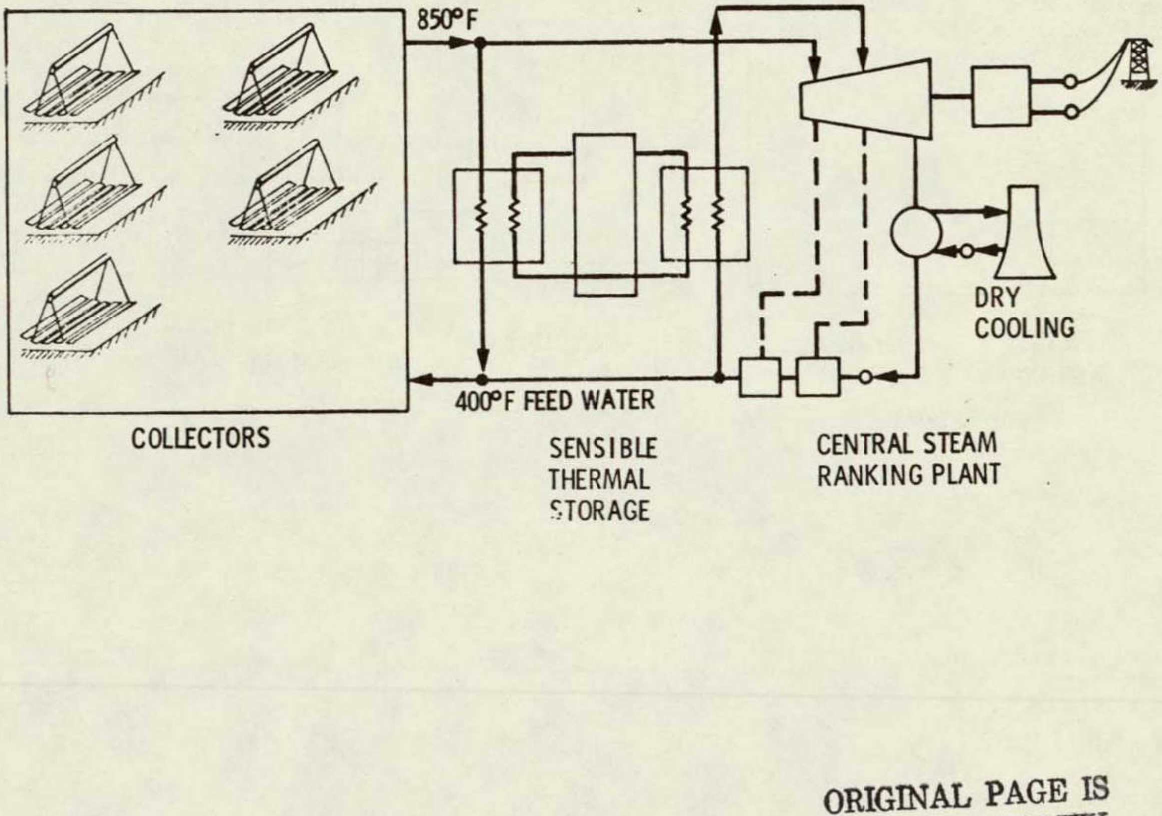

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Figure 3.6-5 Variable slats -- steam transport

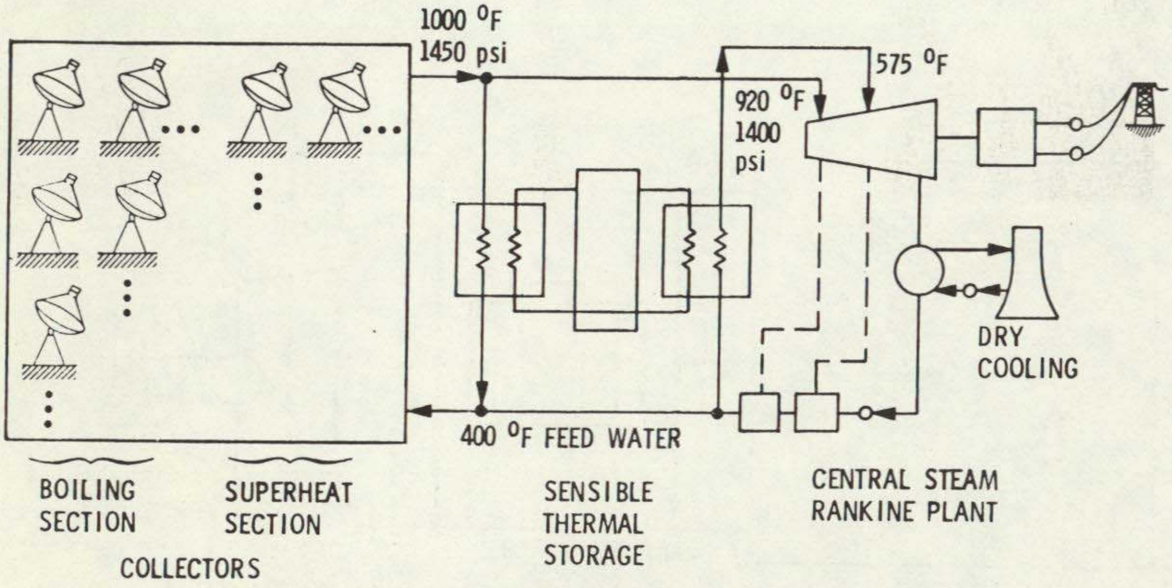

Figure 3.6-6 Parabolic dish -- steam transport

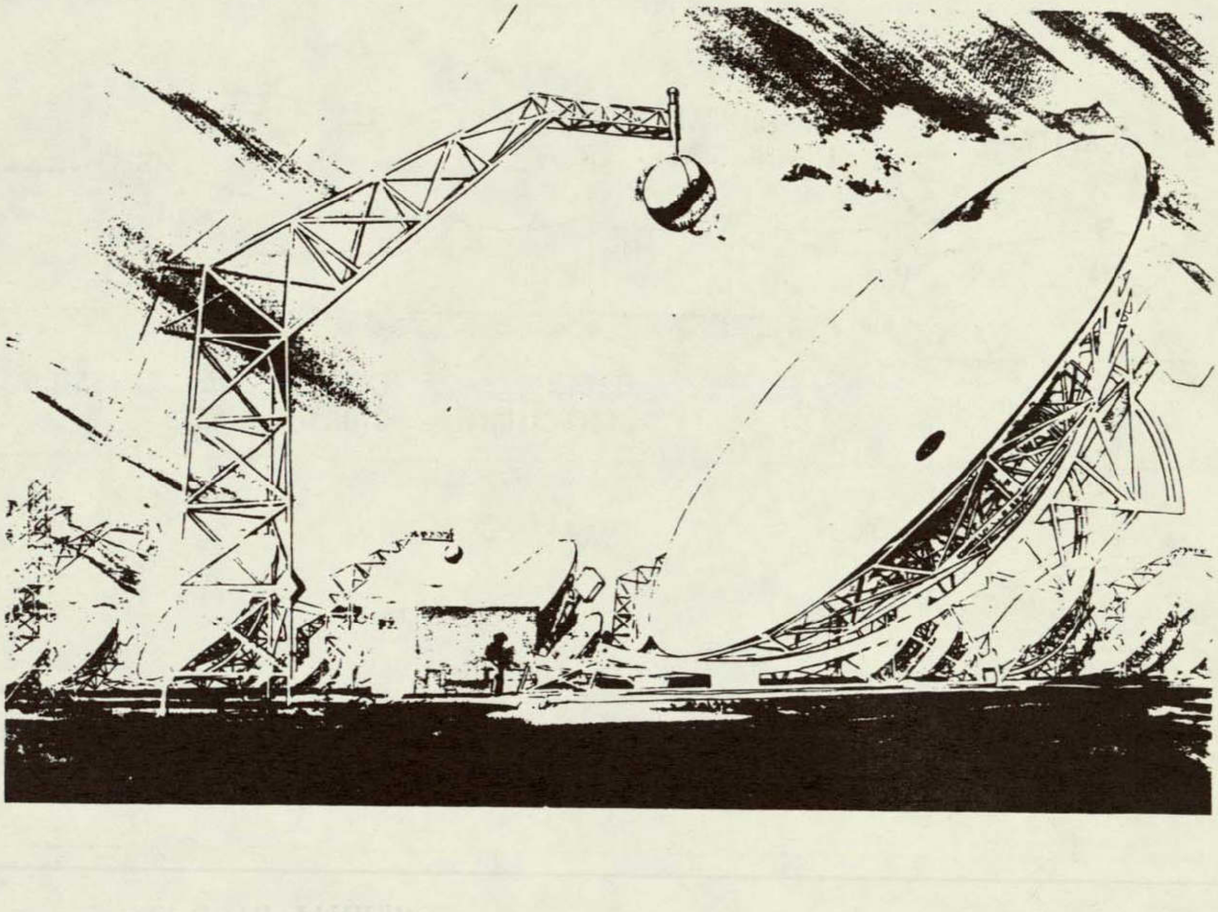

Figure 3.6-7 Parabolic dish system

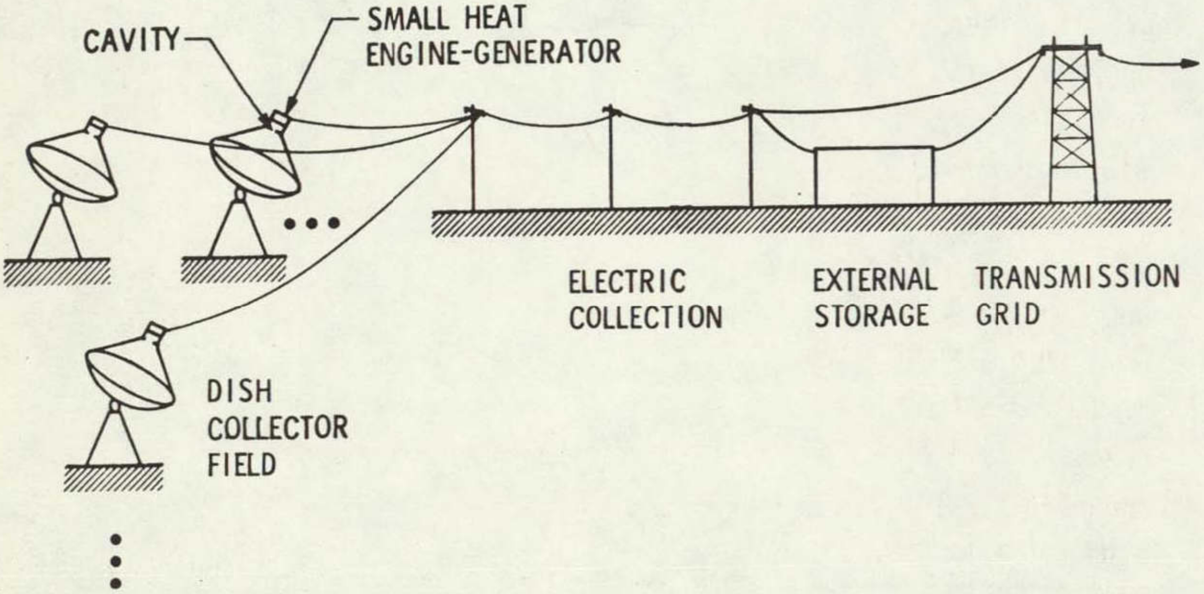

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Figure 3.6-8 Parabolic dish -- electric transport

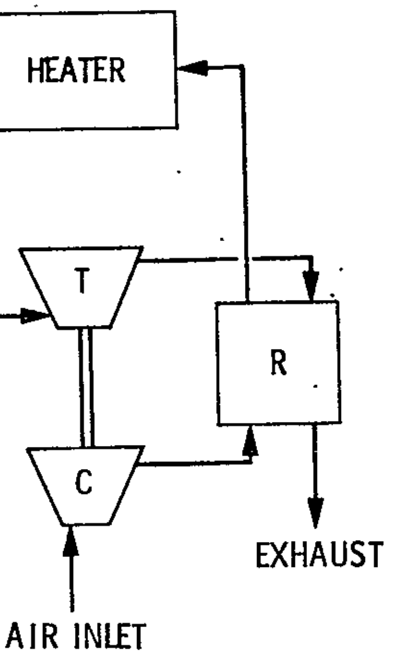


Figure 3.6-9 Open-cycle Brayton

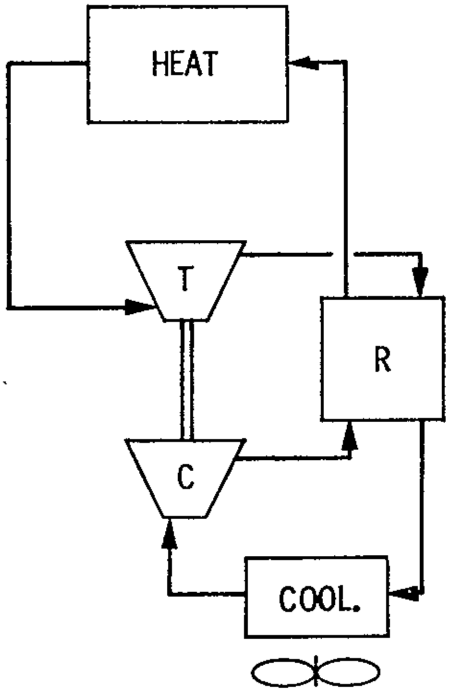


Figure 3.6-10 Closed-cycle Brayton

I'd like to summarize briefly some of the technologies that we're examining for the applications program (Figure 3.6-11). In collector types, the first is a fixed V-trough. The V-trough system is a very low-temperature system and is not likely to be economically practical for electric utility power application. It would use an organic fluid, attaining maximum temperatures on the order of 300°F, with the fluid expanded through an organic-Rankine turbine system.

There are several one-axis tracking collector system possibilities being examined for possible application in this program. The parabolic trough system would normally use steam for the energy transport to a central turbine-generator unit (Figure 3.6-3), although any of these one-axis tracking systems could use small turbine generators associated with either individual collectors or with small groups of collectors. It is not necessary to transport the energy to a central conversion point, although right now the central collection approach appears to be the most practical alternative for steam conversion systems. If we did convert to electricity at the individual collectors, we'd no longer have a practical option of using thermal storage with each unit, but would install an electrical or electrical intermediary storage system, such as pumped hydro. However, when collecting heat to a central point from a parabolic trough, the best form of storage would normally be a thermal storage system. The final conversion to electricity is done using a conventional steam/Rankine system. The same is true for the variable slat system previously described, except that it provides a slightly improved efficiency. A two-axis tracking system, using a parabolic dish with a similar conversion system, will achieve a still higher conversion efficiency.

In the case of the parabolic dish with local conversion to electricity, advanced batteries, pumped storage or something similar might be used for storage. The conversion system will be a small heat engine, either Brayton or Stirling, located at the collector. It may also be possible to develop economic small Rankine units for this application.

COLLECTOR TYPE	ENERGY TRANSPORT	STORAGE	ENERGY CONVERSION
DISTRIBUTED SYSTEMS			
• FIXED-"V" TROUGH	ORGANIC FLUID	--*	ORGANIC RANKINE
• 1-AXIS			
• PARABOLIC TROUGH	STEAM	SENSIBLE THERMAL	CENTRAL STEAM RANKINE
• VARIABLE SLATS	STEAM	SENSIBLE THERMAL	CENTRAL STEAM RANKINE
• 2-AXIS			
• PARABOLIC DISH	STEAM	SENSIBLE THERMAL	CENTRAL STEAM RANKINE
• PARABOLIC DISH	ELECTRIC	ADVANCED BATTERY	SMALL HEAT ENGINE LOCATED AT COLLECTOR
CENTRAL RECEIVER			
• HELIOSTAT (2-AXIS)	OPTICAL	SENSIBLE THERMAL	CENTRAL STEAM RANKINE, BRAYTON

* FIXED SYSTEM CONSIDERED WITHOUT STORAGE

Figure 3.6-11 Some potential collection/conversion systems for small power applications

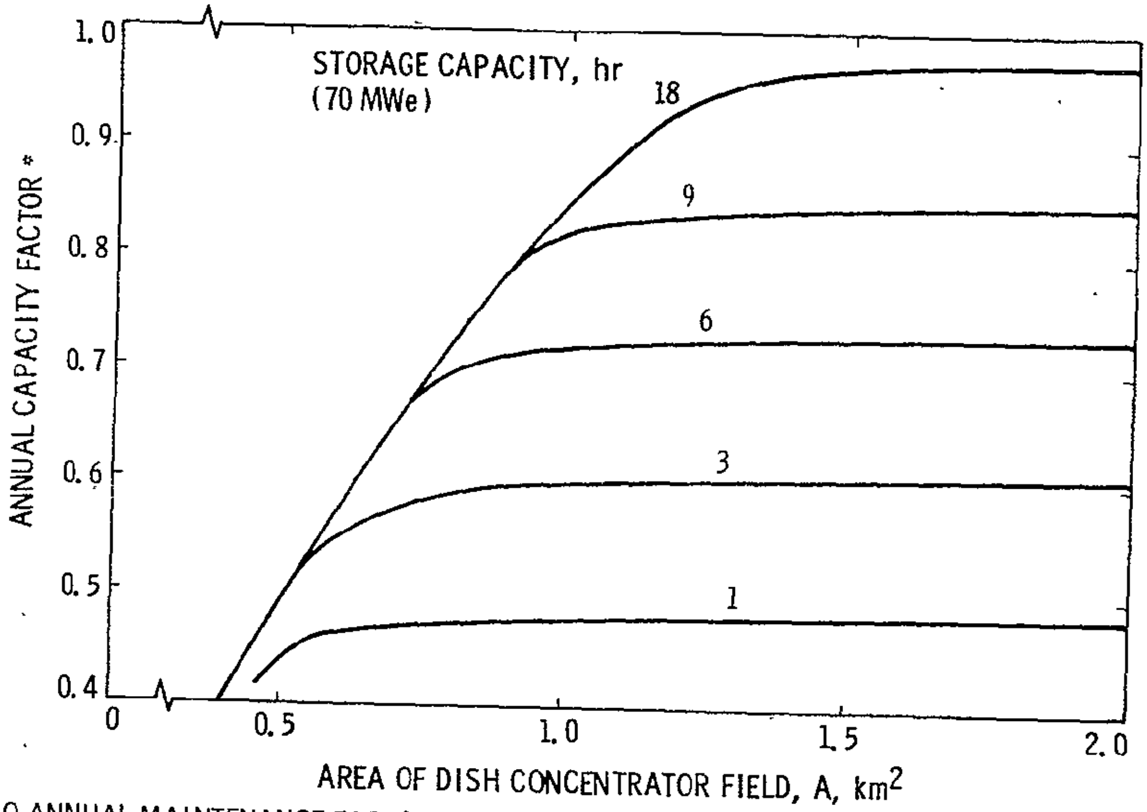
The central receiver plant is also a possibility for SPSA program applications. It is a two-axis tracking system with heliostats using optical energy transport to the receiver, normally using sensible thermal storage, with conventional steam Rankine-cycle conversion. John Bigger has mentioned the EPRI work on Brayton conversion systems for central receiver plants which have the potential of higher conversion efficiency.

In all these systems, conversion efficiencies are extremely important in the effort to minimize the cost, since the collector area requirements are inversely proportional to the efficiency that can be achieved.

Collector area requirements are also affected by the amount of storage associated with the plant. Figure 3.6-12 shows the collector requirements for a 100-Mwe plant, with varying storage capacities. If no storage were provided, about 0.25 KM^2 of collector would be required to provide 100 MWe of peak output. As the storage capacity increases, the annual capacity-factor increases rapidly. Going from zero storage to only one hour of storage raises the annual plant capacity-factor from 0.25 to approximately 0.4. The most cost-effective subsystem size occurs around the knee of the curve. Therefore, to achieve optimum performance with one hour storage would require just over 0.5 KM^2 of collector area. Capacity factor can be signficantly increased so that the plant can begin to function as a true intermediate-range plant by going to a three-hour storage capacity, but, again, the required collector area has gone up. To approach baseload capabilities requires a rather large concentrator-collector field area. Since the collector is usually the largest cost element of the entire system, the plant capital cost increases directly with increasing collector area.

Figure 3.6-13 illustrates an approximate cost ranking of several of the plant technologies discussed for a 100-MWe plant size. These are preliminary rankings, since we are in the early research phases of all of

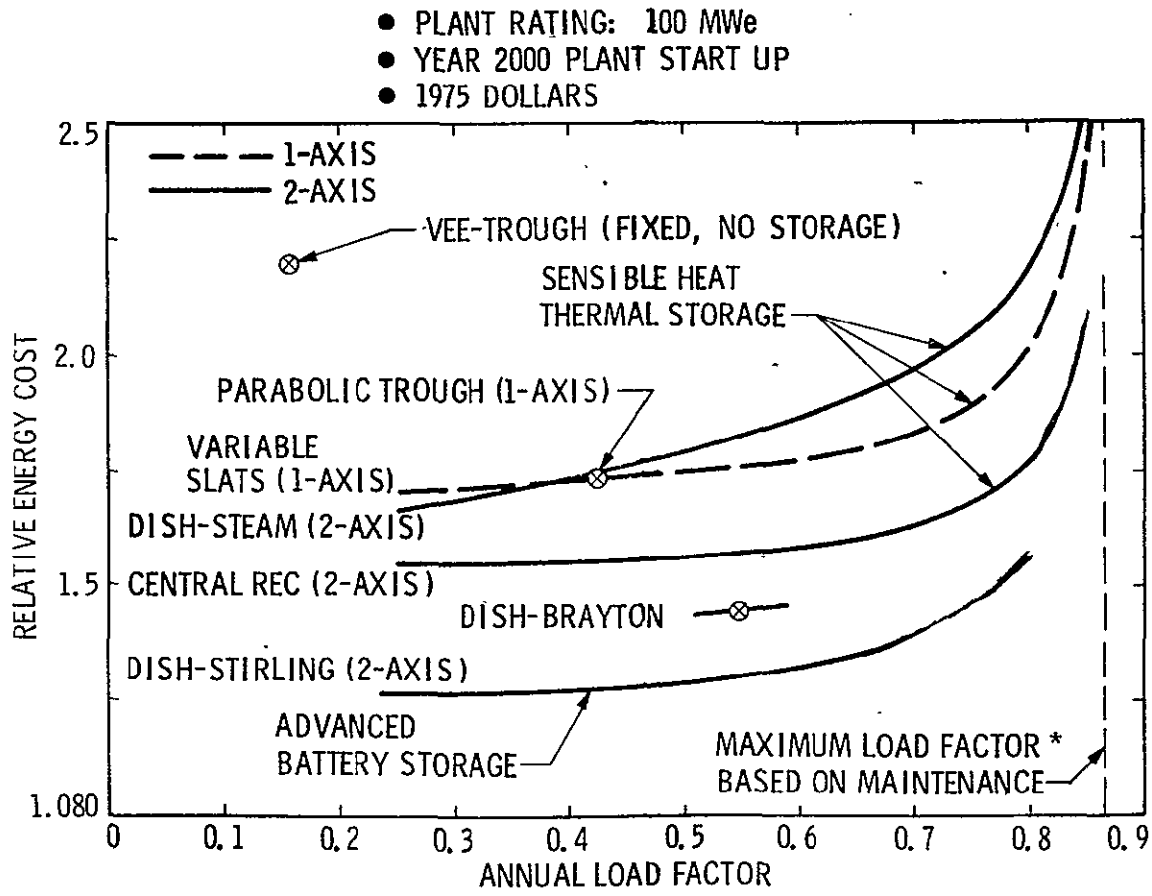
- PLANT RATING: 100 MWe
- INSOLATION: HOURLY INYOKERN CA. DATA
- ADVANCED BATTERY STORAGE



*NO ANNUAL MAINTENANCE FACTOR

Ref: "Projection of Distributed-Collector Solar Thermal Electric Power Plant Economics to Years 1990-2000," DOE/JPL-1060-77/1, December 1977.

Figure 3.6-12 Parabolic dish-electric plant performance



*DOES NOT APPLY TO DISH-BRAYTON AND DISH-STIRLING SYSTEMS WHICH HAVE GENERATION AT EACH UNIT

Ref: "Projection of Distributed-Collector Solar Thermal Electric Power Plant Economics to Years 1990-2000," DOE/JPL-1060-77/1, December 1977.

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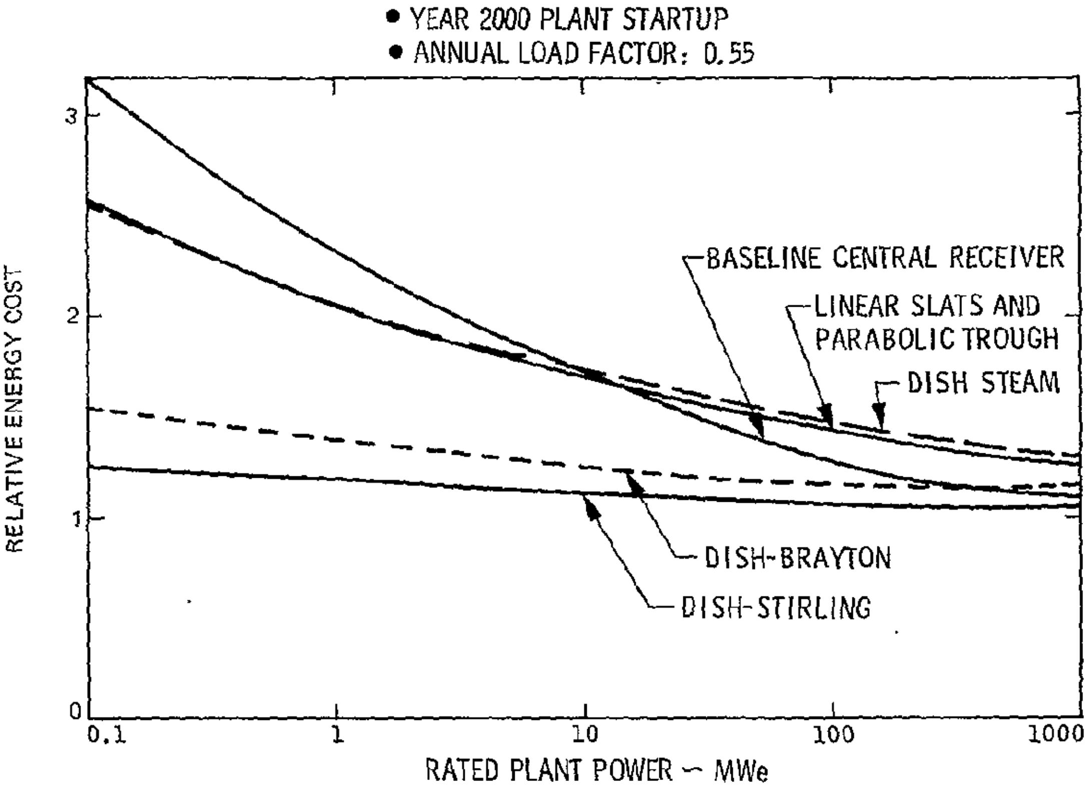
Figure 3.6-13 Solar plant energy costs

these system approaches. The busbar power cost is shown in relative units in order to illustrate the relative cost of the different types of systems, rather than to present actual delivered electrical energy cost.

Actual cost figures are virtually meaningless this early in the development process. The V-trough collector-organic Rankine conversion cycle is highest on the cost scale. The more practical systems with higher conversion efficiencies have lower delivered-power costs. The variable-slat systems and the dish-steam systems, collecting the energy to a central point for conversion, are all in the high-cost range, largely because of the cost associated with collecting and transporting the heat energy to a central conversion point. The central receiver system costs somewhat less. As storage is increased, the cost curve remains fairly flat for the central receiver, because of the relatively small incremental cost of the thermal storage. The dish -Brayton system is still lower in cost than central receiver, and the dish system, with Stirling engines and electrical conversion at the individual units, has the lowest cost of all. Both of these systems are shown using advanced battery storage.

All of the plants that are modular in nature scale downward in size rather well, as shown in Figure 3.6-14. Only slight increases in specific cost occur, as plant size decreases. The central receiver and those systems that require collection to a central point for conversion increase very rapidly in specific cost when decreased below 100 MWe in plant size.

I'd like to mention, briefly, the utility involvement required in order for this program to be completely successful. It's important, for the success of this program, for the utilities and the utility industry to be involved very closely with JPL at every step of the way. The SPSA project is on a very condensed program schedule, and it is important that no false starts be made. Utility input is certainly important in the requirements definition area, which is the first portion of our work. Without co-operation from the utilities, we cannot establish useful oper-



Ref: "Projection of Distributed-Collector Solar Thermal Electric Power Plant Economics to Years 1990-2000," DOE/JPL-1060-77/1, December 1977.

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Figure 3.6-14 Energy cost vs plant size

ating and cost requirements for solar plants. Certainly, in the field-test operations activity, it's critical that the experimental equipment be installed and operated in utility systems. Similarly, as commercialization is investigated, it is absolutely essential that the issues be examined from the point-of-view of the utilities. JPL intends to communicate with the utility community throughout the entire project, with this workshop providing an effective vehicle for the initiation of this communication activity.

3.7 SOLAR POWER RESEARCH AT EPRI - JOHN BIGGER

Solar Thermal Program Manager, Electric Power Research Institute

EPRI was formed in 1972 and opened its doors in 1973. At the present time, we have more than 500 member-utilities in the U. S.: investor-owned, municipally owned, REA, co-op, some of the quasi-federal utilities such as TVA. So, we have a very broad background of support and input to EPRI from the utility industry.

Our research and development funding level this year is about $180 million. Research and development is done mainly with private industry; some with universities and nonprofit organizations. Practically no in-house research is done at EPRI.

EPRI has four major divisions and three support divisions:

- Fossil Fuel and Advanced Systems
- Nuclear
- Electrical Systems
- Energy Analysis and Environment.

Within the Fossil Fuel and Advanced Systems Division, we have four major departments:

- Fossil-Fuel Power Plants, mainly concerned with increasing the efficiency and output of conventional power systems; making existing plants cleaner with air and water pollution programs
- Advanced Fossil Power Systems are concerned with clean fuels from coal, such as coal liquifaction and coal gasification. One of the big problems with the utility industry, as you well know, is the source of clean fuels in the future
- Energy Management and Utilization is concerned with end-use of electrical energy and with energy storage concepts
- New Energy Resources Department is concerned with solar, fusion and geothermal developments.

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Our Solar Program budget for the next five years is approximately $21 million; our budget this year is approximately $4 million. Forty per cent of that is in solar heating and cooling programs; about 38 per cent in solar thermal and the rest is invested in technology assessment projects.

We have projects in three areas of solar electric applications: solar thermal, photovoltaic and wind. In wind, studies are now mainly examining the impact of, and requirements for, wind systems. In photovoltaics, there is one requirements definition and impact analysis study and one hardware development program.

Within the solar thermal area, there are a number of objectives. The first one, and, I think, the most important one, is to assess the potential value of solar-thermal concepts to the utility industry and to an individual electric utility. The second objective included in this area is environmental impacts assessment of the solar plants prior to the industry pouring large amounts of money into this technology.

Under the solar-thermal assessment, we have a section for Requirements Definition and Impact Analysis underway. Essentially, we are examining the impact of three solar thermal technologies:

1) Water/steam central receiver
2) Hybrid central receiver
3) Distributed systems.

We are using three electric utility systems; using utility industry tools, such as, production cost, system expansion, reliability programs, and looking at the impact of these solar models on the utilities. We're concerned with 1985 and beyond. We work, specifically, with three utilities in the Western United States, in this first study. Shortly after the first of 1978, we expect to get underway with what we call "synthetic utilities."

This is a method developed by EPRI to enable us to compare various advanced technologies, their impacts and requirements, on the utility industry and specific utilities.

We have two projects which are examining the environmental impacts of solar plants. First, we're looking at an advanced assessment methodology. The second project is evaluating the impact assessment for five solar technologies:

- Solar thermal
- Photovoltaic
- Wind
- Ocean thermal
- Photoproduction (biomass).

The methodology project is complete; the reports are being printed. The second project drafts are being reviewed. The final versions will be ready after the first of the year.

Many of the Western and Southern utilities are having problems obtaining natural gas supplies for boiler and gas-turbine fuel. It is becoming either short in supply or nonexistent. So, the solar-thermal systems have been proposed as a possible alternative to retiring those plants, in order to keep them operating. Many of them are around 10- to 15-years-old, with a considerable period of use left for the utility. DOE, EPRI, West Associates and a number of utilities will be funding work to examine the feasibility of solar-fossil hybrid repowering.

The cost of the heliostats can be about 40 per cent of the total cost of a solar plant. The Phase I ERDA (DOE) studies have produced four designs. We're not sure that it is possible to get down to a competitive ($75 to $100 per square meter) cost with those designs. We will examine them and see what kind of cost-reduction possibilities there are; in the area of performance requirements, in manufacturing techniques and in installation.

The second major objective of the EPRI solar-thermal program is hardware development. Based on background studies that ERDA, NASA and the National Science Foundation had done in the late sixties and early seventies,we chose not to go the way of the water/steam-central receiver concept. We felt there were some definite advantages for the electric utilities in second-generation Brayton-cycle central receiver systems.

EPRI is supporting the development of two major Brayton-cycle systems. The first one is a closed-cycle gas system. We have completed the first phase, which is the concept definition. We are now involved in the second phase, which is the design, fabrication and ititial checkout of a one-MW bench model receiver. The third phase, the testing of the unit, will begin in November, 1977. Early in 1978, the units will be taken to the Solar Thermal Test Facility in Albuquerque and tested. The closed-cycle project is with Boeing Engineering and Construction Company, Seattle.

The open-cycle project is with Black & Veatch, Consulting Engineers, Kansas City.

The closed-cycle project is using a super-alloy metal heat exchanger. The open-cycle project is using ceramic-tube heat exchangers with gas temperatures around 1900 to 2000°F. In order to increase the efficiency of the system, we are pushing "state-of-the art" of high-temperature technology.

With both of these systems we are intitiating pilot plant specification studies in November, 1977. We are also developing a 10-MWe scale hybrid-system pilot plant, with fossil-fuel backup. We want to demonstrate this in the most efficient manner with a simple system, because we feel thermal storage technology is behind the central receiver technology, today. The pilot plant will be a 10-MW scale, using only one-quarter of the field, so our electrical output will be 2½ to 3 MWe. Our operating date is late 1981, about one year afer the DOE pilot plant.

In addition to hardware development, the EPRI solar-thermal program is supporting a considerable amount of materials research, both supporting the Boeing and the Black & Veatch work; plus supporting work in high-temperature ceramic materials for heat exchangers. This will have applications in fossil fuel and solar technology.

The final objective of the solar-thermal program is to provide input and feedback to the federal program as to utility industry requirements and objectives. Since the electric utility industry in general and the individual utilities in particular are going to be the major market for the solar-thermal systems -- both central and distributed systems -- it is important they have a major hand in the R&D for these systems.

3.8 SOLAR POWER RESEARCH AT SERI - CHARLES J. BISHOP

Senior Staff, Solar Energy Research Institute

The Solar Energy Research Institute's overall mission is to provide significant support the the national program of research, development, demonstration and deployment of solar energy. A central responsibility in this effort is to contribute to the establishment of a solar energy industrial base capable of supporting the widespread commercial use of the technology.

SERI is working toward the creation of a national center of excellence -- a resource dedicated to serving the solar energy needs of the public and industry. SERI is initiating continuing programs in:

- Research
- Analysis and assessment
- Information and education
- Technology commercialization
- International solar energy efforts.

In addition, we expect to assume responsibility for the technical monitoring of a number of existing and planned federal solar R&D programs.

We interpret our charter as rather broad. Our programmatic efforts might be grouped into five general areas:

1) We will be conducting applied research directed toward the timely development of solar energy technologies which have long term promise
2) We will participate in an important way in the conception, evaluation and development of innovative methods for solar energy conversion
3) We will undertake further analysis of issues which affect the near-term utilization of solar energy
4) We will carry out efforts designed to reduce remaining un-

certainties associated with solar energy -- technical uncertainties, institutional uncertainties, economic uncertainties and social uncertainties

5) We will develop and implement methods of providing direct assistance to the public and industry -- assistance in the form of information dissemination and technology transfer designed to facilitate consumer and business decisions regarding solar energy.

SERI is organized into five operating divisions, as shown in Figure 3.8-1. The staff currently numbers 80. Our plans call for a total staff of 113 by October 1; 300 by the first of October, 1978; and, 480 by October 1, 1979 (Figure 3.8-2).

SERI is now housed in interim facilities in Golden, Colorado. We presently have 26,000 square feet of space. Another 12,000 square feet in the same building will be added this fall and an additional 66,000 square feet in March, 1978, when the second building is completed. The first experimental laboratories will be designed into the building scheduled for March completion. The Department of Energy (DOE) now holds an option on 300 acres atop South Table Mountain, in Golden, for possible siting of the permanent facilities.

As our staff comes on board, we are beginning work on 64 tasks which have been identified in discussions with members of the Division of Solar Energy. Most of these tasks are of two general types:

- Planning tasks -- on a branch-by-branch basis -- to define plans with a time horizon of about two years
- State-of-the-art assessment tasks designed to establish databases, examine the efforts that are now underway in different areas and identify important unattended areas.

This task list is being modified and extended periodically, as needs change.

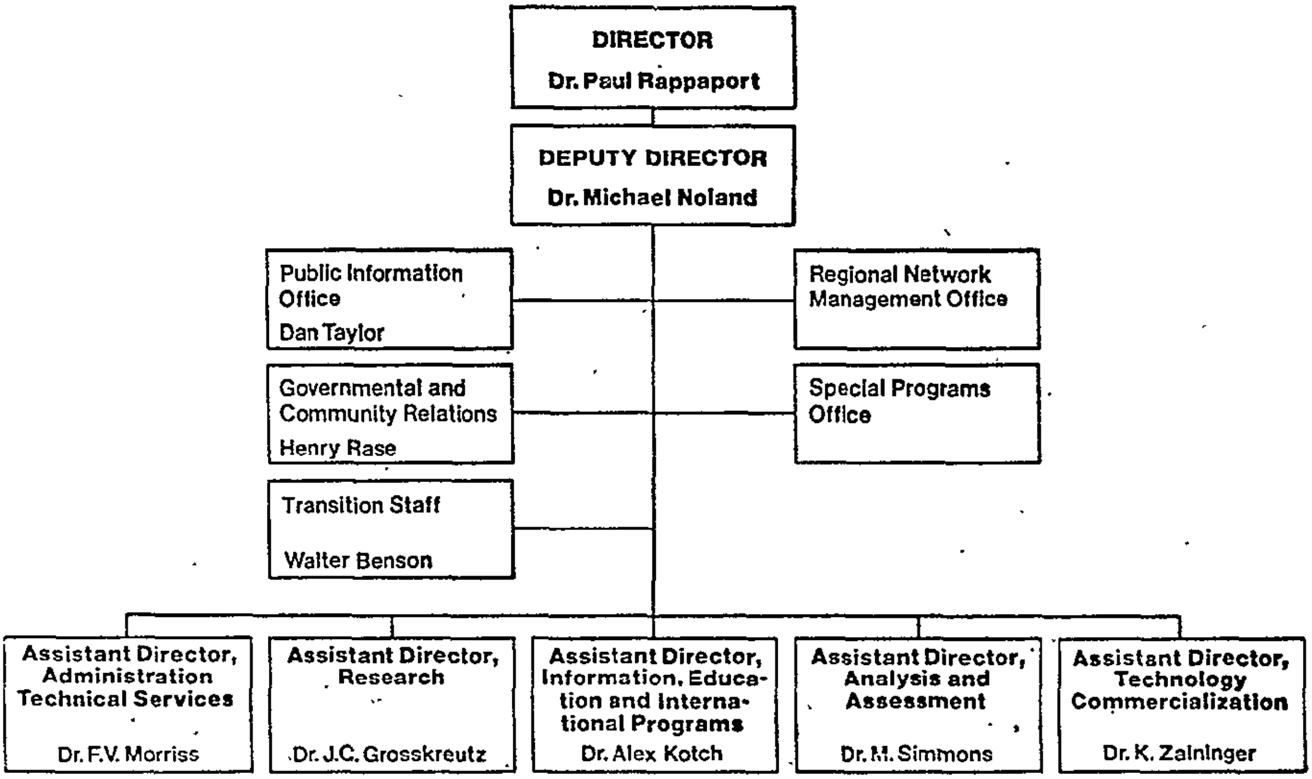

Figure 3.8-1 Solar Energy Research Institute - organization chart (September, 1977)

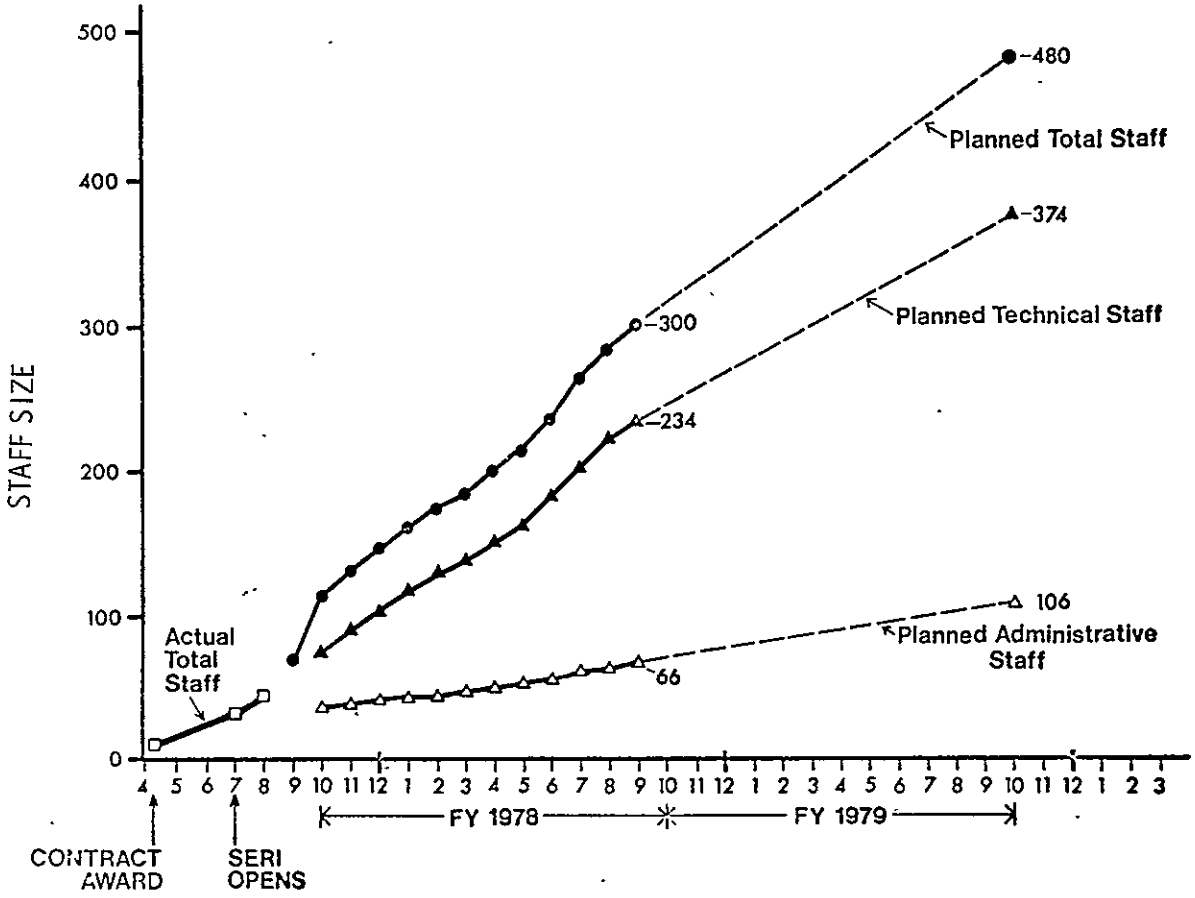

Figure 3.8-2 SERI staffing plan (Staff on board at beginning of month)

Our programmatic and operational objectives are becoming more clearly defined as we continually assess perceptions of SERI's mission. Clearly, we will be conducting solar energy R&D for all of the major functional solar technologies, including passive systems. Support disciplines, such as materials, corrosion, surface physics and so forth, will be undertaken.

Analysis and assessment efforts will include evaluation of SERI, DSE and other national solar energy programs.

We expect to play an important role in the administration of university solar energy research programs -- including the evaluation of proposals and the management of contracts. SERI wants to encourage the universities to get back into the creative mode again.

The technology commercialization effort will include a technology transfer program, a program of assistance to business and industry and a liaison function -- all designed to promote early utiliization of solar energy. The regional SERI network will be an important part of the commercialization effort.

SERI will assume a central responsibility for U. S. involvement in international solar energy programs -- including research, information exchange and technology transfer.

We will establish an information data bank and library which we expect to become the most extensive solar energy information resource in the nation -- indeed, in the world. Utilizing this resource, we should be able to contribute significantly to the DOE's program of providing information on solar energy to the public.

We will host and conduct solar energy conferences, seminars and workshops -- those conceived and organized by SERI or DOE and, by request, those which are part of other efforts.

SERI will manage and co-ordinate the regional SERI network as part of its responsibility to state and local interests and needs.

Finally, we will develop a plan for the permanent SERI facilities, including research laboratories, a conference center, a library and administrative facilities.

Several key projects are currently underway, although the staff is, by no means, complete. The staffing plan, initial task definitions and FY-'78 financial plan are all complete. The Mission Definition Report, which details the mission, philosophy and goals of SERI, why it exists and what it is expected to contribute to the national solar energy program, has been completed and submitted in preliminary draft form to DOE. The Annual Operating Plan, which describes in greater detail the tasks SERI will undertake in FY 1978, and the Facilities Plan, which will include plans for both the interim facilities and a preliminary version of what the permanent facilities might look like, will be submitted by the end of October, 1977.

In conclusion, SERI is now an operating organization, with a team of highly qualified professionals, totally dedicated to the concept of SERI, actively carrying out its intended mission to contribute significantly to the commercial development of solar energy.

(The above material was excerpted from a presentation by Dr. P. Rappaport at ERDA Solar Program Review, September 9, 1977.)

3.9 THE SOUTHWEST PROJECT - KENNETH E. HOGELAND

Principal Engineer, Stone & Webster Engineering Corporation

The Southwest Project is a program to analyze the technical, legal, regulatory, institutional and resource requirements needed to accelerate commercialization of solar electric power generation in the Southwest Region of the United States. This DOE program was originally contracted by the Federal Energy Adminsitration (FEA) as a co-operative effort with the Energy Research and Development Administration (ERDA) and the Department of Interior (DOI).

Stone & Webster Engineering Corporation is the prime contractor on this program and was originally teamed with 11 electric utilities from the Southwest Region to conduct the study. Two additional utilities have since joined this team. The program started September 1, 1976, and will be completed February 28, 1978.

An original objective of this program was to assess the state-of-the-art of solar conversion concepts, including projected costs, from prior or ongoing government-sponsored programs.

Some of the earlier discussions included solar power plant costs, if not on an absolute basis, at least on a relative basis. John Bigger's earlier comment on costs being inversely proportional to the amount of ignorance involved is very astute. In the Southwest Project, we were confronted with our own ignorance about solar plant costs. This was due primarily to a lack of adequate available information or data on costs, from which a total cost picture could be developed from prior or ongoing programs.

To accomplish this study it has been necessary that Stone & Webster conceptually define solar electric generating plants for solar-thermal conversion technology, including central tower and distributed receiver systems, with various energy storage capacities, or hybrid configurations. We also conceptually defined photovoltaic plants and wind energy-conversion system plants, with and without energy storage. In accomplishing these technical analyses, an assessment of the state-of-the-art of solar power conversion equipment was accomplished. Construction, operation, maintenance, reliability and availability were defined. Capital, operation and maintenance costs were also estimated.

The expected load-growth generation expansion plans for large, medium and small utilities, using conventional generation plants, were analyzed through the year 2000 to establish a baseline for comparison. System reliability and life-cycle costs are being evaluated with the solar plants defined above included in the utility generation plans.

Institutional factors affecting commercialization are being evaluated. These are:

- Financial and economic factors in commercialization
- Governmental factors in commercialization
- Institutional arrangements
- Role of electric utilities in research
- Development and demonstration.

Institutional analyses are identifying barriers to commercialization of solar electric power systems; the programs, methods and incentives supporting commercialization.

There are some cost analysis results from the Southwest Project analyses. A trough distributed-receiver solar-thermal power plant of 100-MWe rated capacity has a capital cost range of $3,623 to $4,951 per kW* without energy storage. Adding six hours of thermal storage to the system increases costs to $7,390 to $10,033 per kW*. For comparison, a similar capacity central-receiver solar-thermal plant will have a capital cost of $1,540 to $2,265 per kW* without storage and $2,831 to $3,943* with six hours of thermal storage. These values are mostly influenced by the cost of the solar equipment which is currently available from government-sponsored programs and directly from equipment manufacturers.

The Southeast Project is similar and was just awarded to Stone & Webster. It, however, has the biomass and ocean thermal-conversion systems added to the systems to be evaluated. There is really not much more to be said about this project at the present time except that it includes more than utility applications. It includes dispersed facilities and solar total-energy systems.

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*Editor Comment:
The costs presented above are based on current hardware prices and assumptions used for the Southwest Project and are higher than the JPL cost projections for the 1985 to 2000 time period.

Comparing Power Options 4.0

INTRODUCTION

A panel discussion was held October 11, to discuss and compare various power options competing with solar energy and the issues involved in implementing and commercializing solar thermal electric power. Each panel member gave a brief presentation, after which discussion revolved around questions posed by the moderator, with participation by the members of the general session.

Moderator - Vincent C. Truscello

Panel - Frank R. Goodman, Jr.
Peter Steitz
Merwin Brown

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4.1 INTRODUCTION - VINCENT C. TRUSCELLO

Manager, Solar Thermal Power Systems Project, Jet Propulsion Laboratory

The purpose of this panel discussion this morning is to try to set the stage for many of our small discussion groups later on this morning and all day, tomorrow. What I'll try to do is to ask certain questions of the panel, questions that I hope will be of interest to all of you; which will get you thinking of additional questions. Maybe there will be more you will want to hear on a particular subject or issue or, perhaps, just a highlighting of that issue. We will address several issues that appear to be important. The kinds of questions that I'll be asking are along the lines of:

- What, why, how and where is solar's competition?
- How does the competition compare?
- Why would a utility consider solar as an option?
- If a utility wanted solar, how would it use it?
- Where in the country would these plants be situated?
- Do we have any good ideas as to when these types of plants might be implemented?
- When would the utility start considering the implementation of these systems?
- Who would use them?
- Are there any special groups of utilities who would use them?

The panel will try to give insight into these questions and any others that you would like to pose to them on this topic or Power Options.

4.2 FACTORS INFLUENCING SOLAR TECHNOLOGY ADOPTION - FRANK R. GOODMAN, JR.

Resource Development Engineer, Los Angeles Department of Water & Power

Several factors that will influence the introduction of small solar thermal power plants into future utility generation mixes will be given as topics for discussion by the panel. These factors can be categorized as either favorable or unfavorable to the introduction of solar plants.

The category of favorable factors includes the need for diversity in generation mix, with no overdependence on any one energy source because of risks, such as a drought or a rapid change in international fuel prices. In addition to being a source of energy, solar plants may have some allowable capacity credit, particularly when the installed amount of solar plants is a small percentage of a utility's total generation capacity. The allowable capacity credit, if any, that a utility may be able to give a solar electric plant will be significantly less than the plant's rated output during peak sunlight conditions. The effective capacity will depend on the amount of system storage already existing in the system and on the amount of dedicated storage installed with the solar electric plant. At one extreme, a solar electric plant, having no dedicated storage and operating in isolation from other generation, can be given no effective capacity in a system with a continuous load. The solar electric plant in this case is only a fuel saver which can supply the load during the periods of sunlight availability. However, when a solar electric plant is assessed together with a mix of other generating plants, using conventional utility reliability planning tools, some effective capacity credit for the solar electric plant may be justified. Recent analytical studies have been performed that indicate this is the case. This allowable effective capacity is the consequence of a probabilistic treatment, in which the occurrance of certain events can be made independent. For example, the scheduled outages for maintenance of conventional generation could be made in midday periods, when the solar plants are expected to be near their peak rating. The fact that solar electric plants operated in conjunction with a generation mix can be expected to have some allowable capacity credit, as well as energy credit, can be considered as favorable to the introduction of these plants. The amount of capacity credit, which has been predicted by long-range studies, can only be substantiated when operating experience with solar electric plants has been obtained. In any case, the allowable effective capacity will decrease as the percentage of solar plants in a utility's generation mix increases. These comments apply, generally, to solar electric generation and are not specific to solar thermal technology; that is, they also apply to photovoltaics and wind-energy conversion.

Another favorable factor for the introduction of solar plants is that environmental, political and economic pressures, such as maintaining the nation's balance of trade, may lead to introduction of solar plants before their break-even cost with other generation forms has been achieved. The modularity of small solar plants is also important. For dispersed applications, such as on-site electricity production at a customer's demand point, small solar power systems may be sited on existing easements or property and some reduction of land costs may be possible. The assignment of time-of-day rates may serve as a financial incentive for a customer to install his own small solar power system. For example, on a typical day, a customer's requirements for energy could be met by his own solar electric system during onpeak periods when his electric rate is high. The customer's demand during period of darkness might be served by the local utility. These latter periods are, typically, offpeak and and a lower electric rate could be in effect. The customer's demand from the utility would, of course, depend on how much storage, if any, was installed with his solar electric system. If provision is made for the customer to sell his surplus daytime solar power to the utility, some additional financial credits may be possible. The issue of small solar plant ownership is not resolved, and the preferred owner from an operational standpoint is the utility rather than the customer.

Many of the factors which are unfavorable to the introduction of solar plants are a consequence of the diffuse and intermittent nature of solar radiation. The use of large land areas for solar plants may be judged environmentally unacceptable by some. The large amounts of capital required may be prohibitive. Even if solar plants were economically viable, significant operational problems exist due to the fact that sunlight availability is not entirely predictable. A generation mix containing a solar electric plant would have special dispatch problems for which operating personnel would have to be trained. The solar plant itself would require special operating and maintenance personnel. Some utilities, particularly small ones, may not have the staff for these purposes. Finally, it is noteworthy that most of the foregoing comments apply generally to small solar power systems and are not technology specific. An additional factor influencing future introduction of small solar thermal power plants will be the extent to which they are competitive with other solar technologies, such as photovoltaics.

4.3 BASIC POWER SUPPLY ECONOMICS - PETER STEITZ

Planning Engineer, Burns & McDonnell

I thought it might be illustrative to consider how small solar thermal systems might fit into the small utility generation mix by reviewing some basic electric utility economics and the outcome for some specific examples and inputs.

The power supply problem of small utilities can be appreciated by considering a typical utility load duration curve shown in Figure 4.3-1. A load duration curve is simply a distribution of a system's loads during specified intervals over some time period. The area under the load duration curve represents the system's total energy requirement for the period.

For any utility, the fundamental economic problem is to supply the energy requirement of the system (i.e., the area under the load duration curve) at the lowest cost that will ensure reliable service. Electric utilities usually classify their power supply resources into base, intermediate, and peaking capacity types. These resource types supply the energy requirements for a system as illustrated in Figure 4.3-1. Baseload resources are associated with high fixed costs and low variable costs, such as coal- and nuclear-fueled generation. Peaking capacity types, like combustion turbines, usually have low fixed costs and high variable costs. Intermediate power supply resources fall between the extremes of fixed and variable costs. The problem for the utility is to minimize its costs of power generation by optimizing its mixture of these three categories of resources.

To illustrate how the optimum generation mix of a small utility can vary for different inputs, I would like to examine a hypothetical utiity system and consider initially for that system some typical currently available technologies and their costs.

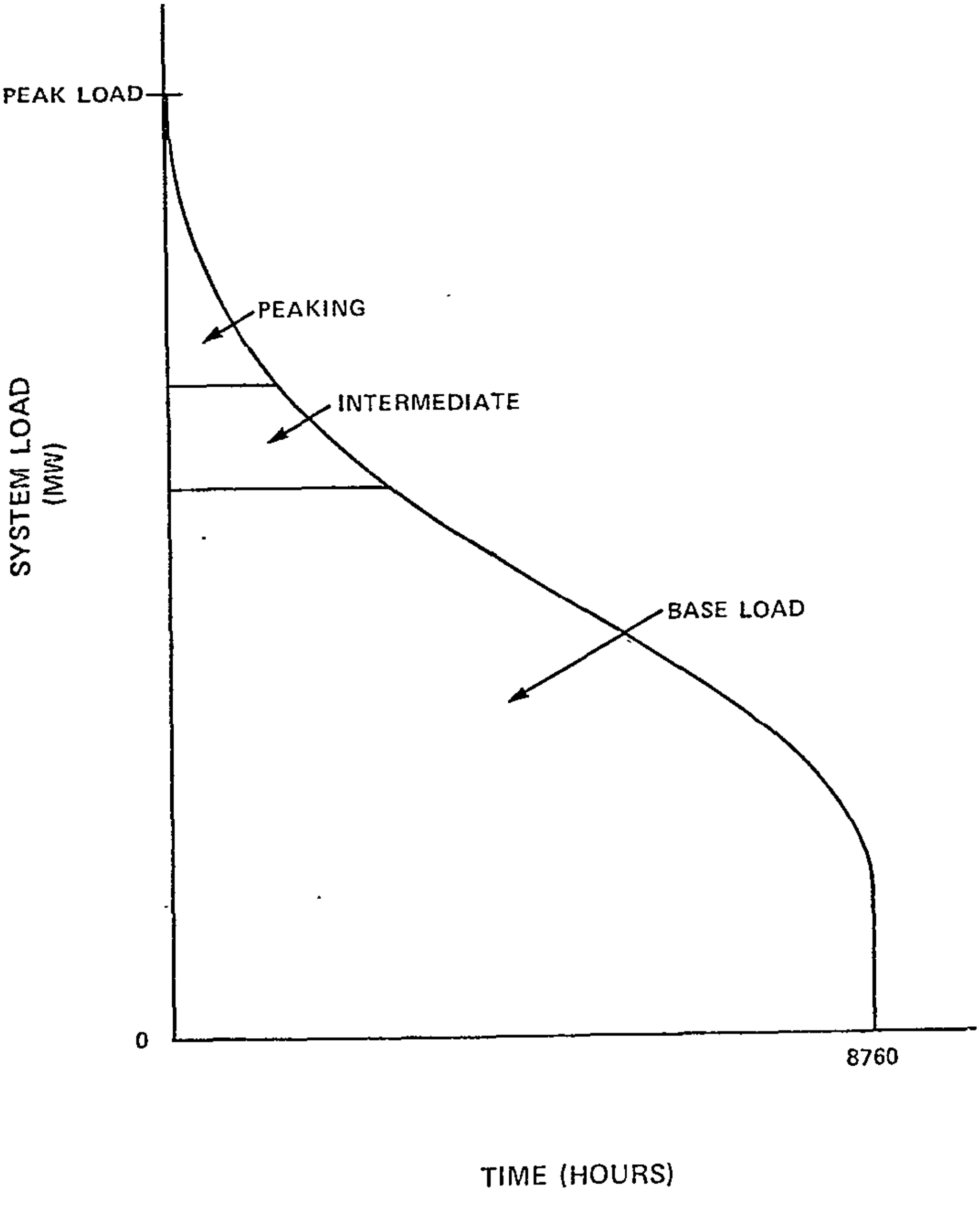

Figure 4.3-1 Typical utility load duration curve

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Our hypothetical system has a 50 per cent load factor and plans to meet its entire load with new generation (assumes no existing generation). This new generation can be made of 8-MW diesels, 50-MW combustion turbines, or 600-MW fossil-steam units, installed either individually or through joint action with other utilities. The capital costs in 1976 dollars used for each generation type are shown in Figure 4.3-2. The coal-fired steam unit has the highest capital cost at $577/kW and the combustion turbine the lowest at $164/kW. These capital costs, along with operation and maintenance and other annual costs translate to the annual fixed costs shown in Figure 4.3-3. Again, the steam turbine has the highest annual fixed cost, and the combustion turbine has the lowest.

The fuel prices assumed in 1976 dollars are:

- o Coal $0.75/MBTU
- o Oil $2.50/MBTU

Using these base coal and oil prices, and variable operation and maintenance costs, the total annual variable costs for each unit type are shown in Figure 4.3-4. As can be seen, the variable costs are least for fossil-steam units and greatest for combustion turbine units.

To determine the optimum mix for these technologies and inputs, I will use the simplified generation expansion model (SGEM) approach developed by Economic Sciences Corporation in conjunction with the staff of the California Energy Resources Conservation and Development Commission. SGEM is a graphic procedure used to determine the least-cost mix of generating capacity from a utility load duration curve and annual cost curves for various generating technologies. The procedure is illustrated in simplified form in Figure 4.3-5.

At the top of Figure 4.3-5 is a load duration curve and at the bottom are curves representing annual costs (dollars per kilowatt of capacity for

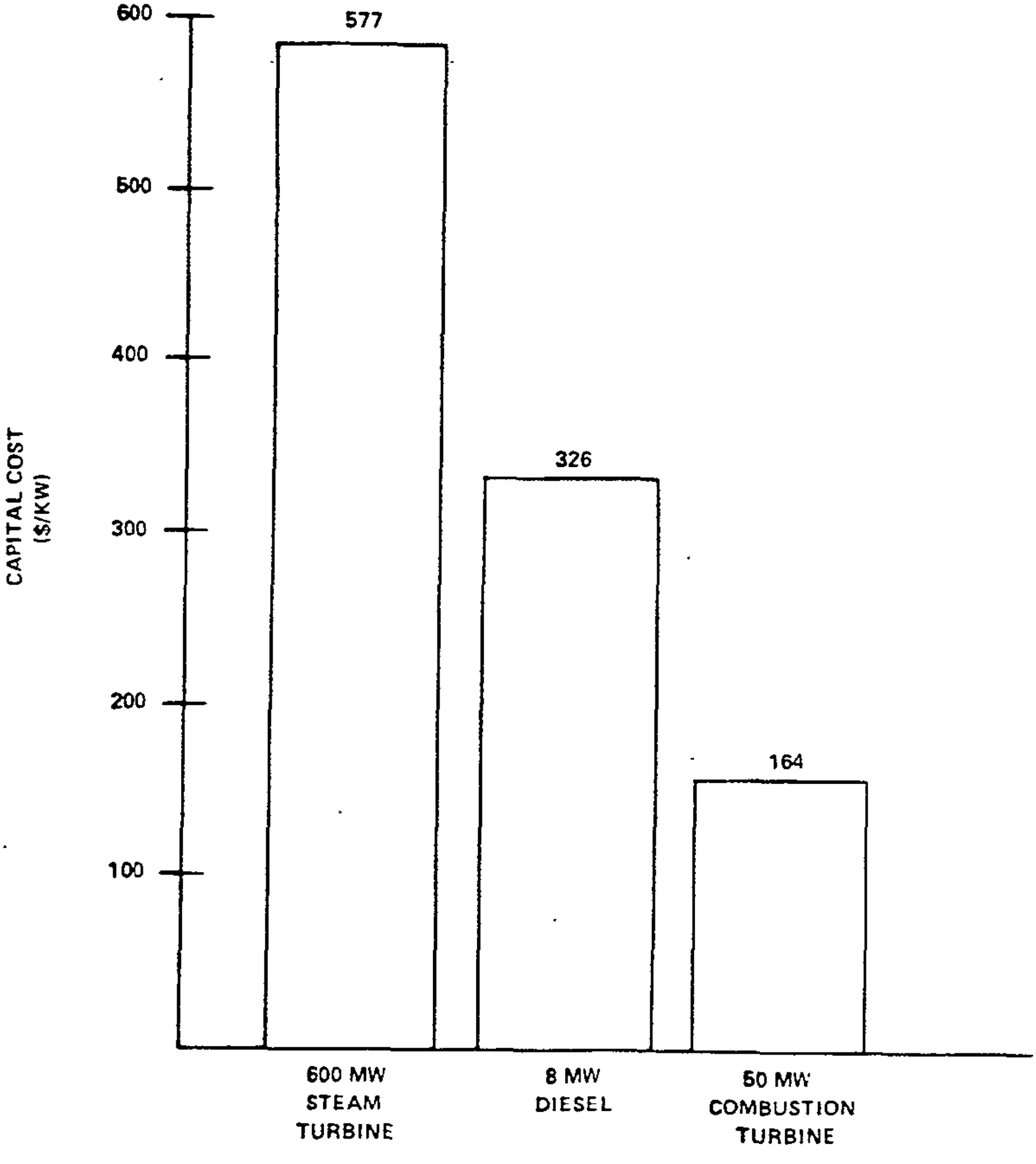

Figure 4.3-2 Generating unit capital costs (1976 dollars)

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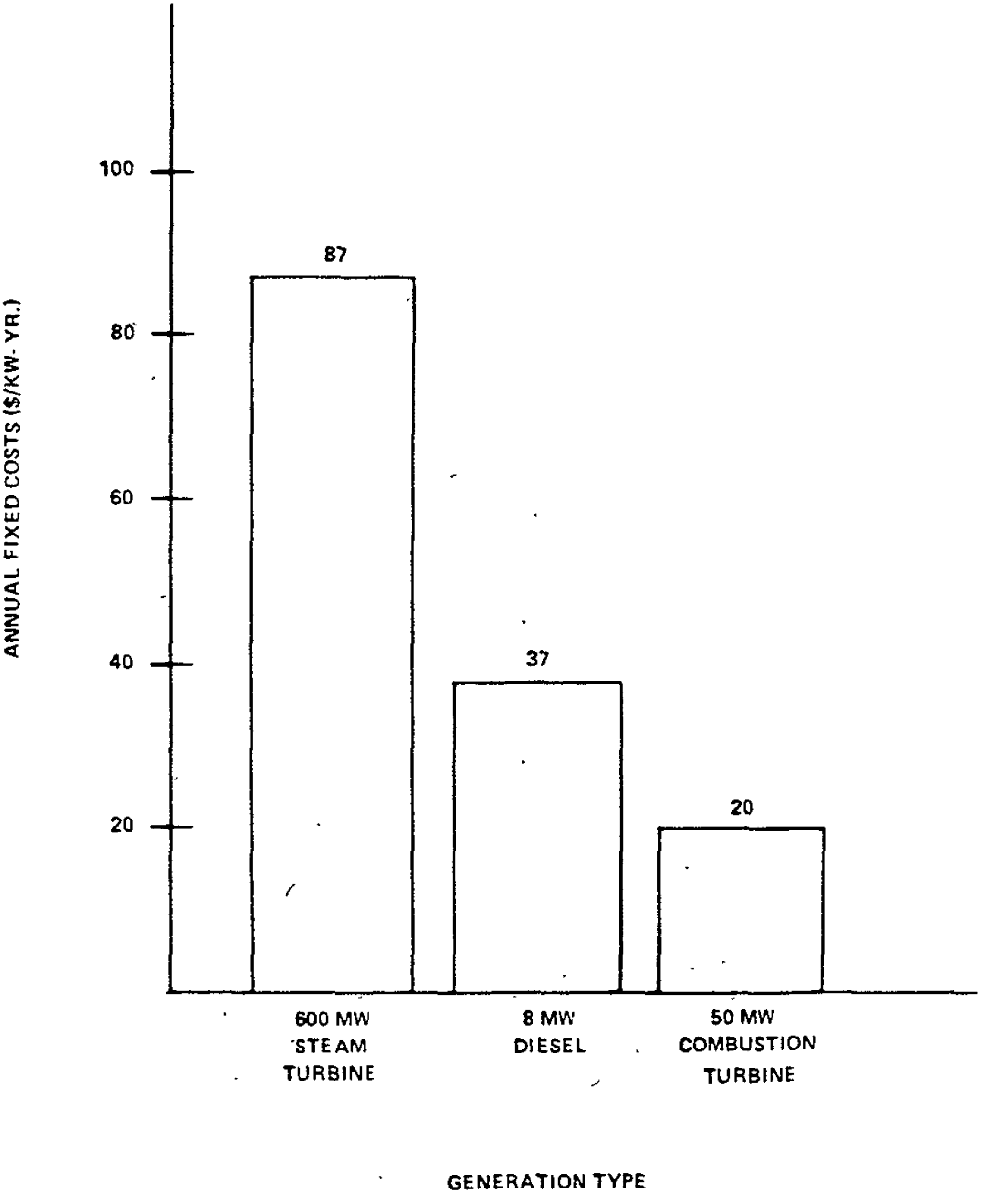

Figure 4.3-3 Generating unit annual fixed costs (1976 dollars)

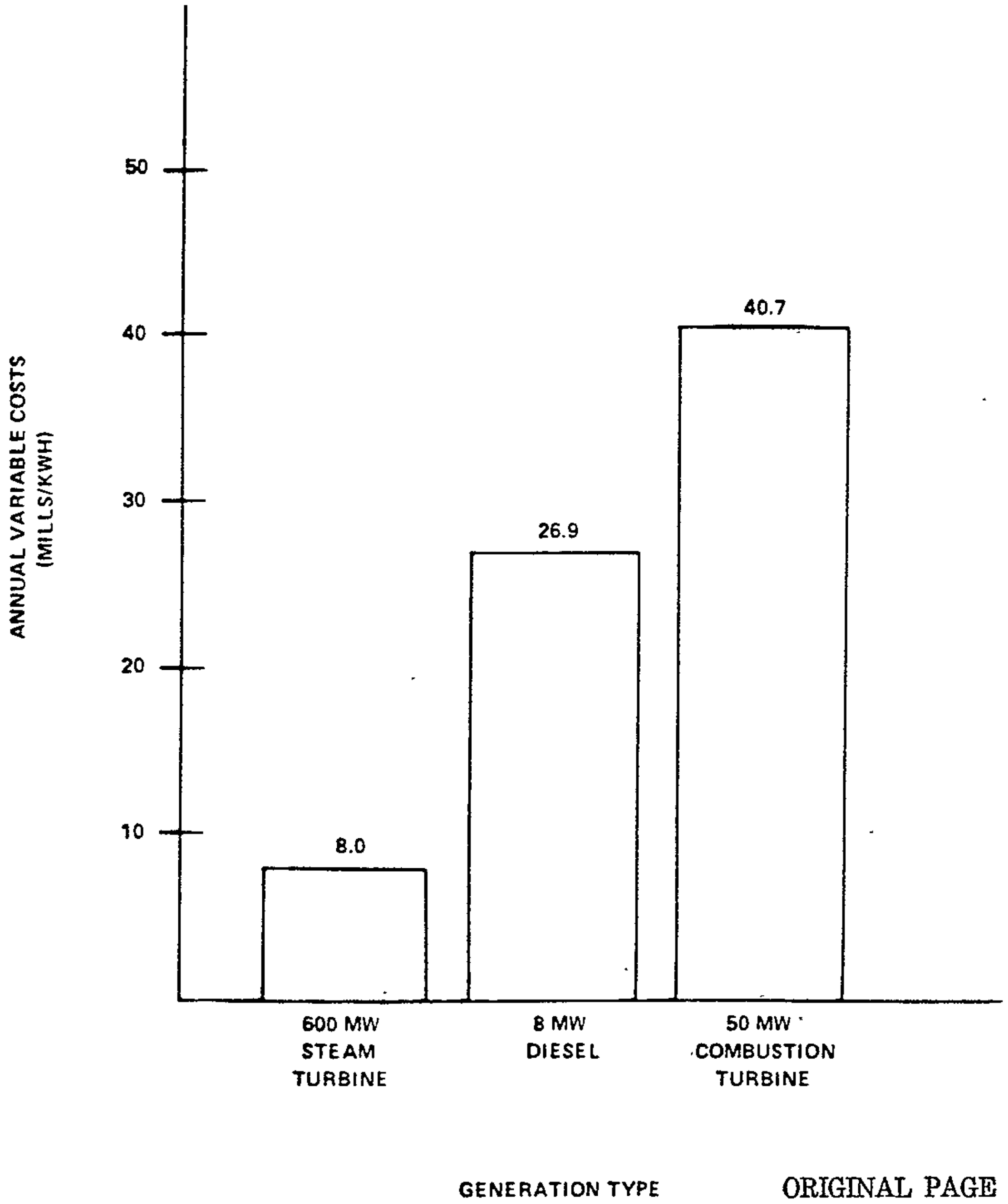

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Figure 4.3-4 Generating unit annual variable costs (1976 dollars)

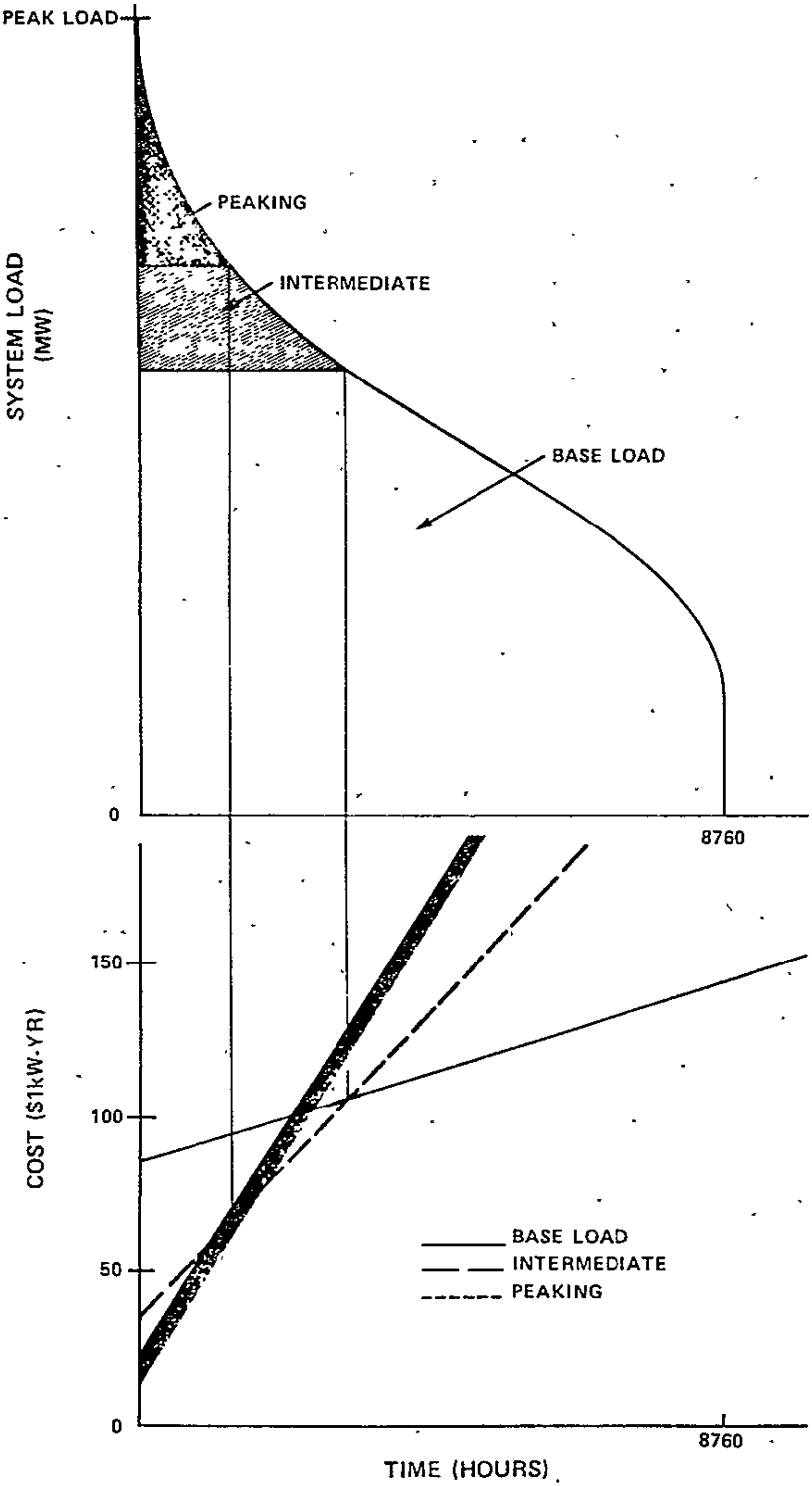

Figure 4.3-5 Determination of optimum generation mix

the three types of generating technologies). The initial point for each curve on the cost axis reflects the capital cost of a given technology, and the slope of the curve reflects operating costs, including fuel. The intersection of the cost curves in the bottom of the figure shows the break-even hours of operation for the various technologies. When these break-even points are extended to the load duration curve, an estimate can be obtained of the optimum capacity mix for a system for a given set of inputs. Using this methodology and the above assumptions concerning technologies and costs, the optimum generation mix shown in Figure 4.3-6 was obtained.

As can be seen, the optimum mix consists of 29 percent combustion turbines, 8 percent diesels and 63 percent fossil-steam units. It might be expected that the generation mix will vary with changes in fuel prices. As a measure of the sensitivity of this generation mix to the coal price assumed, the optimum mix was recalculated for a coal price of $1.20/MBtu. At this coal price, the proportion of coal-fired generation is reduced to 54 percent with a corresponding increase in the amount of diesel generation and no effect on the combustion turbine element.

To see what impact a large increase in oil prices would have on the optimum generating mix, the oil price was assumed to double while the price of coal remained at $0.75/MBtu. The optimum mix under this scenario is shown in Figure 4.3-7. In this case, there is a substantial increase in coal-fired generation to 72 percent. But even for $5.00/MBtu oil, a significant amount of oil-fired generation (28 percent) is justified in the capacity mix.

I have also included some results for this type of an analysis for the fuel cell. Basically the same costs and assumptions as shown before were used except that in Figure 4.3-8, a first generation fuel cell having a capital cost of $250/kW and heat rate of 9,000 Btu/kWh was assumed

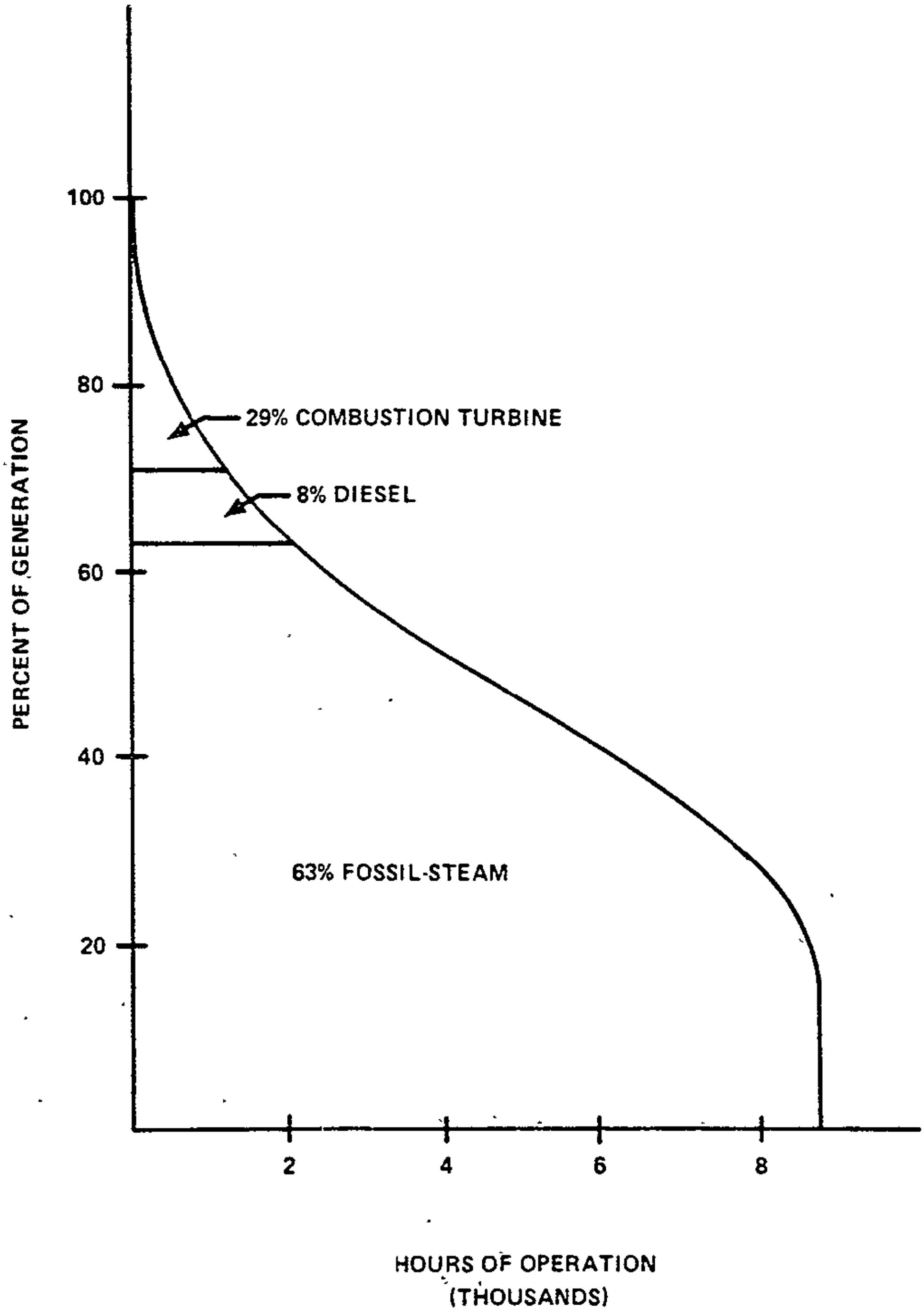

Figure 4.3-6 Optimum generation mix at base oil and coal prices

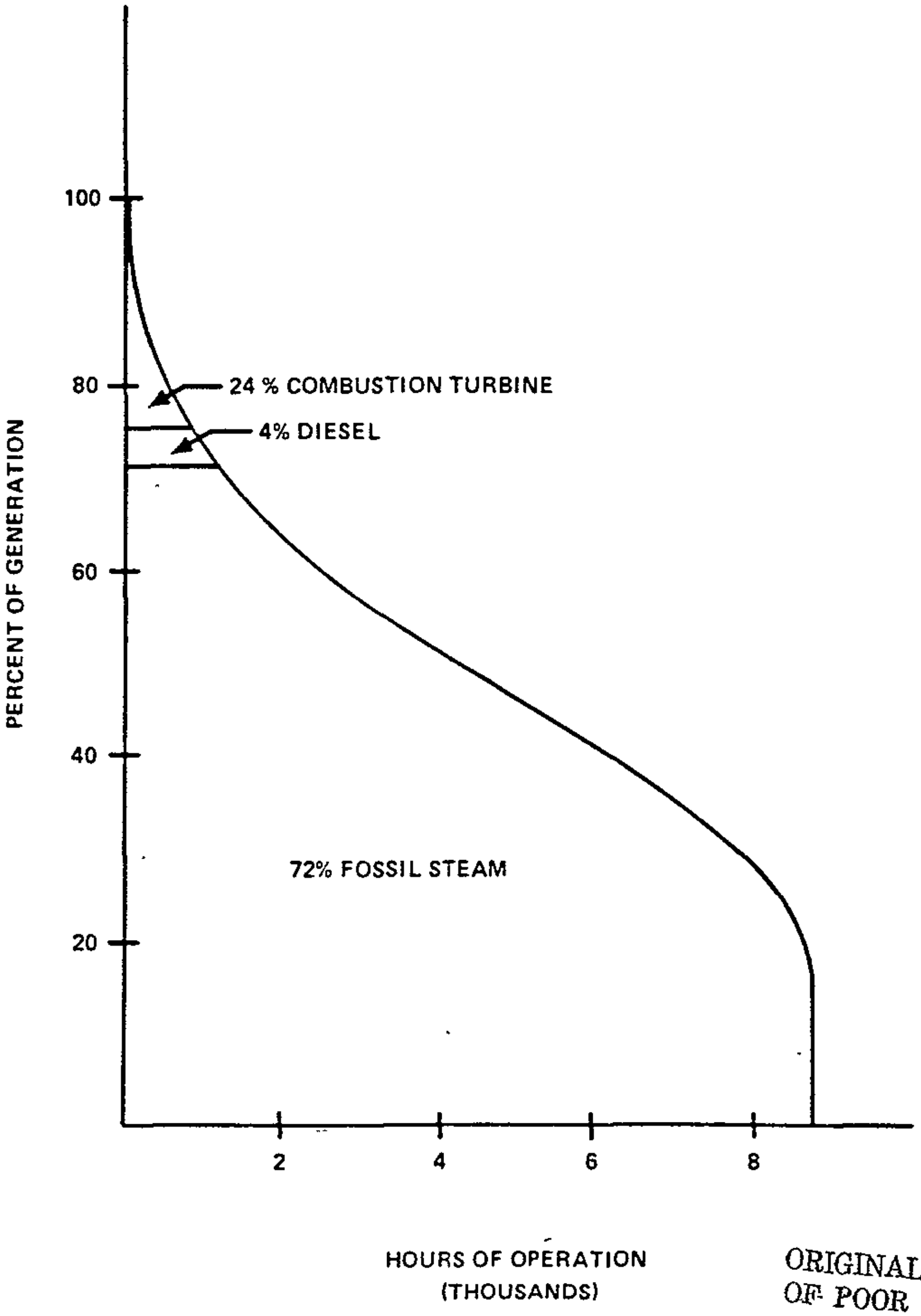

Figure 4.3-7 Optimum generation mix with oil price doubled

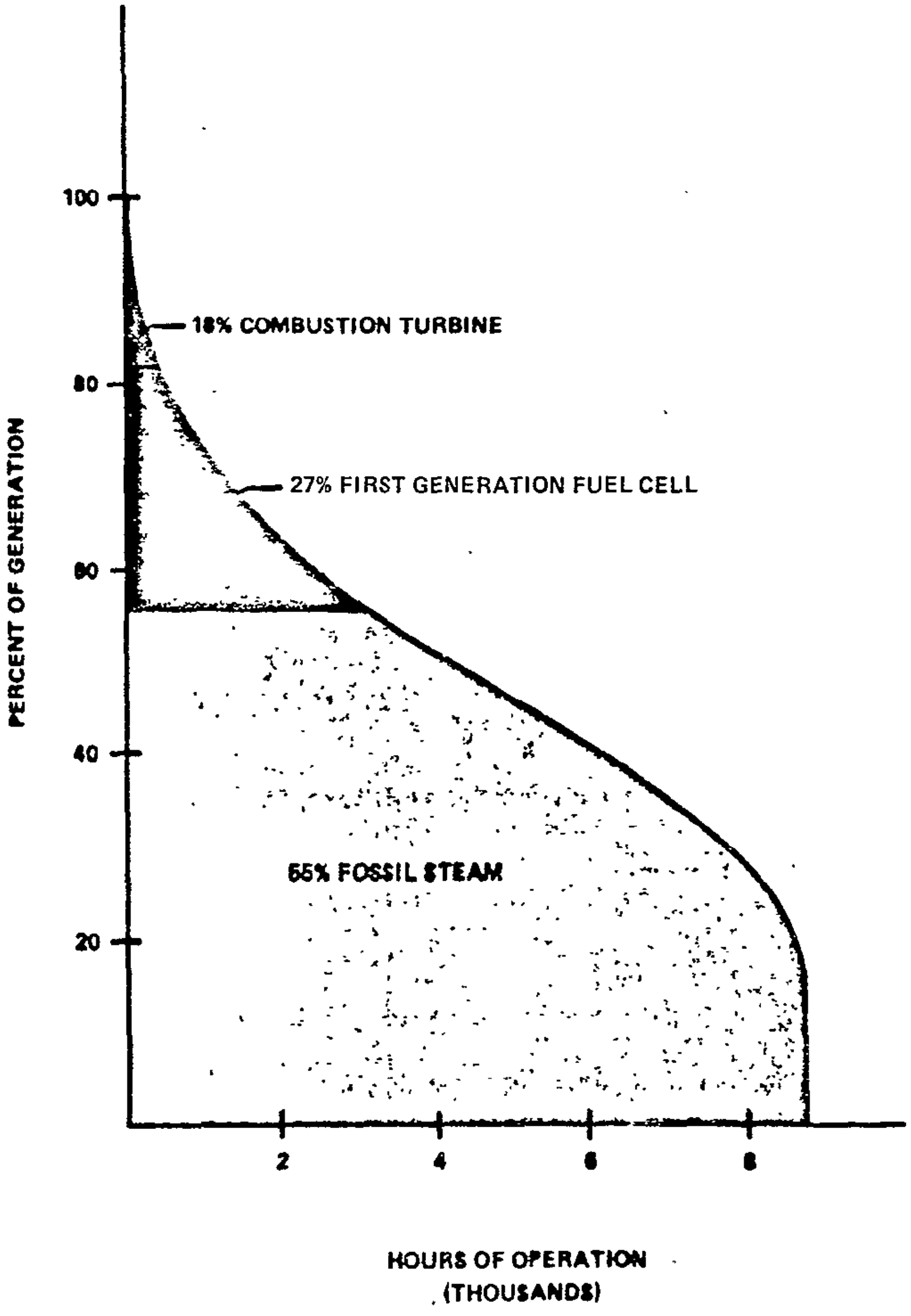

Figure 4.3-8 Optimum generation mix with first generation fuel cell

to be available. As you can see, under the base scenario it penetrated 27 per cent of the capacity mix. In Figure 4.3-9, an advanced fuel cell having a capital cost of $200/kW and a heat rate of 7,350 Btu/kWh is assured to be available. It totally dominates the intermediate-peaking region, penetrating 55 per cent of the capacity mix.

Since a solar thermal system uses energy of the sun for fuel, its energy cost is essentially zero except possibly for some variable operation and maintenance cost. Consequently, one might expect the curve representing a solar thermal system in Figure 4.3-5 to be nearly horizontal. Under that assumption, small solar thermal systems would begin to become competitive with the baseload generation in Figure 4.3-5 at $145/kW of annual fixed costs, with the intermediate range generation at $110/kW of annual fixed costs, and with the peaking generation at $65/kW of annual fixed costs. The derivation of these figures is illustrated in Figure 4.3-10 which is identical to Figure 4.3-5 with hypothetical solar thermal cost curves. Assuming a 9 per cent annual fixed charge rate for a municipal system, these threshold values of annual fixed costs convert to $1,611/kW of solar thermal capital costs if energy is generated for 8,760 hours or the entire year, $1,222/kW if the energy is generated for only 3,200 hours per year, and $684/kW if the energy is generated 1,400 hours per year.

The above is a relatively simplified but excellent methodology for getting a handle on the impact of key cost parameters on a system's power supply costs and optimum generating mix. A more sophisticated analysis would be required, of course, to determine the long-range optimum power supply plan for a system. However, the methodology is useful in terms of helping one conceptualize the relationship of a small solar thermal system, and, for that matter, any power generation technology, in the small utility resource mix.

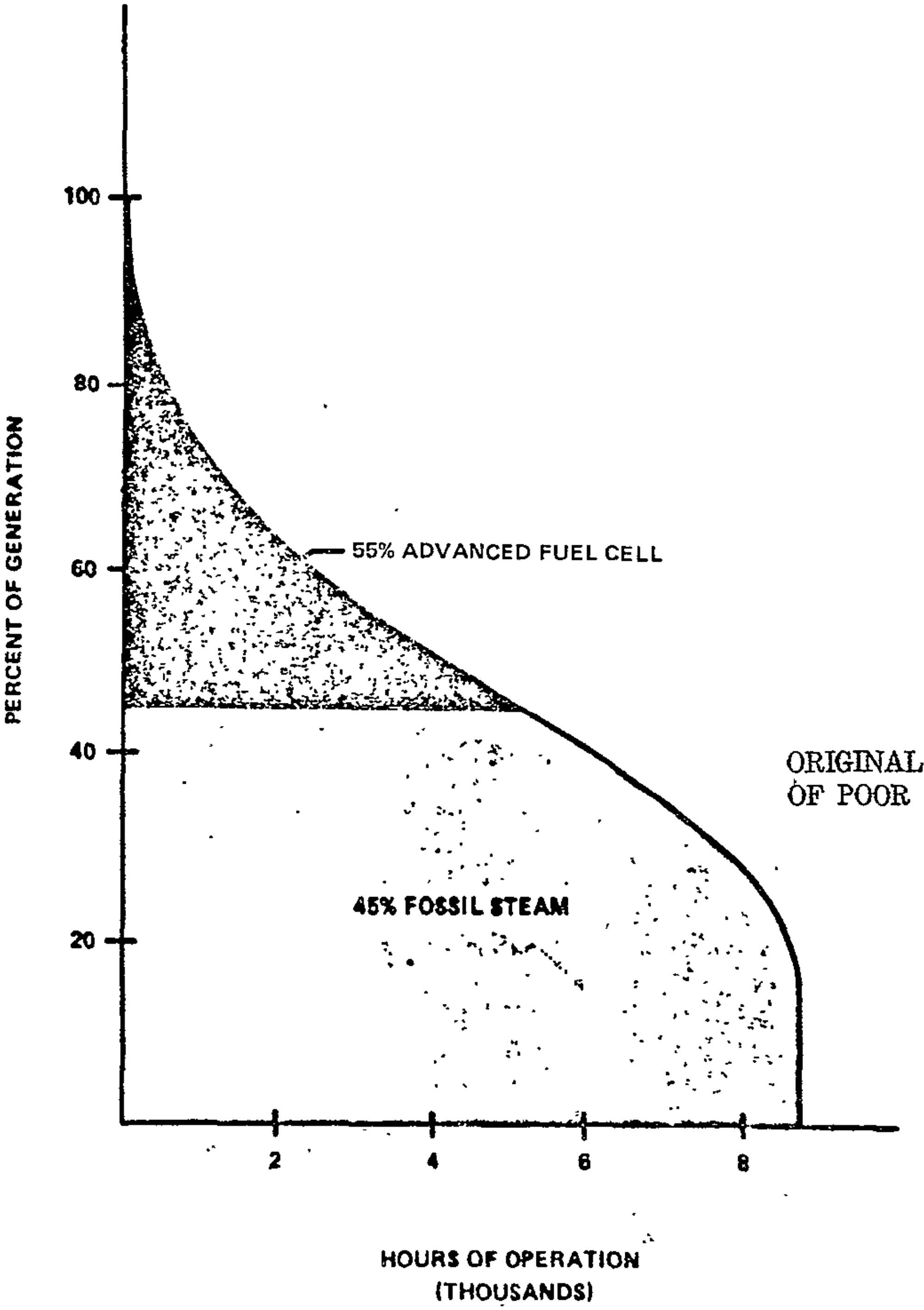

Figure 4.3-9 Optimum generation mix with advanced fuel cell

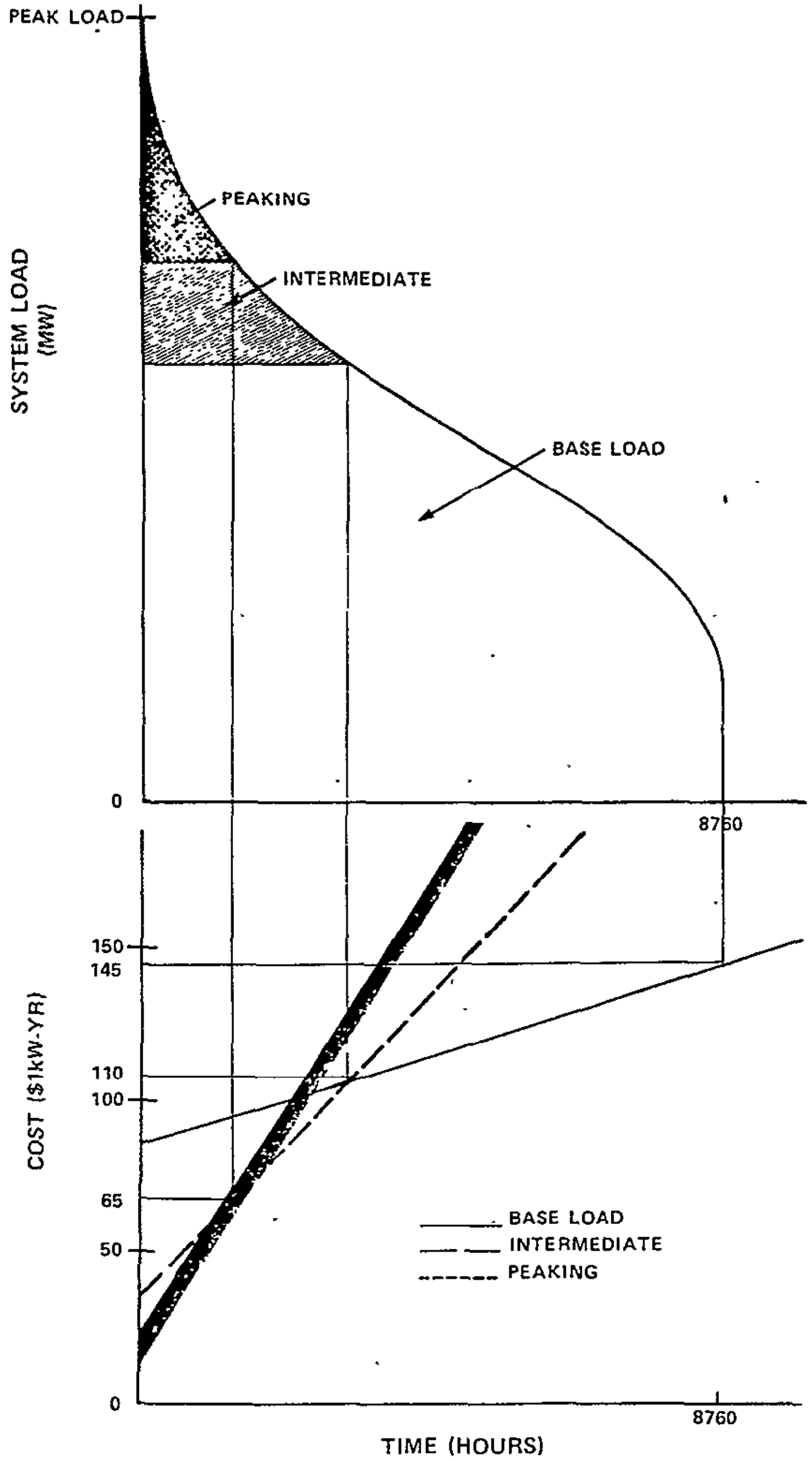

Figure 4.3-10 Determination of threshold of solar thermal penetration into optimum mix

4.4 GENERATION MIX PLANNING - MERWIN BROWN

Manager of Research, Arizona Public Service Company

As Peter Steitz told you, the utility that tries to minimize its overall generation costs has to partition its generation mix with the high capital cost plants with low fuel cost in the baseload portion of the load-duration curve, and the lower capital cost plants with the high fuel cost in the peak and intermediate. It is necessary to do this kind of generation plant mixing, in order to minimize the cost, with few exceptions. Some utilities do not have a choice of generation mix, either due to size or due to location and availability of resources. Taken on an average across the nation, however, the utility generation mix will incorporate a number of different types of generations, suited to specific base-, intermediate-, or peakload applications.

So, how does solar fit into this? Solar is a strange beast. It is uncommon to utilities. Solar tends to have relatively high capital cost, with very low fuel costs -- essentially zero, depending on how it's treated. According to that criterion, solar would fit best in the baseload. Unfortunately, the resource, unlike other baseload technologies, is not always available and not readily storable. Unlike the nuclear plant with fuel in its core that lasts up to three years, or a coal plant with a 90-day coalpile, the solar resource is variable and unpredictable. So, solar does not conveniently fit the usual method of partitioning in the load-duration curve.

Studies have been done that say probably the best place, at present, for solar in the load-duration curve is a compromise between attempting to put the high capital cost-low fuel cost solar into the baseload, and putting it in the peaking, where it would be competing with the highest cost alternative energy generation, such as oil-fired plants. With some storage, that compromise is in the intermediate area. This trade-off comes about because solar becomes a baseload by adding capital investment, that is, more solar collectors and more storage to allow operation of the solar plant during the time when the sun is not available. The effect is to increase the capacity factor by increasing capital cost. Because of the relatively lower generation costs of alternative baseload technology, this expansion of capacity credit into baseload gets stopped at the intermediate area. In short, based on projected economics around the year 2000, solar electric generation may be competitive with oil-fired generation and some of the higher-cost coal-fired generation, but in no way can it be economically extended into the baseload area where it is going to start displacing nuclear and coal. I don't think in our lifetimes we can expect solar thermal electric, or any solar electric for that matter, to take over the whole generation mix. It's going to have a tough time economically, supplying the very top peaking, and an even tougher time supplying the baseload. That situation leaves high-intermediate or low-peaking, with respect to a load-duration curve, as the most likely near term use for solar electric.

The small utility has a problem, in that the bigger the solar plant is, the more percentage that this plant is going to attempt to supply of the generation mix. This makes it tough for them to take something with a very limited utilization factor. About the only way a smaller utility could substantially use solar electric is if it is isolated from the grid; in other words, not in competition with the grid. It could then, maybe not cost-effectively nor cheaply, possibly use solar in a large way.

There are some other things to consider. It isn't a simple straightforward matter, unfortunately. The small solar unit does have some advantages over the grid and the larger capital cost power plants, up around the $1,000/kW range. For example, small plants could be sited closer to the end user, resulting in lower transmission and distribution costs. Also, the small plant has shorter construction times, which generally leads to lower interest-during-construction cost. Because of the smaller incremental additions of capital investment, or capital plant, the cash flow would be smoother. Those are all the advantages with the small system, but, based upon what is now known, they are not sufficient for small solar electric to make much of a penetration beyond the intermediate and near-peaking areas. If small solar plants have a place in the small utility, they will probably be an intermediate or peaking alternative investment that allows the small utility to join the power-pooling of the general utility grid.

4.5 DISCUSSION

Following the formal remarks made by each of the panel members, the moderator and workshop participants were invited to pose questions to different panel members. A paraphrased summary of the major issues discussed is presented here.

o Could a solar thermal power plant ever be considered for baseload planning?

Merwin Brown,

It is true that once built, a solar plant will contribute to meeting the demand for electricity during peak, intermediate or baseload periods as long as the sun is shining. However, you must have guaranteed 24-hour availability of power to economically justify a capital expenditure for baseload equipment, and solar can't provide that guarantee.

Frank Goodman,

No one wants an overdependence on any one form of power generation, such as conventional fossil-fired baseload plants. However, the cost of power generation equipment is borne by a public resistant to price increases,and it is difficult to avoid dependence on these plants when they are significantly less expensive than alternative systems.

o Why are we trying to re-invent the wheel? What about low-cost opportunities for retrofitting our existing steam power plants to use solar energy as the heat source?

Peter Steitz,

Since 75 per cent of the small utility systems in this country do not use steam, a significant retrofit program would be difficult to design.

Frank Goodman,

The lack of availability of land for the collector systems near many existing power plants is a significant problem.

Workshop participant,

EPRI and DOE are now looking at possible solar-fossil hybrid retrofit sites, totalling as much as 40,000 MWe capacity.

o If reliability and competitive capital and operating costs were satisfactorily demonstrated, could a baseload solar plant operate with a minimum fossil-fired back-up capacity as required, due to the expected isolation intermittence?

Peter Steitz,

Yes, theoretically, it could be done; especially since solar power has such environmental and public acceptance advantages. However, there are many different parameters which will have to be examined before these types of decisions can be made.

Merwin Brown,

It's possible, but we must be aware of certain possible effects in long-range planning. A radical climate change in a given location could occur over a 10- to 20-year period, making a solar plant tremendously inefficient.

Frank Goodman,

A self-contained solar plant would require a great deal of storage capacity. It would probably be better to combine solar with conventional equipment having guaranteed availability in a hybrid plant design.

Workshop participant,

Every solar plant must have total redundancy with guaranteeable reliable equipment because of the unpredictable availability of insolation.

o What are the key issues in deciding to adopt solar plants?

Merwin Brown,

We (the utilities) simply must be conservative by the nature of our business. It takes a long time for significant change to happen. The urgency of the energy situation only complicates the problem.

Peter Steitz,

Loads are becoming more and more difficult to forecast and plan. Decision or planning strategies are constantly being modified because increases in acceptable risks are becoming a way of life.

Frank Goodman,

This question, like so many issues facing solar, is very regional in nature. The pace of implementation and level of accepted risk will be determined in part by the availability of local reliable energy sources, such as coal in the Midwestern states.

Workshop participant (medium-sized utility),

We would be extremely cautious and require credible operating data before we would consider installation of solar equipment. We expect, along with Chauncey Starr (founding President of EPRI), that there will be no fuel problem for at least the next 50 years which would hinder our generation planning. Therefore, we will wait for "the big guys" to take the risk and prove the technology, before we make any move toward solar. For instance, we waited 10 years after nuclear power had demonstrated capability before getting involved in that field.

Workshop participant,

We must be cautious of over-localization regarding these planning decisions. Many small scope decisions in favor of solar thermal power could add up to a poor national policy. A mechanism should be devised for co-ordinating local decisions on a national level.

Workshop participant,

It seems to me that we're getting ahead of ourselves at this point. These questions can't be adequately addressed this early in the developmental process. The best plan of action now is to proceed with the experimental and demonstration projects in order to prove the technology's feasibility in the first place. Long-range planning strategies can then be formulated on the basis of better and more information.

o In light of all the apparent barriers, why would you seriously consider solar thermal power?

Peter Steitz,

We've simply got to consider all the viable alternatives and solar is one of them.

Merwin Brown,

It's impossible to predict the economic and political environment in the future; therefore, we have to "cover all the bases." Paticularly since the long-term potential is so great, we cannot neglect the development of solar power.

Frank Goodman,

Whenever it's going to happen, one day fossil fuels will run out. We must begin now to prepare for switching over to other forms of energy.

4.6 SUMMARY

Solar thermal power is related to other power options in a number of areas:

- Utility economics
- Fossil-fired hybrid plants and equipment redundancy
- Generation-mix planning.

In planning for the adoption of solar power systems, it is very difficult to predict how the economic climate may change to favor higher-risk technologies. In any event, solar is not likely to compete strongly against conventional systems in the near future.

Once technical reliability has been established, solar equipment will most likely be implemented in solar-fossil fuel hybrid plants to provide intermediate or peaking power capacity. Some amount of conventional generating capacity must be provided, in order to counteract the unpredictable availability of the sun. The urgency of the energy crisis continually increases the attractiveness of solar as a power option and raises the acceptable risk in planning decisions. However, utilities must be able to provide their customers a guaranteeable service; therefore, conservatism will continue to be an earmark of conscientious utility generation planning over the next 15 years.

Interactive Sessions 5.0

INTRODUCTION

Workshop interactive sessions were conducted to give the participants an opportunity to discuss important topics in a small group atmosphere. The participants listened to overview presentations prior to breaking up into groups of five or six for discussions. Following discussions of the topic and identification of the issues, the small groups reported back to the general session.

This section contains the overview presentations followed by a ranked listing of the major issues identified in the small discussion groups. A short summary statement of the major conclusions is also included.

5.1 INSTITUTIONAL ISSUES

5.1.1 Overview Presentation - Robert L. Mauro,

Director of Energy Research, American Public Power Association

I'm going to talk about the setting in which the institutional issues arise in connection with energy policy, rather than the institutional issues themselves. The problem of institutional issues reminds me of a book by Jack Douglas entitled, "Never Trust a Naked Bus Driver." There is a chapter in it titled, "Famous Bastards." It only had one sentence in that chapter. Simply, "You know them all, already." The same thing is true of the major institutional issues: You know them. I really don't have to talk about them, because the really interesting issues are the environmental ones, and someone else is speaking on that topic.

Many of the concerns about dispersed solar thermal generation are common to other technologies. We have heard much discussion here about solar, but not a lot on dispersed generation. You have cogeneration, small hydro, fuel cells and a number of other technologies that are coming along, which are dispersed energy sources. They are likely to be demonstrated, and attempts at marketing them, will be made well before dispersed solar thermal. That means these technologies are going to face many of the institutional and utility interface problems that dispersed solar thermal must solve. That's worth keeping in mind. Another thing worth keeping in mind is that we have both wind and central station solar thermal demonstrations coming along, and they'll have to face the problem of being intermittent energy sources. At the same time, or slightly before, dispersed thermal is going to have to address this problem.

I believe it's worth looking at these two technologies, to see, basically, what problems arise, how they deal with these problems and how successfully they were dealt with.

Almost every issue that solar thermal energy development will face, will be faced by these other technologies, in one form or another. What we have to do is to translate how these issues impacted these other technologies, and what that relevance is to dispersed solar thermal. This, however, is an aside to my topic.

The concept I want to begin with is that fundamentally, the management of energy supply, distribution and use is an integral part of the ability of society to function. Certainly, the summer's events in New York illustrated that. For an energy policy to be effective, it has to coincide with the fundamental aims of our social and economic development. That may well include, and in this society I believe does include, environmental concerns. I really think the acid test for an energy policy is: 1) that it meets the government's legitimate insitutional concerns, principally national security and economic stability; and 2) that it meet, at the same time, a public acceptance test. That test is really that the energy policy be consistent with state, local and individual aspirations as to the kind of society, lifestyle and economic condition which people want.

I think the government's concerns, which are addressed pretty well in President Carter's National Energy Plan, is to minimize the effects of another oil embargo and the impact of buying foreign oil at a high price. That is basically what the President wants to do. He's going to do it three ways: He's going to stockpile; he's going to curb consumption, which is conservation; and he's going to go to fuel-switching to domestic fuels and renewable resources, which some wags have termed "Burn America first."

There is some question of whether the current policy can be effectively implemented, largely because the President has other, conflicting, aims which directly conflict with environmental concerns about coal development and utilization. There's no question, at least in my mind, that, by and large, the policy is reasonably appropriate from the governmental standpoint. I think that the public acceptance question is a different matter. It's a far more difficult issue, and really has not been addressed by this Administration, or any other Administration. The proof is that the Senate could so easily shred the Carter energy plan. If there were overwhelming public support for that plan, there's no way the Senators could have done what they've done to it. I really think the nature of the problem is very simply this: It's difficult to convince people, who today are paying around 60 cents a gallon for gasoline, living in single-family homes and driving big cars that they should want to pay two dollars a gallon for gasoline, live in cluster housing and drive small cars. It's a little like selling death; you can't do it. Yet, that's basically what the government's policy is and that's probably why half the people don't believe there's an energy problem. If they ignore the fact that there's an energy problem, they don't have to change anything. They don't have to change their aspirations. It's going to take a long time, without a clear and present and continuing energy problem that everybody's aware of, to get people to change energy consumption patterns. By a long time, I mean as much as two generations.

Difficult as this is, if that were the extent of the problem, we could probably deal with it. But it's really more serious and complex than that. It's worse than that because of the other half of the population, who thinks there's an energy problem, is polarized on how to deal with it. At one end, you've got industry and labor, primarily with a rather traditional supply orientation. At the other end, you've got the end-use orientation primarily sponsored or advocated by the environmentalists and the consumers. Their principal aim, rather than developing energy supply and fuel, is to curb energy waste and curb energy use.

The problem is that the opposing groups spend too much of their time throwing stones at each other, and both groups tend to discount the importance of the other's contribution to the solution. Because the U. S. tends to operate on a consensus, the situation results, basically, in nothing being done.

And, finally, and in a sense -- most unfortunately, since energy is politically center stage -- it becomes a very convenient vehicle for demagogues and for people who want to express a range of social and political views unrelated to solving energy problems.

Let me make a few comments about the supply orientation and how this ties into the solar question. The traditional supply view is growth. It is the traditional view that what we need is continued economic, material and technological growth. If we don't have this growth, we are going to have massive unemployment and we're not going to provide hope for upward mobility among the lower classes and among the disadvantaged and the poor. The way we have to grow is by uncoupling the available energy supply from its traditional resource constraints. The chief constraint is fuel. The supply-oriented technologies advocated are primarily the breeder and fusion, in the long run. From this perspective, the view of solar energy and particularly dispersed solar generation is that it's an expensive, undependable technology of perhaps some regional interest in areas such as the Southwest.

On the other end of the energy policy spectrum, you have the end-use advocates. Their view is that our energy consumption is intolerably high and that it cannot be sustained at the present rate. They believe that only a fundamental restructuring of our society will allow us to solve our energy problems and that really entails returning to a simpler lifestyle and living in closer harmony with nature. Their fundamental view of energy policy is, of course, diametrically opposed to that of the supply orientation. They contend that to reduce energy consumption is not necessarily to reduce the quality of life (and you can read there, to some degree, gross national product). This is basically a belief that the quality of life (GNP) can be uncoupled from energy consumption. Of course, their solar view is quite different, that solar is a clean, free, safe and eternal energy source.

What comes out of this maelstrom is regulation. Generally speaking, the society restricts behavior it doesn't approve of and wishes to curb through regulation. At the same time, it provides incentives -- primarily financial -- to encourage behavior patterns which society believes are beneficial to its perpetuation. Thus, for instance, regulation is the primary mechanism used to stop polluting, while tax subsidies are the primary means used to encourage solar heating and cooling. In the current situation, there's a tendency for advocates to muddy the waters by seeking incentives for the technology they favor, while attempting to raise artificial barriers against the competition.

I think it's important when talking about institutional barriers to realize that they exist to protect something, whether it's the environmentalist protecting the environment; whether it's the utilities or industry protecting economic and competitive positions; whether it's a PUC seeking to protect low rates. Therefore, if you want solar thermal generation to succeed, it should be non-threatening to both groups. In fact, to build a constituency for the technology and to get the tecnology implemented, what you really need is to demonstrate the value and the compatibility of solar thermal with each of the conflicting energy views. That doesn't mean that solar is going to have an identical role in each of the scenarios. It does mean it can fit in there someplace and help the people who foster or advocate those views to reach the goals they wish to attain. It's only through broad-based support that you can overcome the opposition to solar development.

Where does this lead us? Traditionally, our society has synthesized conflicting views to reach consensus. In this instance, I believe, that's exactly what's going to happen. For this synthesis to occur, the concept of the elctric utility is going to have to change and to be broadened to become that of an energy utility. Electricity will be supplied by a combination of large and small dispersed units. Remote operation of dispersed units will be integrated with direct load control, thermal electric storage and, probably, with remote meter reading. Besides moving beyond the customer's meter, the utility already is getting into home weatherization, energy audits and residential temperature conditioning. That means solar heating and cooling; it means heat pumps; it means district heating, and perhaps a number of other areas that utilities are not concerned with today. This is going to be done because revenue needs will require it, and regulatory bodies are going to say you have to do it.

In addition, I believe that the concept of energy conservation is going to have to be transformed into positive goals for industry. Energy conservation is essentially a negative concept for industry. It's going to have to be sold on the basis of increased productivity per unit of energy consumed. I don't think that the environmental regulations are likely to be relaxed -- they're going to be more stringent. Manufacturers, by and large, are going to have to modify their industrial processes accordingly. That may mean, in many instances, substituting electricity for primary fuels. This may dovetail nicely with the renaissance of cogeneration, which could be solar as well as anything else, assuming site availability. Returning to my central theme, the institutional issues that arise in connection with energy policy can become an imposing barrier to solar development if we do not recognize them and take appropriate steps to overcome them. These barriers exist because organizations in the energy industry have difficulty coping with solar electric technology. The first step in equipping utilities to deal with dispersed solar generation is to develop an understanding of the technology through workshops such as this one.

5.1.2 Issues and Conclusions

This section is based on the consensus derived from the interactive discussion groups regarding institutional issues.

The utility industry, along with the government, must take on the task of educating the public regarding solar power, in order to avoid public disillusionment and dissatisfaction.

Public perceptions and opinions of the solar energy development program are important, particularly as they relate to the following areas:

- The public currently has unrealistic expectations regarding the cost and availability of solar electric power
- The public may come to distrust the utility/energy industry if they consider solar development and implementation to be advancing too slowly
- An untimely response by utilities and industry to public pressures could result in uneconomic generation-planning decisions and equipment purchases
- Regional attitudes toward solar vary widely, requiring regional responses and solutions.

The risk threshold for utilities investing in an uncertain technology is largely a function of the size of the utility and whether or not it is a private organization.

A mechanism must be devised to manage the use of large amounts of public funds for the development of high-risk technology.

Some utilities' role in solar development is limited by their charter. Often, the charter needs to be expanded.

Integration of solar plants with existing conventional systems requires that the related institutional and political barriers must be defined and, subsequently, overcome.

A climate must be created which will permit large and small, municipal and private utilities to co-operate and combine forces for the purposes of funding solar development and pooling power.

A trend exists among smaller utilities to band together to pool and share ownership of capital equipment.

Small utility companies have special problems with respect to:

- Operation and maintenance
- Labor unions
- Training requirements.

These problems are intensified in regard to high-cost, high-technology equipment.

Current solar regulatory uncertainties leave plant design requirements undefined.

Cogeneration is politically and socially favored, yet will require a special effort to solve the related technical and insitutional problems.

Roles in solar thermal power research and development need to be clearly defined as they relate to:

- Government (federal, state, local)
- Private research
- Utilities
- Equipment suppliers

Small utilities are often not able to raise the necessary capital for solar plants.

The major institutional issues in adopting solar thermal power are external to the utility organization itself.

5.1.3 Summary

Making valid and wise decisions regarding the institutional issues is, indeed, difficult. This task is further complicated by the existence of many poorly-defined and wholly unpredictable groups in the utilities' environment, whose interests and influence cannot be ignored. Some of the important groups include:

- Government agencies
- Regulatory agencies
- Special interest groups
- General public
- Other utilities

Purposeful and intelligent marketing and information dissemination must be performed to lay an adequate foundation for the development of solar thermal power, and to overcome the institutional barriers constraining the adoption of this advanced technology. Major components of the utility environment to be dealt with are:

- Demography/geography
- Law and politics
- Technology
- Economics
- Public opinion

In order, successfully, to implement solar thermal technology, a utility must not only be adaptive, but innovative in response to the many and diverse institutional issues surrounding the implementation of solar thermal power.

5.2 ENVIRONMENTAL AND SITING ISSUES

5.2.1 Overview Presentation - Edward J. McBride

Systems Engineer, Black and Veatch

I will try to give you an outline of topics and fundamental issues to be considered in the site selection for a solar power plant. Then we will discuss them in the small groups and the report-out session.

In 1973 and '74, Black and Veatch did a study for NASA's Lewis Research Center in which we compared trough collector, dish collector, and central receiver power plants in the 100 to 1,000 MW size range (Figure 5.2-1). I want to stress the sizes. We concluded that the central receiver was a clear winner in that size range. However, I'm not making a claim that it will be cost-effective at the one megawatt level. It is the system that we've been studying at Black and Veatch for the last four years and the one that I know the most about. It is also the one that has the most complex siting requirements, and it's the design I'm going to discuss today. Some of the consistencies with the dish and trough type systems will be obvious; some of the differences will also be obvious, and I'll try to point them out. Nevertheless, looking at the larger central receiver plants will provide a good basis for analyzing the smaller distributed systems.

Black and Veatch teamed with Honeywell and Babcock and Wilcox in a 10-MW power plant design for the ERDA pilot program. In our design, the distance from the ground to the radiation zone aperture at the top of the tower is approximately 450 feet. The receiver tower for a 60-MWe plant is 650 feet from the base to the top. This size plant requires 6,244 heliostats and takes up 160 acres of ground for a nominal 50-MWe plant.

When you look at site selection for central receiver plants, there

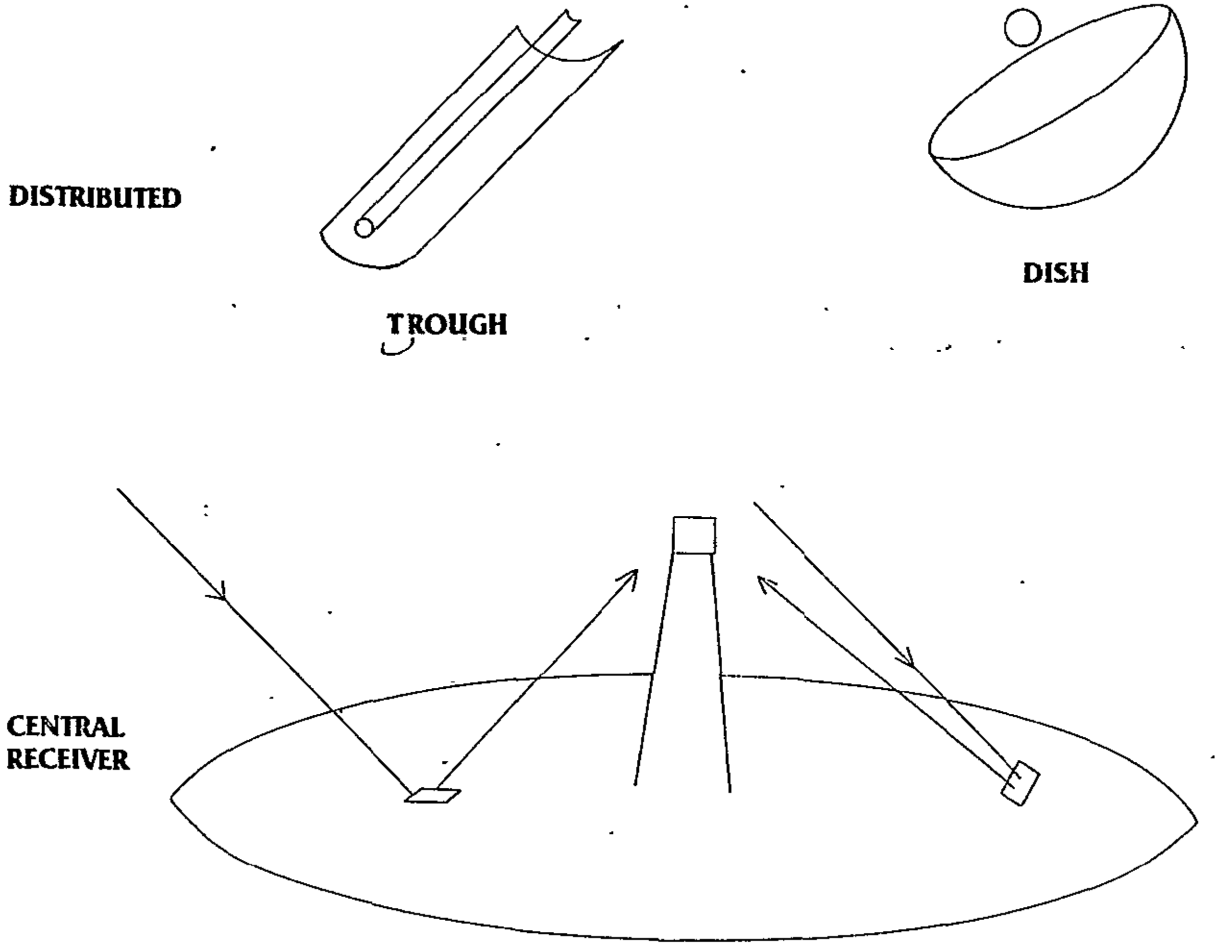

Figure 5.2-1 Types of systems: Dynamic conversion solar electric plants

there are three fundamental considerations:

- The engineering aspects:
  Plant placement has a major effect on performance and a major effect, therefore, on the cost of the plant and the contribution of capital investment to busbar energy costs.
- Environmental aspects:
  People think mostly in terms of land use and the cost of dedicating large land areas to a solar plant. Radiation problems, heat problems, and thermal pollution are also included here.
- Safety aspects:
  These considerations include the problems of burning and blinding animals and people. They also include the safety requirements caused by the extreme height of the receiver towers.

When you look at the site characteristics for siting a central receiver plant, there are five basic elements to be evaluated for engineering and cost purposes:

- Insolation
- Meterorology
- Seismology
- Topography
- Hydrology

We'll cover insolation later in a little more detail.

Meteorology, particularly the type of cloud cover over a central receiver plant, or any other type of solar plant in general, is as, or more, important than the hours of clouds. A cloudy day, followed by a clear day, etc., is not too hard to handle from a power plant control system point-of-view, but a half-hour clear, a half-hour cloudy, etc., is very difficult to handle. Winds are also important. Unlike distributed collectors, central receivers cannot accurately function in 30- to 40-milean-hour winds, because the heliostats have to track with a 1½-milliradian accuracy ($\sim$3/20°). The troughs and dishes of distributed collectors do not have to track the sun with nearly that accuracy, so the wind is not as much of a concern to them.

Seismology: In one sense, the type of seismic area affects the whole plant, because, if there is a tremor and your collector system becomes misaligned, whether dishes, troughs, or heliostats, the entire system must be readjusted. But, the tall tower has special seismic considerations. In the 60-MWe plant designed for EPRI, a General Electric Frame 7, 60-MWe regenerative gas turbine is mounted at the top of the tower. It weighs 880 tons and is 108-feet long. That tower will take a seismic zone-three nuclear design-basis earthquake. However, the cavity receivers have forty-foot long silicon carbide ceramic tubes. Those tubes would have to be replaced following a major earthquake; there's no question about it. There is no economic way to make all the equipment in that tower function properly in a seismic zone-three design-basis earthquake.

Topography: For a distributed collector system, it is probably not as important as for a central receiver plant. The plant cannot tolerate rapid fluctuations in ground elevation. Many low ten-foot rolling hills will cause shadowing and blocking among the heliostats; however, a constant slope is permissable. In fact, a constant slope, increasing to the north, is the most preferred type of topography.

Hydrology: Depending on the type of system, you have to reject heat to the atmosphere by one means or another. If you use the open Brayton cycle, hot air is discharged. In a water/steam system an air-cooled condenser can be used, which is very expensive and decreases the efficiency of your turbine generator equipment because of the high back pressure. The other alternative is a wet system. Now, if you use a water-cooling tower, there are significant water requirements. Suggestions have been made to place these power plants in California, with access to the Los Angeles aqueduct. However, this alternative is unreasonable and other cooling water sources will have to be found.

Let's go back to insolation for a moment. Figure 5.2-2 shows the average level of insolation in various regions of the country. (The greater the number, the more sunlight per year.) Now, as anyone who has been in Topeka or Kansas City on a hot August day can testify, the sun is as intense there as it is anywhere else in the country. So, a 50-MWe peak plant will produce about 50-MWe anywhere on a clear day, but only about half as much annual energy will be generated by that plant in Kansas City as in Death Valley. Most of the available figures showing mills per kW hour for a solar plant are based on plants sited in places such as Death Valley. The place where that power plant is located has a direct effect on the mills per kW-hour cost of the power, since the capital cost of that plant per unit area is roughly the same everywhere.

Now, when you get into environmental considerations, you must include the following:

- Birds:

  Birds can collide with the tower. There's nothing that can be done about it. Also, birds can be blinded or burned. There's nothing that can be done to stop it. I don't mean to take it lightly, but if people worry about birds too much, then no one is ever going to build one of these plants. I don't know any way to solve that problem.

- Thermal pollution:

  Negative thermal pollution; environmentalists may point out that it's just as terrible to have negative thermal pollution as it is to have positive. The system is taking heat that would normally strike the ground, converting some of it to electricity, and pumping it down a piece of copper wire.

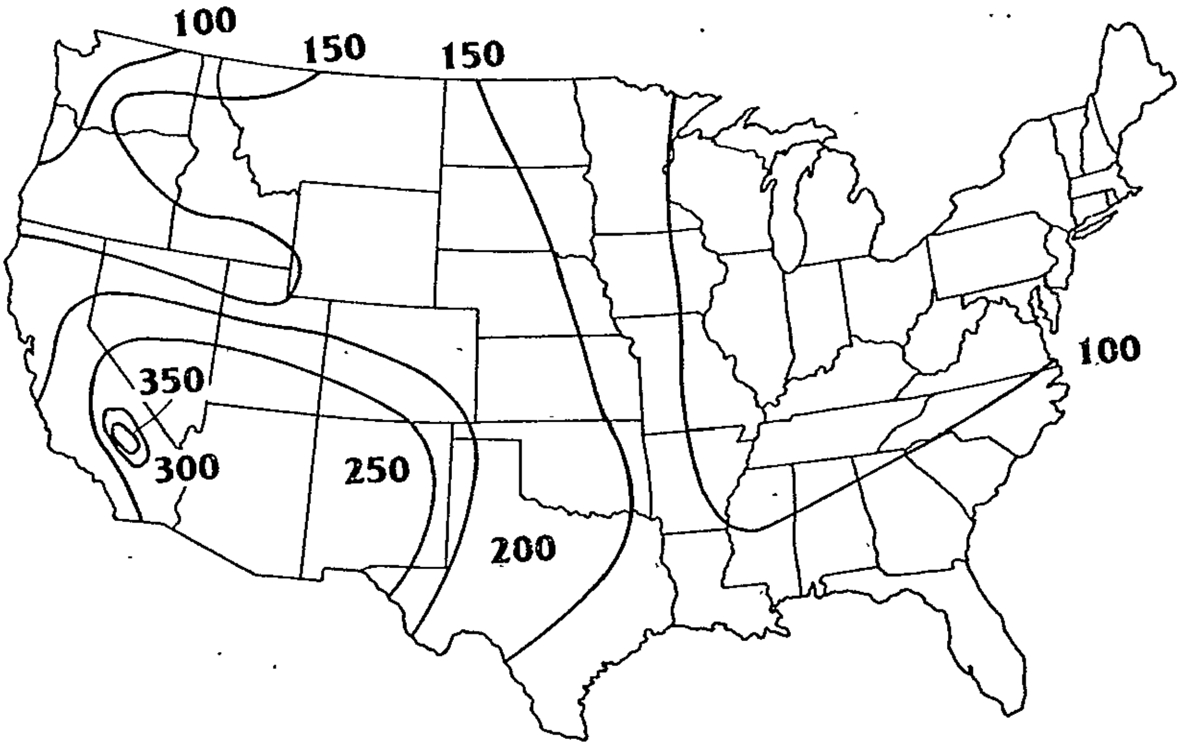

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Figure 5.2-2 Direct insolation - mean daily energy (Langleys)

Subsequently, it is cooling off the site of the solar power plant. There may be some animal that cannot live if you lower the temperature. This is no joke. There might be some ground squirrel that lives only in Death Valley and if the ground temperature drops by four degrees, that ground squirrel will not live, or mate, or something, and the plant will not be built on that site. That is the thermal aspect of the environmental considerations.

- There's also a thermal aspect of safety; however, it is not a problem for the low-lying distributed collection systems. Safety will be further discussed later.

A one-MW pilot plant or one-MW-small power system will probably not operate with the same overall thermodynamic efficiency as a large plant. Therefore, expect the land use per unit of capacity to rise somewhat. A 50-MW Rankine system with 210-MW hr storage, requires approximately 640 acres. An average shows eight acres per megawatt. To erect a 100,000-MW capacity plant will require a site 35 miles square. It is my opinion that that is not very much land to devote to 100,000-MW capacity, when you've got a country that's having an energy crisis. I do not believe that land use is a significant environmental consideration. Now the particular piece of land that a utility chooses may run into environmental considerations at the local level, but the total amount of land that we are talking about for use by solar power plants in this country is not large.

Safety; there are two fundamental considerations in safety:

- People can be burned or blinded by high intensity radiation.
- Aircraft:

  A central receiver plant with a tall tower can cause interference with aircraft.

On the burns and blindness issues, it all comes down to a physical optics problem. A perfect focusing mirror is a parabaloid of revolution or essentially a small section of a sphere. Because of the large distances, if the sun were a point, no matter where the sun would be, there would be two foci from that mirror, F^1 and F^2 (Figure 5.2-3). It is designed so that the on-axis focal length is equal to the distance from the mirror to the target and F^1 will always be closer and F^2 will always be farther from the surface. They are line foci. Obviously, the mirror is never going to be perfect, and the sun is not a point. Nevertheless, there will be extremely high-intensity radiation from a mirror at those focal lengths. Now let me just dismiss the aircraft question very simply: Aircraft could run into the tower. Well, aircraft could run into anything tall. We have a lot of power plants in this country with tall smokestacks, and there are known ways to solve the problem. If the normal FAA regulations with strobes and lights are heeded, the problem is solved.

Regarding the problem of disorienting the pilot: If he flies at 30,000 feet over the tower of this plant and looks down at it, while it is functioning normally, it will look very dark. Remember, that much of the light that was going to hit the ground is being reflected where the pilot can't see it, into the receiver. So, the plant will look like a black spot on the ground. Even in the worst case, when, for some reason, every single mirror on the ground is aimed at a point 35,000 feet up when a Boeing 707 is going by, the radiation intensity would be on the order of two per cent as bright as the sun. You would be able to look directly at the plant from 30,000 feet without damaging your eyes, and you would not be in the path of the light for a long period of time. This has to do with the fact that a focusing mirror has a spreading image over very long distances. Even if all the heliostats were overlayed, you would not blind the pilot or burn up the aircraft. There are 6,244 heliostats in that single 50-MW plant. Some of them are bound be working improperly, perhaps, from locking up the mechanism. If this occurs, no matter where the sun is, there will be two foci and they will

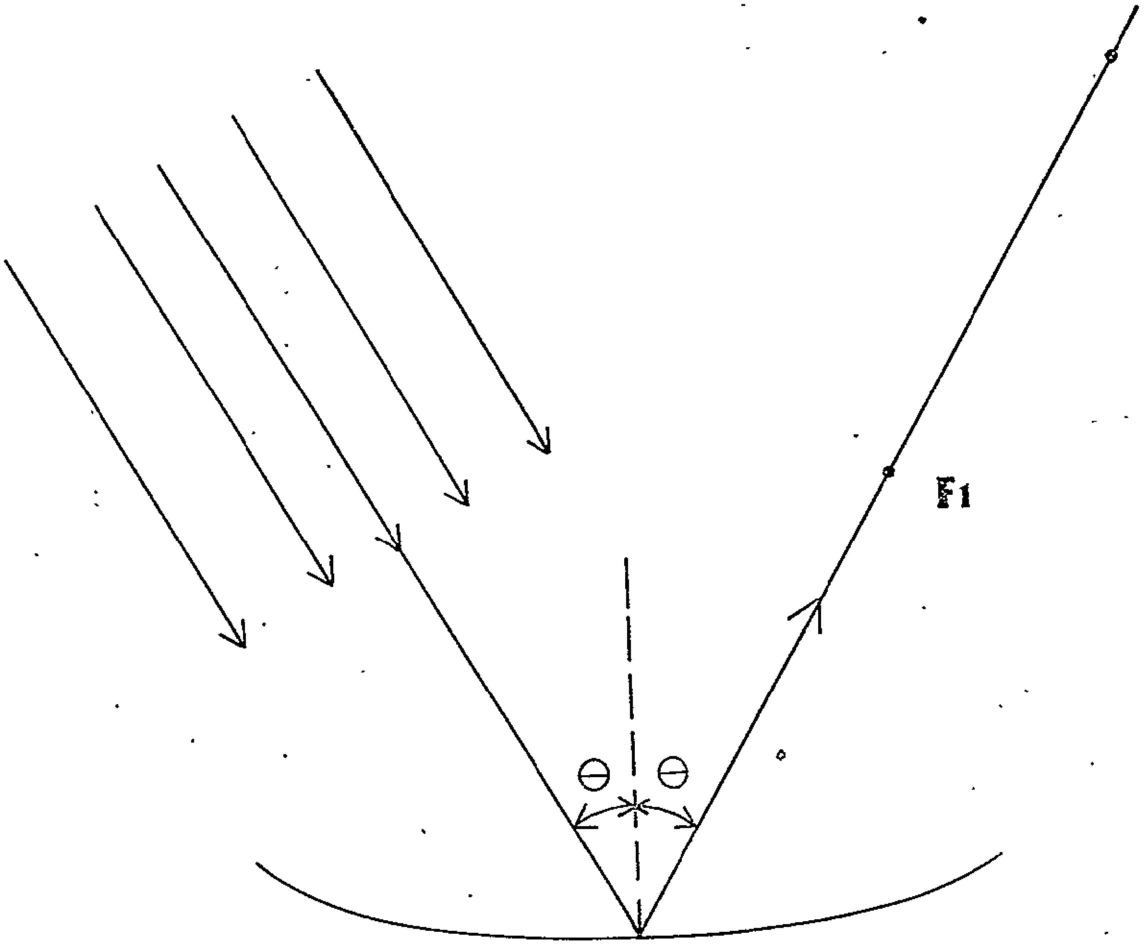

Figure 5.2-3 Central receiver plants: Optics of focusing mirrors

just continue to move in space as the sun moves. There is no way in the world to determine where those foci are going to be and to make sure that no one gets in the way of them. It is the heliostat that is malfunctioning without anyone's knowledge that causes this problem. Normally, the one that malfunctions visibly is turned over in a stow position to eliminate this problem. The heliostats that become misaligned, with their foci moving within the sphere of influence of the power plant, are the ones that become dangerous. They are at the places where people working around the power plant might be. These people can even be at ground level, depending on the orientation of the mirror. So, there is a fundamental safety consideration with central receiver plants that deals with focusing the heliostats. If a person walks into that zone, he or she can suffer eye damage and can suffer burn damage, depending on how good a mirror it is. So, a problem exists which must be dealt with.

Summing it all up very simply, central receiver plant site selection has the following characteristics:

- o Similar to fossil fuel and nuclear
- o Strong impact on cost
- o Land use not significant
- o Environmental and safety impacts

SUMMARY

If plans are to reject heat with water, the plant will have to be near water. The power plant should not be built on top of a fault, because of the danger of a possible earthquake. Do not build the plant where there are 200-mile-per-hour winds, because they'll knock the central receiver down. The same basic requirements apply to solar plants as to conventional systems. Where the plant is located has a strong impact on the cost-benefit analysis of that solar power plant, no matter what kind of solar power plant it is. I do not think that the total land use we are considering is a significant problem, although there are environmental and safety issues that are not yet resolved.

In conclusion, the site-related issues and problems in the development of solar thermal power are not trivial, but are clearly solvable.

5.2.2 Issues and Conclusions

Space is a definite problem in municipal-urban areas regarding:

- o Aesthetics and public acceptance
- o Land availability
- o Operations and maintenance.

Plant siting and feasibility studies should be performed on a regional basis, not just in the Southwest, due to significant regional variances in:

- o Economics
- o Insolation
- o Institutional requirements
- o Cooling water availability
- o Animal and bird populations
- o Energy storage options (e.g. pumped hydro storage).

When investigating specific plant sites, effort needs to be directed toward distinguishing the microclimate effects, as well as identifying general regional characteristics.

Water requirements for solar thermal power plants need to be more clearly defined.

Distributed-type systems would be well suited for siting at or near major load centers, such as an industrial plant or shopping center.

Special problems may arise in siting and licensing hybrid solar plants with fossil-fuel backup systems.

A mechanism needs to be established between the government and the owners involved, regarding the use and control of offsite land as it may affect available insolation, "sun rights," etc.

It is unclear whether siting a solar thermal power plant involves more problems or just new and different types of obstacles, when compared to siting a similarly-sized conventional plant.

Land requirements increase as available insolation decreases.

The public's general inclination toward solar must be tempered by an awareness of the actual environmental requirements and costs of solar thermal power plants.

Rural siting of solar plants is significantly simpler than urban siting, especially regarding aesthetics and safety considerations.

Clarity regarding environmental and other siting requirements must be developed through the establishment of specific governmental regulations.

Competing land uses affect long term planning for solar plants.

Central receiver and distributed systems have different siting requirements with respect to:

- Seismic susceptibility
- Type of acceptable terrain (contours)
- Safety
- Ability to utilize marginal land.

5.2.3 Summary

Information on environmental and siting issues, particularly regarding distributed systems, is incomplete and somewhat unclear. Problems encountered in siting a solar plant may or may not be greater than those involved in siting conventional plants. This issue must be clarified by the establishment of specific siting and safety regulations and requirements. Also, the public must be educated to the environmental issues involved in solar power adoption, particularly the land area requirements and subsequent effects for municipal plant locations.

There exists a definite need for more regional and microregional site investigations, particularly outside the Southwest. Problems related to climate, land contour, seismic susceptibility, space, aesthetics and insolation must be resolved on a case-by-case basis.

Siting and environmental barriers to solar plants are indeed solvable; however, the key issues and goals must first be specifically defined prior to the initiation of any major actions.

5.3 FINANCIAL ISSUES

5.3.1 Overview Presentation - Tifton Simmons

Vice President, Smith, Barney, Harris, Upham & Co.

First, we will discuss the methods of financing currently used in the electric utility industry and then look at some general criteria for investment which we hope will include all the utilities that are here today. Also, we will discuss the present and future status of financing and the question of whom should assume the risk of putting up the capital for solar energy development. I'll give you some examples that our firm has been involved with in terms of financing projects that are not totally proven, at least in the electric utility industry. Finally, we will talk a little about the function of grants-in-aid.

Taking the investor-owned utilities, first, they are primarily from retained earnings, sale of debt and sale of equity securities. All three sources are limited in terms of the ability to affect charge rates which, in turn, reflects back to public utility commissions. Secondly, the terms under which these utilities issue their stock and bonds put certain restrictions in terms of debt equity and in terms of debt service coverage. Those are the kinds of restrictions or limitations encountered in investor-owned utility financing.

The Rural Electric Co-operatives (REC's) are financed generally through government guaranteed programs such as the Federal Financing Bank or the Co-operative Finance Corporation. There is also some tax-exempt financing available now for pollution control facilities. The primary restriction here would be acceptance by the REC of various projects to be financed.

Regarding municipally-owned utilities, which I believe constitute the bulk of the people here, they do some financing through retained earnings or whatever you want to call it -- the bottom line. They also

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issue revenue bonds for capital additions. In some cases you'll find issuance of general obligation bonds which also go into the tax base of the community, I'd say, in terms of dollar volume, definitely the most common form of financing is the revenue bond approach. This type of financing goes back to the utility being able to charge enough for electricity to pay its obligations and debt service.

There's a new form of finance that is probably of interest to small utilities known as the joint action approach. Several of you here have financed under it, and some of you are in the process of studying it. It allows several small utilities to group together to finance either an entire plant or part of a large plant and affect economies of scale. Basically, the relationship between the small utility and the issuer, which is usually a brand new political subdivision created under a particular state law, is a "hell or high water" contractual arrangement. That is, the city utility agrees to make certain payments whether or not anything is built, finished, operates, etc. In a sense, it is the same as issuing their own debt, in terms of obligation to pay. The restrictions to the issues of debt in a typical municipal utility are also in terms of coverage of debt service, earnings. They, of course, do not have the debt equity restrictions which you find in investor-owned utilities.

There is a general criteria for utility finance. I think it is very important to recognize that utility finance, the capital market that supplies utilities, whether investor-owned, municipal or REC is a low-risk capital investment. Consequently there is a low return on those investments, there is no speculation involved. So, I think that early in the game you should erase the idea of large amounts of capital being available for speculative, unproven technology, such as solar.

Presently, particularly for utilities, there is little ability to finance something that is not economically feasible, particularly when dealing with the kinds of capital dollars we are talking about here. There are institutional factors that influence the general criteria we are talking about, such as utility commissions in various states. Some states have siting commissions, which is another hurdle. I understand in Minnesota, for instance, anything over five megawatts has to be approved by a statewide siting committee. So, there are additional steps, such as political and institutional requirements, that are going to be included in establishing economic feasibility.

The investor-owned utility group has gone through a period of tight money in the last several years; however, it is loosening up somewhat. They have had poor rate relief from public utility commissions which has severely restricted their ability to finance. In contrast to that, municipalities presently enjoy a tremendous amount of flexibility in their ability to issue revenue bonds. They can do things that countries cannot. Last week our company was involved in managing a $100 million issue for a utility in Lafayette, Louisiana. I'm quite sure that France couldn't have sold $100 million in bonds last week under the same terms and conditions. So, presently, there is a tremendous amont of flexibility in municipal finance.

Let me return now to my point regarding flexibility in financing in terms of municipal versus investor-owned utilities. A few years ago, it actually got to the point where municipal utilities were, and still are, having to take over capital investments for investor-owned utilities. For example, the North Carolina Municipal Power Agency has been formed to purchase a plant from Duke Power. Also, Con Edison sold two plants to the New York Power Authority.

Now, I'd like to focus in a bit on the municipal market. There is a tremendous volume of muncipal bonds being sold now, approximately

$40 billion a year. We are seeing this figure experience a growth in volume percentage which might be on the order of 15 to 20 per cent with an increasing percentage of that money is going for capital investment in the municipal utility field. But you shouldn't lose sight of the fact that municipal utilities are competing with housing, hospitals, and several other requirements for capital investments right now.

In terms of the future of finance, there is going to be more competition in the marketplace for municipal utilities. They are facing huge capital programs, as you all know, not only in solar energy. There are some possible institutional changes, such as the constant talk of the change in the tax-exempt status of revenue bonds. As you know, interest on municipal bonds presently is tax-exempt under federal IRS regulations. The future is also going to depend on the ability of municipal utilities to have retained earnings, in a manner similar to the necessity for such earnings in the financing of investor-owned utilities.

Now, I mentioned earlier the assumption of risk, because it is probably the reason that I'm here. You just cannot assume that investors will be willing to assume the risk for a new unproven technology, or for that matter, a proven technology. The investors are going to put up the money and, even for a coal-fired plant, they are going to tie you every way that you can be tied to be sure they are paid. Dont't think that it's going to be any different in 20 years. It's going to go from bad to worse. There is another element in finance, venture capital finance, whereby vendors or people in certain small areas of technology might receive risk capital. This risk capital is usually in the form of equity or a combination of equity and convertible bonds. However, the dollar volume of that type of finance is very small. At this workshop, we are talking about hundreds of millions of dollars for solar thermal power plants. A gigantic venture capital investment might be two or three million dollars, and again, that money is not going into municipal utilities, it's going to the people that are building, manufacturing and developing new ideas.

Obviously, the second group that could assume the risk would be the utilities themselves, and in turn raise their rates to the people that buy the electrical energy from the utility. So, to the extent that a utility desires to invest in solar or any other form of technology, it's going to have to do everything it can to assure investors, particularly on the municipal level, that they will raise the rates to whatever is necessary to pay off the bonds. I might add that what we are talking about at this workshop is small utilities and investing in small plants, and it strikes me that it is probably not going to work. The most logical thing in terms of finance, it seems to me, would be for a large utility, or a group of large and small utilities ultimately to be involved in these initial solar plants. For example, I could see a Salt River Project and an Arizona Public Service Company combine and each put in $10 million or so for solar development. We've been involved with the Salt River Project to the tune of over a billion dollars and a few million more for solar will not make much difference. It's really a question of diversifying in a high-risk technology with existing plants. A fellow told me story about a veterinarian in Colorado. He was a large-animal veterinarian; cattle, horses, etc. A woman came in in a panic and had a canary in her hand. The canary was in bad shape, so the doctor looked at it. As he did, the canary died, so he chucked it in the waste can and said, "Well, there goes my canary business." And I guess if your utility can afford to do away with its "canary business," it can afford the high-risk technology.

That brings us to the alternative of the federal government assuming the risk one way or the other. These risk assumption possibilities are policy matters that certainly go far beyond finance. I think, to some extent, we've tried to indicate that initially it's going to be very tough for there to be any other way to finance, unless you go to very big utilities who are willing to put up their own money in a diversified power supply program including solar.

Then there is the question of grants. Is there some way that a grant system might lessen the risk, because what we are really talking about here is risk? One option, of course, is an outright grant-in-aid for a certain percentage of capital cost. By this, I mean a grant that would not be recoverable by the federal government. Actually, what this does is reduce the capital cost. Solar power is a capital-intensive operation. Consequently, if you reduce the net capital cost to the utility, a solar project becomes more feasible. If we get consulting engineers that can agree to that, maybe you can finance the risk. There are also limited types of O&M grants which I don't think are too significant here. I don't, personally, have a feel at this point about what O&M costs are as a percentage of total costs in a solar plant.

Another possibility is a construction advance where the government would put up the money during construction. I can see various ways of this working, but basically at the end of the construction period, when the plant is operating, the utility, in effect, buys back the plant by repaying the grant, hopefully, without paying any interest on the loan during construction. This method accomplishes a number of things: First of all, it reduces the startup risk, which may be significant in a solar power plant. Also, interest during construction, particularly with a long construction period, could be 20 to 25 per cent of your total capital cost of a project. So, some sort of grant that can cut out interest during construction, which is effectively reducing your capital cost, could also effectively increase the feasibility of the project and, consequently, its financing ability.

I did want to say, however, that there has been financing of projects being built which were not totally without technological risk. Three years ago, we financed some peaking bulb-turbine units at Rock Island Dam in the Columbia River for the Chelan County Public Utility District, to the tune of just under three hundred million dollars. These bulb turbines had never been built or installed in the United States, although they are a proven technology in Europe. Additionally they have never been built anywhere in those sizes before.

Another example: We're hopefully in the process of financing a gas synthesis unit for four cities in the State of Louisiana. There are some problems there, unrelated to technology, which may keep it from getting off the ground, but it's our view at this point that this project is financeable. We've already had two or three sets of consulting engineers, vendors, etc., who have given opinions as to the economic feasibility of the project. Another instance involves a predecessor of the Nebraska Public Power District. About 20 years ago, Nebraska was involved in a prototype nuclear unit. Apparently, the funding for the nuclear portion of the plant came from grants-in-aid, and the steam turbine generator portion of it was funded at that time by Consumers Public Power District. The plant basically was not economically feasible after it came online. Consequently, the nuclear portion was removed and the turbine portion was rebuilt into what is now Sheldon Station. So, these are at least some examples of financing projects that are not totally proven from a technological standpoint.

5.3.2 Issues and Conclusions

The issues and conclusions below were compiled from a general session question and answer period. No small discussion groups were formed on this topic.

Creative solutions must be found to the financing questions surrounding the development of solar thermal power. Particularly, since solar will be competing against low-risk conventional technologies for a limited amount of available capital.

No "rule of thumb" currently exists for analyzing acceptable risk levels and their effect on investment return rates.

The feasibility of solar thermal systems for financing purposes, would best be demonstrated by the endorsement of a number of reputable design engineering consulting companies, accompanied by firm pricing and availability from recognized equipment suppliers.

The government will most likely have to fund the first few high-cost experimental/demonstration systems. However, it may well be feasible to sell back the system to the host utility at a competitive price based on the unit's performance during the trial period and thereby recover a portion of the initial investment.

A financing entity must be identified who is willing to accept maximum capital and escalation risks involving solar investments, since conventional financing bodies are unwilling to accept these risks.

5.3.3 Summary

Clearly, no new technology can be developed or implemented without adaquate financing. Solar thermal power is presently a high-risk capital-intensive long term investment. Due to the stiff competition with lower-risk investments for limited funds, new means of financing must be developed to support the required research and development activity.

Since the financing companies have said that solar will receive no special treatment regarding investment requirements, etc., this special support will most likely have to come from:

- Government
- Private industry
- Groups of utilities
- Individual utilities.

Numerous differences in the financing capabilities of various types of utilities illustrate that significant efforts, and perhaps some changes in today's established systems, must be undertaken to provide the economic environment necessary for the development of solar thermal electric power.

However, the most effective means of acquiring a financable status for this technology, is to reduce capital and operation costs and increase reliability through effective and efficient research, development and demonstration, by both government and private industry.

5.4 SITES FOR EXPERIMENTAL SOLAR THERMAL SYSTEMS

5.4.1 Overview Presentation - Herbert J. Holbeck

Task Manager, Field Test Integration, SPSA Project, JPL

INTRODUCTION

The purpose of this workshop session is to obtain input and feedback from potential users of solar thermal electric experimental power systems. My remarks are not intended as an overview presentation as such but rather as an introduction to the interactive small group discussions which are the major part of this workshop session. The participants of this workshop represent a cross-section of potential users of solar thermal technologies, and discussion inputs are expected to provide valuable project planning information to the Small Power Systems Applications Project. Your inputs are especially desired relative to:

1) Integration of site activities with the experimental power system development
2) Reasonable expectations for site proposal responsibilities

You have already provided inputs in these areas during other scheduled and unscheduled discussions and in your response to survey questionnaires. Now we will key on some of those issues which you have identified as important.

The following topics will be covered in this session:

1) The current plans for the first Experimental System for the Small Power Systems Applications Project will be briefly described. Since the project has already been described, this review will focus on those aspects of the first experiment which have an impact on siting.
2) Some site integration issues will be described. Your discussion inputs will affect resolution of some of these issues.
3) Highlight results from the survey questionnaire will be presented.

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These are valuable both as inputs and as a device to select discussion topics.

4) The group discussion topics will be introduced, and we will break into small groups.

DESCRIPTION OF FIRST EXPERIMENTAL SYSTEM

This morning's brief review will emphasize those aspects of the project which impact siting of the first experimental system. The power systems development is planned in three phases:

1) Phase I will consist of several parallel systems definitions studies with each study concentrating on a particular solar thermal technology. These studies will develop preliminary system designs and define technology readiness with respect to parametric variations in factors such as:
   - o Insolation
   - o Load factor
   - o Storage
   - o Development time
   - o Size of experimental system.

   At the conclusion of the Phase I studies a technology approach will be selected and the Phase II and III efforts will be defined in more detail.
2) Phase II will provide subsystem technology development as required. Components and subsystems will be developed and tested at the module level.
3) Phase III will consist of the final design, fabrication, installation, and testing of the Experimental System.

The solar thermal technology for the first Experimental System will not be determined until completion of the Phase I studies. Some possibilities are:

1) Small central receiver
2) Line focus (trough)
3) Point focus, distributed receiver, generation at receiver, thermal transport, central generation

The experimental plant size is currently considered to be approximately 1-MWe; However, in the Phase I studies plant sizes from 0.5 to 5-MWe will be considered. The detailed application requirements are still being developed. Current thinking includes the following:

- Small community type of application
- Incorporation into utility system
- Experimental operation
- No load type restrictions (tentative).

The phase I system definitive studies are scheduled to start on or about April 1, 1979, and last for 10 months. The duration of the Phase II and III efforts will be better defined during Phase I. Currently, it is expected that the Phase II subsystem technology development will take about 18 months and that the Phase III system development installation and test will take about 36 months.

Siting efforts will occur in parallel with the phased power system development. Current plans call for the siting RFP proposals, evaluations, and selection to occur in 1979 during the Phase I system definition studies.

SITE INTEGRATION ISSUES

Detailed siting requirements will depend on the results of upcoming systems definition studies. However, some general requirements are:

1) Sufficient annual and seasonal direct insolation so that a solar thermal electric power system is a potentially viable alternative. Detailed trade-offs between insolation and economic factors will depend on the system technology. The

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intent is to consider siting in several regions rather than limiting sites to those with the highest insolation values. However, economics will limit sites to those with better than average direct insolation.

2) A land site of approximately ten acres will be required. Geologic and topographic requirements will be similar to those of a typical light industrial facility. Additionally the site should be level or moderately sloping up toward the north.
3) Transportation access and utility services should be available.
4) The site should present no acquisition problems and must be available for power plant use during the life of the experiment.

Two categories of site integration issues can be considered:

1) How should site activities be integrated with the power system development?
2) How much should a site proposer be expected to offer?

Both of these issues are affected by the small community emphasis for the first experiment. It is expected that site proposers will include several types of utilities of various sizes, as well as small communities. The problems for a small site proposer with limited resources may be quite different from those of a large, well-staffed utility organization.

Some activities which require integration of siting and power system development efforts are:

- Site and power system layout
- Site preparation
- Construction
- Power system installation
- Power system check-out and testing
- Experimental operation
- Power production scheduling
- Power plant safety.

Some items which could be provided by a site proposer are:

- Land site
- Site preparation
- Utility system integration
- Access roads
- Utility services
- Cooling water
- Environmental impact statement
- Site approvals and licenses
- Visitor center
- Engineering and environmental data
- Local public and government relations
- Plant security and general maintenance
- Support of experimental operation

SURVEY RESULTS AND DISCUSSION TOPICS

The survey results showed considerable agreement although there were some differences in the responses from large and small utility representatives.

The consensus high-priority site integration issues with a major user involvement were:

1) Plant and site layout
2) Site preparation
3) Construction scheduling
4) Experimental operation
5) Power production scheduling

The consensus items for a site proposer to provide were:

1) Land site
2) Partial site preparation
3) Access roads (excepting construction)

4) Ordinary utility services
5) Community and local government relations
6) Plant security and general maintenance

Items considered to be problem areas were:

1) Funding of site costs
2) Environmental impact statement
3) Site approvals and licenses (beyond local level)
4) Cooling water
5) Experimental operation

For the small group discussions we would like you to concentrate on the siting problem areas. The items from the survey results may be considered as a starter list. However, if other items occur to you, feel free to bring them up. We want to get your frank inputs so that our site planning efforts will be as realistic as possible.

5.4.2 Issues and Conclusions

The small discussion groups formed to respond to this topic were organized by the industry sector. Each issue or conclusion stated below is keyed to the appropriate sector. The sectors include:

- Rural electric co-operatives (REC)
- Small municipal utilities (SMU)
- Medium municipal utilities (MMU)
- Large municipal utilities (LMU)
- Investor-owned utilities (IOU)
- Architect/engineering firms (A&E)

A process needs to be developed for selecting a host utility which will insure the succes of the experiment, as well as allow the maximum number of utilities to respond to the solicitation (REC and SMU).

A request for qualifications, including a statement of the purpose and objectives of the experiment, needs to be distributed to utility companies to:

- Allow utilities to evaluate realistically their own interest level and potential for being selected as the host utility
- Permit JPL/DOE to perform an efficient screening of prospective utilities (LMU, IOU and A&E).

Subsequent to screening prospective utilities, an RFP needs to be distributed. The RFP needs to describe clearly the role of the host utility, JPL and DOE. The methods for proposal evaluation also need to be described to avoid unnecessary proposal efforts and permit utilities to obtain appropriate credits in the evaluation process (LMU, MMU, IOU and A&E).

When investigating prospective utilities, JPL should consider companies that currently have installed generating capacity (IOU and A&E).

The proposal evaluation process needs to include a consideration of whether or not a small utility has the resources in space, dollars and manpower to host an experimental solar installation (SMU).

The differences between an "experimental," a "demonstration" and a "pilot" plant must be clarified, particularly regarding the role of the host utility (SMU).

The utility and local community should have responsibility for, and control of, the site preparation. (REC)

The prime contractor for development of the experiment should have primary responsibility and control over construction of the experimental solar plant on the utility site (MMU).

Some of the important parameters to consider in the site selection include:

- Water requirements
- Proximity to transportation by road, rail and air
- Heat-rejection requirements and facilities
- Distance from primary assembly plants
- Size of the experimental system (500 kWe, one MWe or five MWe) as compared to the capacity of the host system
- Insolation availability and requirements
- Support services and technical expertise of the host utility.

5.5 SMALL UTILITY PLANNING AND SOLAR COMMERCIALIZATION

5.5.1 Overview Presentation - Peter Steitz

Planning Engineer, Burns & McDonnell

INTRODUCTION

I consider myself fortunate to have this opportunity to discuss with you the subject of power supply planning for small utility systems. I hope, during the course of my presentation, to convey to you some of the essential elements of this planning process and how it might impact on the future development of small solar thermal systems in this market. I plan to address the following specific topics:

- The characteristics of small utilities
- The power supply alternatives of small utilities
- The small utility power supply planning process
- Some basic power supply economics.

CHARACTERISTICS OF SMALL UTILITIES

Our experience at Burns & McDonnell has been that the power supply situation of small utilities can vary significantly from system to system. This was emphasized to us recently in a study we are performing for the Electric Power Research Institute (EPRI) involving the potential application of fuel cells to small municipal and rural electric utility systems. As part of this study, we defined the characteristics of small utilities in the United States. The systems studied were those with 1974 peak demands between 2 and 500-MW. The distribution of small utility peak demands within this range is shown in Figure 5.5.1-1. As can be seen, the majority (83 percent) of these systems had peak demands between 2-MW and 50-MW.

We found in the EPRI study that both the size and geographic location of a small utility can have a major impact on its generation mix. The observed variation in capacity mix with system size is illustrated in Figure 5.5.1-2. The smaller systems were found to have predominantly

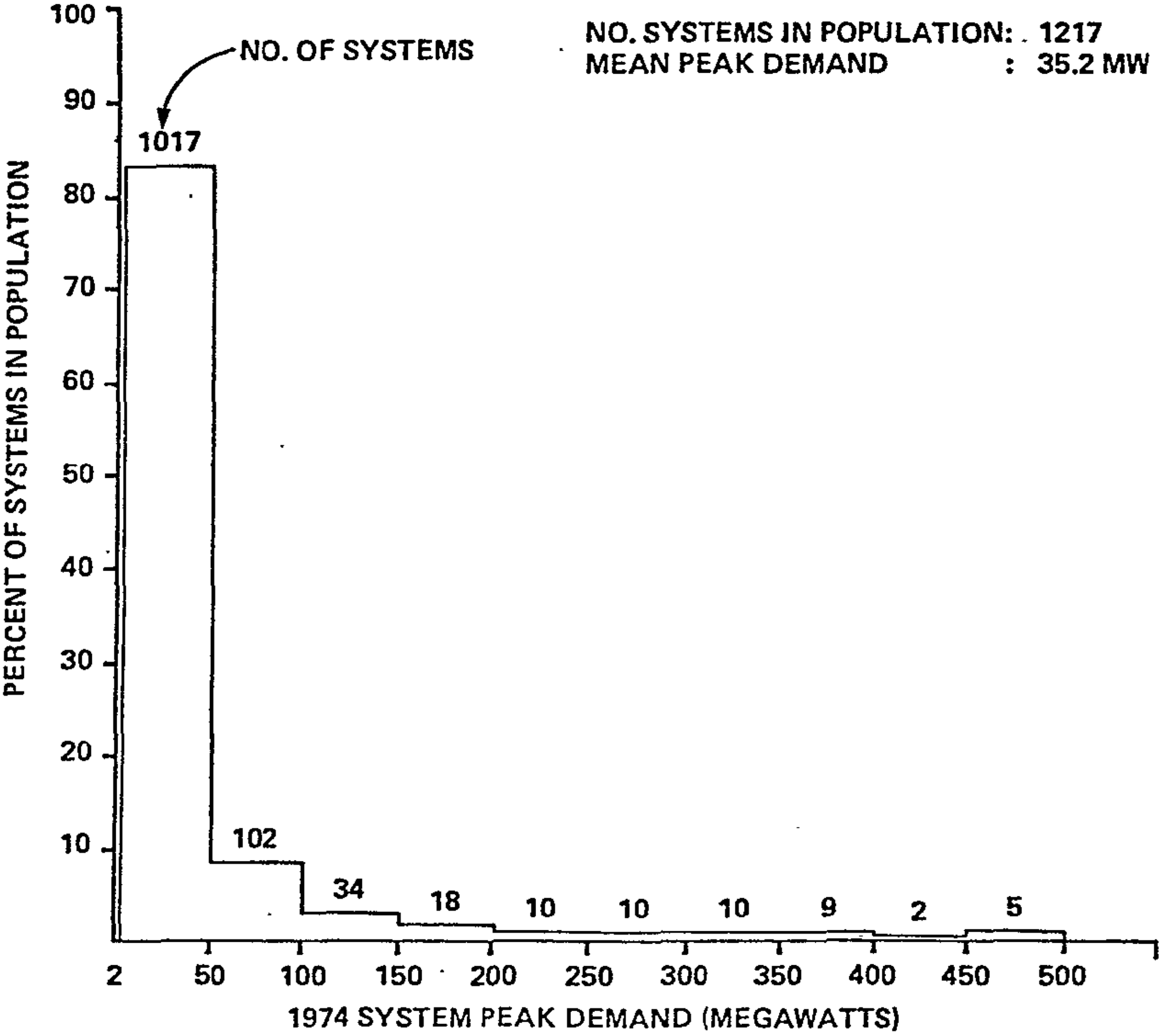

Figure 5.5.1-1 Distribution of peak demands (All systems with 1974 peak demands of 2-500 MW)

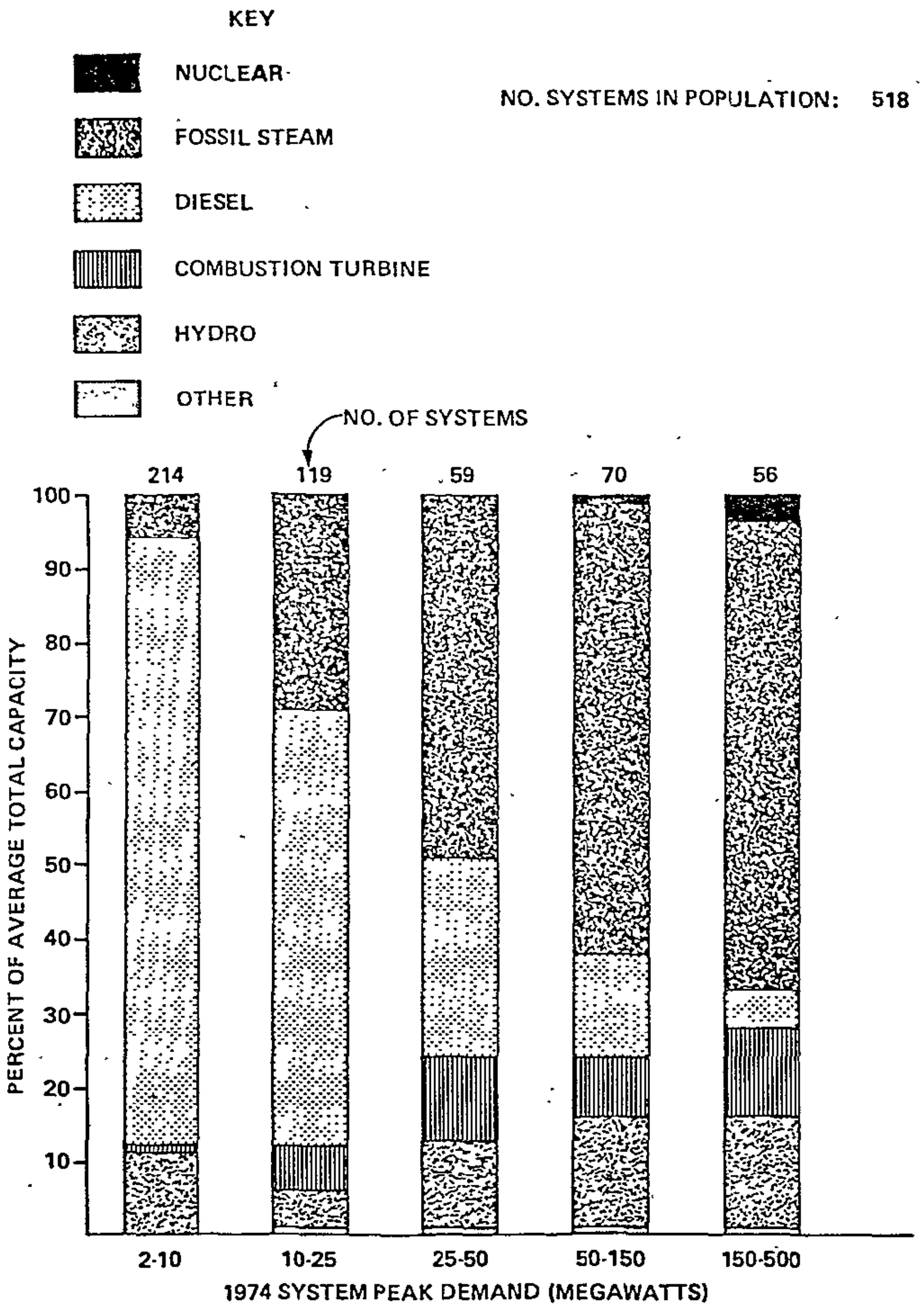

Figure 5.5.1-2 Distribution of capacity types
(Small systems with generating capacity)

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diesel capacity, whereas, larger systems have primarily fossil-steam generation. This same pattern generally prevails in all geographic areas except the Northwestern States, where hydroelectric generation dominates most systems. The distribution of fuel types was also found to differ with system size, although less dramatically, as shown in Figure 5.5.1-3. Capacity capable of burning oil was found to be predominant for small system sizes, but coal-burning capability nearly equaled oil- or gas-only-burning capability in the larger systems. Fuel types for the larger systems varied more by region, with coal predominant in the Great Lakes and North Central regions, hydro in the Northwest, oil in the Northeast, and oil and gas in the South and Southwest.

Where advanced technologies such as solar, geothermal, and wind are involved, there are obvious variations in potential among utilities with geographic location.

The study's results also confirmed that a system's geographic location can affect its load factor and load growth rate, two parameters impacting a system's long-range planning.

The distribution of annual load factors for small systems is shown in Figure 5.5.1-4. The calculated average was 49.2 percent with a standard deviation of 9.2 percent. The regional variation in load factor among municipal systems is shown in Figure 5.5.1-5. Whereas, the average 1974 load factor for all small municipal utilities was found to be 48.8 percent, the average varied regionally from a high of 54.7 percent in the Northeast and Southwest to a low of 43.4 percent in the South Central Region.

The distribution of 1968-1974 load growth rates among small systems is shown in Figure 5.5.1-6. The average, as can be seen, was 8.0 percent with a standard deviation of 4.5 percent. Annual load growth rates

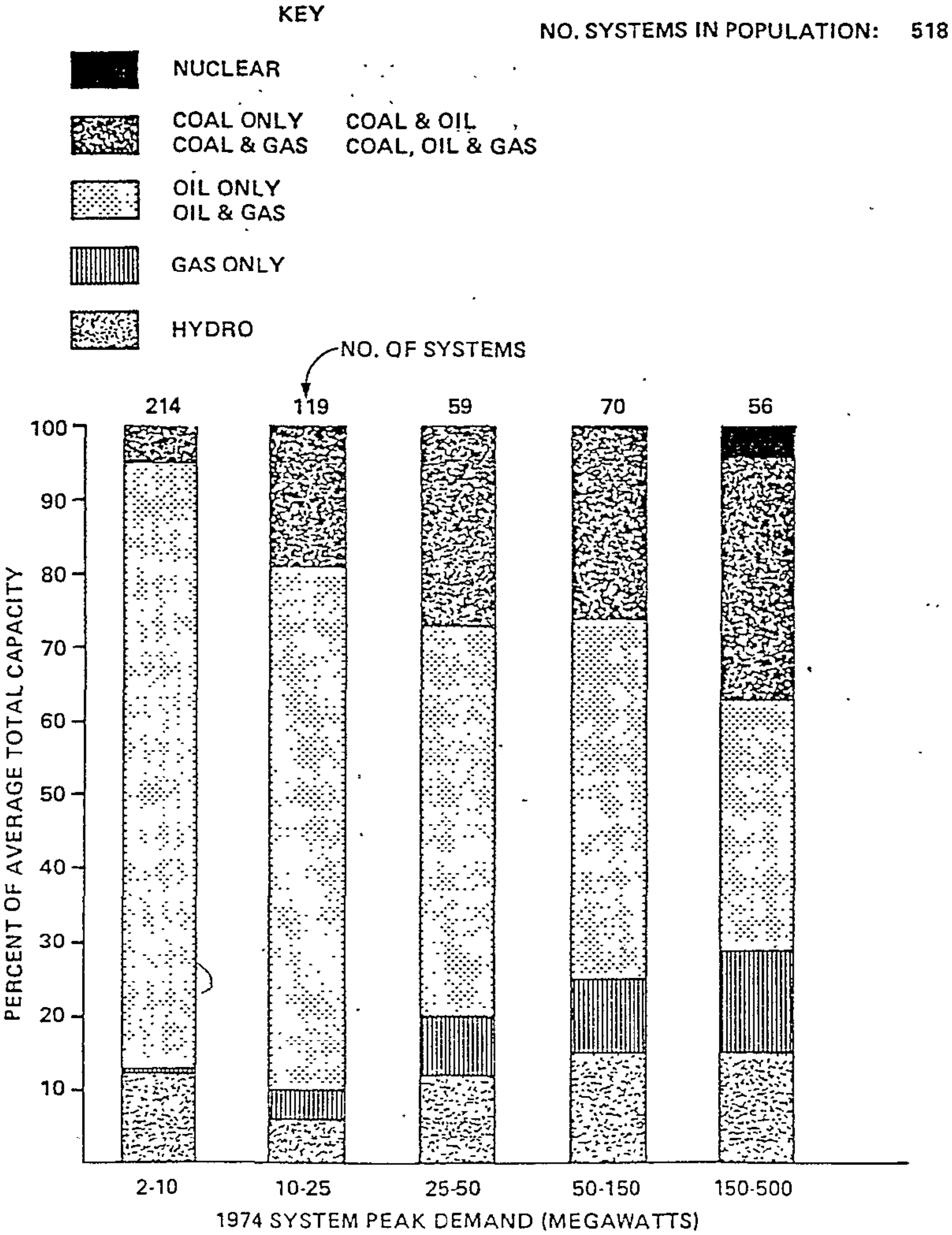

Figure 5.5.1-3 Distribution of fuel types
(All small systems with generating capacity)

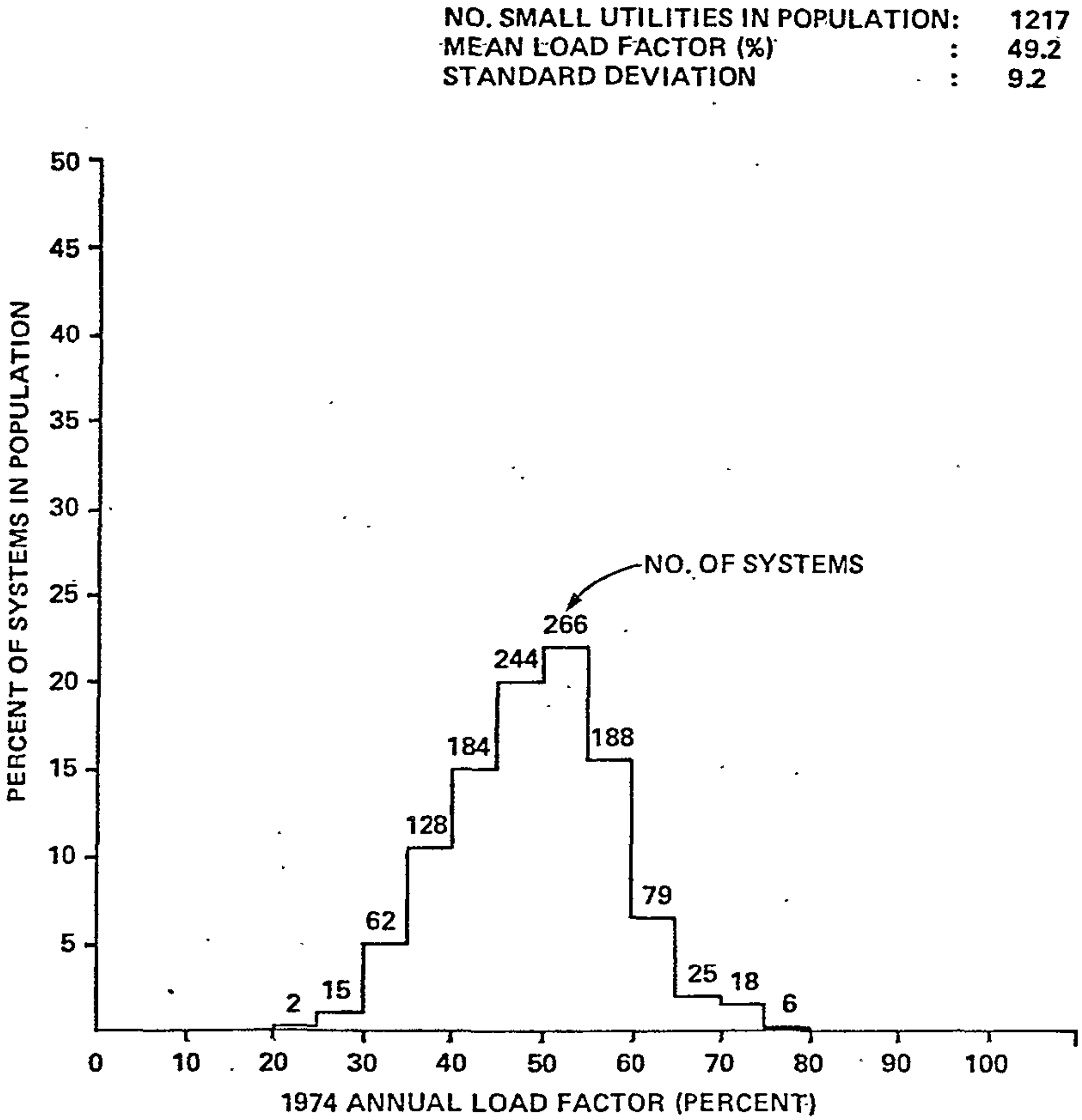

Figure 5.5.1-4 Distribution of annual load factors
(All systems with 1974 peak demands of 1-500 MW)

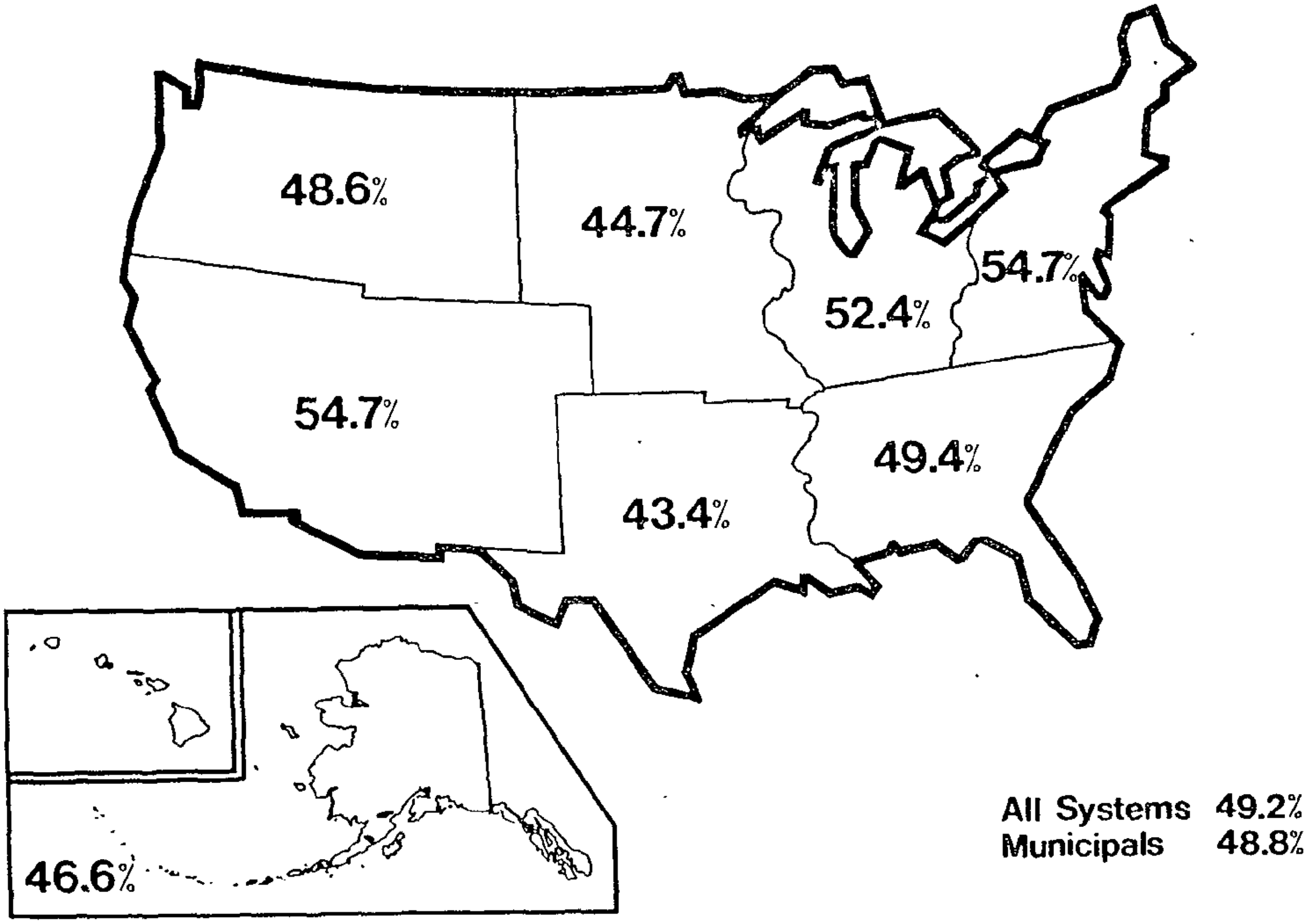

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Figure 5.5.1-5 Regional load factors (1974)

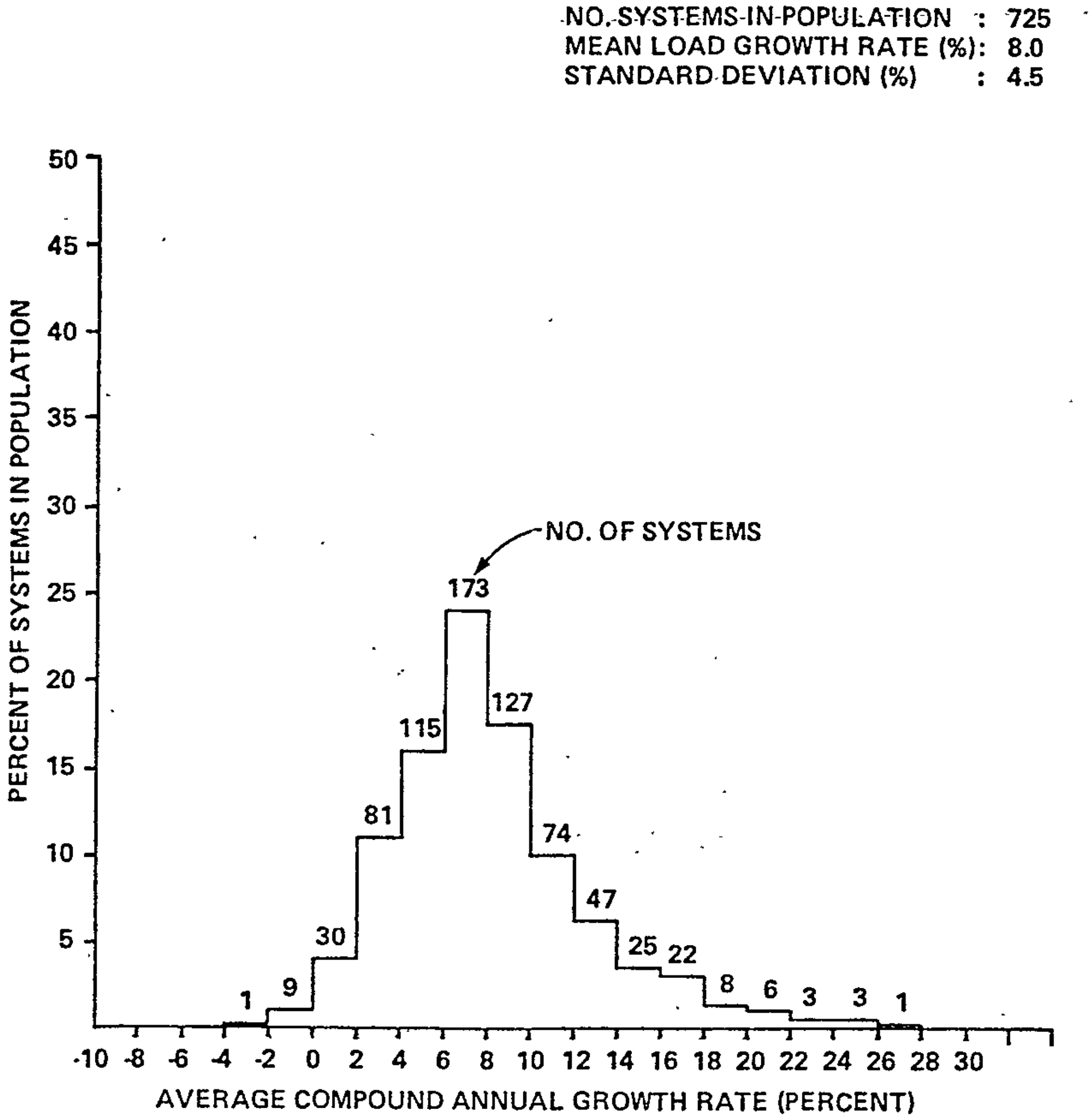

Figure 5.5.1-6 Distribution of compound annual load-growth rate 1968-1974
(All systems with 1974 peak demands of 2-500 MW)

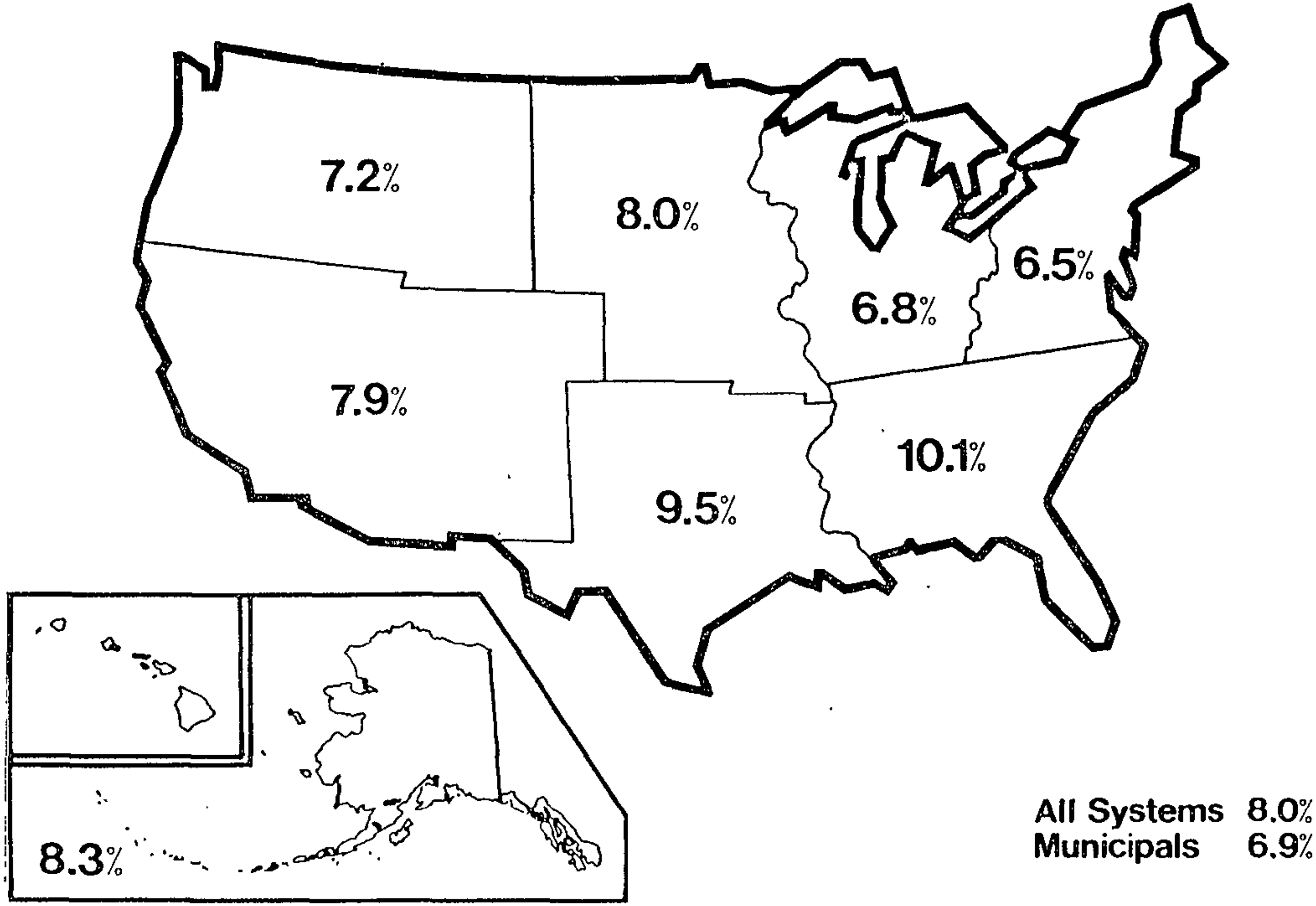

Figure 5.5.1-7 Regional average annual compound load-growth rates (1968-1974)

varied even more dramatically by region as can be seen in Figure 5.5.1-7. The average load growth rate for the period 1968-1974 for municipals was found to be 6.9 percent. (The average for all small systems was higher because of a 10.5 percent average growth rate for rural systems.) Regionally, however, municipal growth rates ranged from a high of 10.1 percent in the Southeast to a low of 6.5 percent in the Northeast.

In addition to the differences observed among small utilities due to variations in size and location, we found that the existing power resource mix can vary dramatically even when systems are similar in size and located within the same geographic region. A major difference among small utilities involves the type of ownership (municipal, rural co-operative, or investor-owned) which influences the type and cost of financing to the system and the laws and regulations under which it operates. The specific utilities with which a system is interconnected and the provisions of the interconnection agreement are important in determining a system's purchased power costs, reserve margin requirements, as well as the nature and availability of emergency, economy, and maintenance power.

I mention these differences to emphasize that each small utility has a unique power supply situation and a utility's particular situation can have a significant impact on its future power supply planning. Consequently, caution must be exercised when attempting to apply the results of generalized studies to specific systems. However, despite the many differences between small utilities, there is a basis for commonality in in that the fundamental principles involved in planning for and operating a 3-MW system are the same as those for a 3,000-MW system. The only real difference is the magnitude of the effort and the degree of sophistication involved in carrying out the various steps in the process.

POWER SUPPLY OPTIONS FOR SMALL UTILITY SYSTEMS

Basically, any utility requiring power supply resources can obtain these in one of four ways:

1) Build its own power supply facilities
2) Participate in the construction of power supply facilities with other systems
3) Purchase power from other systems
4) Any combination of 1) to 3) above.

The choice as to which of these options a utility selects for its power supply can involve economic, technological, environmental, legal, political, and philosophical considerations. The choice will depend upon the circumstances and each utility must make its own decision based on its particular situation. Some of the location-related factors which can affect a municipality's power supply choices, such as load factor, growth rate, and existing generation mix, have already been mentioned. Geographic location can also influence fuel costs and the availability of alternative power supplies. The size of a utility is another significant factor influencing a system's power supply alternatives.

It used to be economical for small utilities to install small gas- and oil-fired steam and diesel units for baseload purposes. In recent years, however, the costs of constructing and operating baseload facilities have increased to the point where, for most small systems, the independent development of baseload generation is no longer economically feasible.

The major factors contributing to the decline in the development and use of gas and oil-fired steam and diesel generating units for baseload purposes have been the large increases in the prices of oil and gas and problems of fuel availability, especially for gas. Another reason for this decline is the policy of the U.S. Government to promote the use of coal and nuclear fuels for baseload generation. Coal and nuclear generating plants, however, are even less economical in small sizes than oil and gas-fired units. With a few exceptions, most coal-fired steam units being built today are at least 200-MW in size while nuclear units are typically about 1,000-MW in size.

Since it is not economical for small utilities to independently install new baseload generation, many are taking advantage of opportunities to participate (share in the ownership) of large new baseload facilities with other utilities. The other baseload alternative for small utilities is to purchase power from neighboring utility systems. Many small utilities can, however, still justify the independent installation of conventional intermediate and peaking capacity types such as diesel and combustion turbine units. In addition, it appears that some advanced technologies, such as the fuel cell and the organic Rankine-cycle bottoming on a diesel or combustion turbine, will be available in the not too distant future to augment the generation alternatives available to small utilities.

The above alternatives loom as the primary competition which solar thermal systems can expect to confront in the small utility market. There are, of course, a host of other technologies undergoing evaluation such as wind and geothermal generation. Some of these may also offer significant competition to solar thermal systems in the small utility market, especially in certain geographic areas.

THE POWER SUPPLY PLANNING PROCESS

Against the preceding background, I would like to review the procedure that a small utility would typically follow in developing a power supply program. The steps are summarized in Figure 5.5.1-8 and discussed below:

Development of Load Forecast:

The basis foundation for any utility system's long-range planning

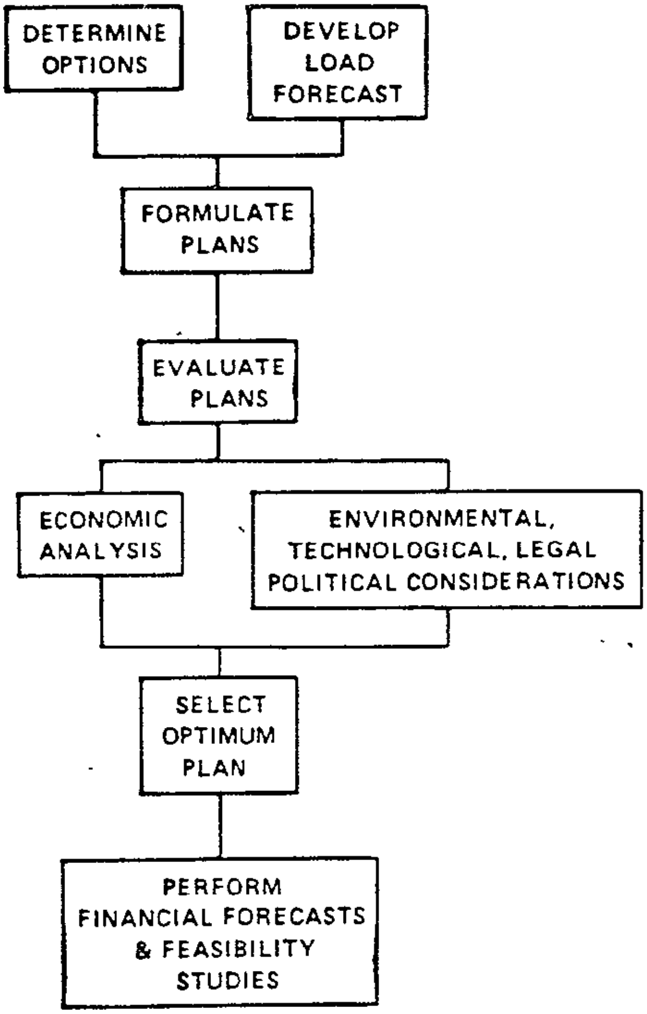

Figure 5.5.1-8 Development of a power supply program

effort is a good load forecast. Load forecasting techniques range in complexity from simple time series analyses (or trending) to complex econometric modeling. The complexity required depends upon individual circumstances of which the most important will probably be the system's size. Other factors affecting the complexity are the length of time to be projected and the economic stability of the area, among others.

Determination of Power Supply Options:

Another important initial step in establishing a power supply program involves determining what the system's power supply options are. This is an on-going task which requires that the small utility be aware of and involved in what is happening in the way of power supply in its area and region, including joint action projects. It also requires the small utility to keep abreast of technological developments both for conventional generation methods and the advanced technologies.

Formulation of Alternative Power Supply Plans:

Once a load forecast has been developed and the available options have been determined, the next step involves the formulation of alternative plans, the exercise of reasonable judgment usually permits the planner to reduce the alternatives that need to be examined to a manageable number. I might note that there are in existence computer programs which can directly formulate an optimum power supply plan for a utility given a set of input parameters. However, this approach is usually too complex, costly, and thus, impractical for the smaller utility systems.

Economic Analysis of Alternative Power Supply Plans:

As I suggested previously, the choice of a power supply plan can involve a number of considerations. However, the plan selected must ultimately be supportable on an economic basis. Consequently, the economic analysis of the alternative power supply plans becomes s key hurdle in the selection of the optimum plan. There are a number of ways in which the alternative power supply plans for a utility can be analyzed on an economic basis.

One approach is to project the costs of power for the entire system over a period of time, usually at least 15-20 years into the future using a computer model. Data used to develop these cost projections include, capital cost estimates, fuel prices, purchased power costs, interest rates, operation and maintenance costs, and generating unit heat rates, to mention just a few. Using this approach, not only the power costs associated with a given power supply plan for each year of the study period, but also the present value of the power cost for a plan over the study period can be calculated. In general, the most economical plan is the one having the lowest present value of power costs.

Selection of the Optimum Power Supply Plan:

Once the economic analysis has been completed and once all the other pertinent inputs have been evaluated, the optimum power supply plan can be selected. Again, all of the factors (social, environmental, technological, political) mentioned previously in addition to the economics would be taken into account in determining what the optimum plan is. A consideration of these factors could lead to the selection of a plan which is not necessarily the least expensive power supply alternative.

Input to Financial Forecasts and Feasibility Studies:

Selecting a power plan is, of course, only one step toward acquiring additional power supply facilities. If the construction or purchase of facilities is called for, financing must be obtained. This requires the preparation of a feasibility study which typically includes a projection of the revenues and expenses (financial forecast) for the power supply system.

In addition to the above steps, siting studies and environmental analyses may be required in order to establish the feasibility of specific projects and to obtain approvals from cognizant federal, state, and local agencies. The process can be quite complex as illustrated by the list of data requirements in Figure 5.5.1-9. However, the basic steps involved are the same regardless of the technology being evaluated although different obstacles may be encountered along the way. Ultimately, people select a small utility's program of power supply expansion and improvement. It is the City Utility Commission or the Rural Electric Co-operative's Board of Directors who make the decision weighing the various economic, environmental, political, and other factors. It is they who must be sold on the technology.

- DEMOGRAPHIC DATA
- FUEL DATA
  - PRICES
  - AVAILABILITY
  - TRANSPORTATION
- CAPITAL COSTS
  - GENERATION
  - TRANSMISSION
- PURCHASED POWER COSTS
- WATER SUPPLIES
- ENVIRONMENTAL REGULATIONS
- PLANS OF REGIONAL UTILITIES

Figure 5.5.1-9 Data requirements for power-supply planning

Basic Power Supply Economics

(Please refere to Section 4.3 for a discussion of this topic)

CONCLUSION

Major efforts are currently underway to develop new technologies in the electric power field. Many of these new technologies have the potential for application in small electric utility systems and among these are solar thermal systems. Small utility systems vary considerably in terms of size, load factor, ownership, load growth, geographic location, and other characteristics. These small utilities will compare the new technologies including solar thermal with the existing technologies. They will consider a variety of factors in selecting technologies to expand or modernize their generating facilities including economic, technological, social, environmental, and political factors. Ultimately, with the new technologies as with the existing technologies, it will boil down primarily to a matter of economics. The new technologies will have to be economically competitive if they are to become an established part of the generating mix of the small electric systems in this country.

5.5.2 Issues and Conclusions

Following the presentation on utility planning by Peter Steitz, from Burns & McDonnell, Thomas Kuehn, of JPL, presented the major results of the questionnaire on the commercialization of solar thermal electric equipment, that was distributed at the workshop. The results of this questionnaire are tabulated in section 8.2. Presented here are the issues and questions which arose from the large group discussion on the commercialization process.

What is the most cost-effective size and timing for demonstration projects, considering the influences of:

- o State of the technology
- o Engineering reliability
- o Risk
- o Public expectations and acceptance
- o Political pressures
- o Value and cost of acquiring data?

To what extent does the success of demonstration projects depend on cost and risk sharing and federal economic incentives in the utility industry?

What is an acceptable risk for utility companies, and how can barriers to utility involvement be reduced?

The role of the government in commercialization should be to advance technology development; however, the government should not become the driving force in commercialization and market development. Worthwhile federal incentives to utilities in the adoption of solar thermal technology include:

- o Research, development and demonstration funding
- o Loan guarantees
- o Interest and/or O&M subsidies

- Sell back of experimental equipment
- Lease option to buy.

Private industry needs to be vitally involved in the final stages of commercialization in order to develop an economically and technologically viable solar power industry.

5.5.3 Summary

Cost effectiveness and risk are the main barriers which must be overcome in paving the way for commercialization of solar thermal electric power equipment. Issues need to be resolved in two major areas:

- Solar technology, plant operation and maintenance, and reliability
- Availability of risk-sharing opportunities and incentives.

The roles of the participants involved in commercializing solar power need to be more clearly outlined. However, it appears that the government must provide significant assistance during the initial stages of commercialization. Yet, the private sector must eventually be able to support and manage a mature solar power industry.

Dinner Presentations 6.0

6.1 SOLAR ARCHITECTURE IN THE ASPEN AREA - GREGORY FRANTA

Architect, Sundesigns Architects

(Note: the following article, "Architecture, the Sun and the Roaring Fork Valley," presented by Gregory Franta, AIA, and prepared by Gregory Franta and T. Michael Manchester, was submitted as documentation of Mr. Franta's informal comments at the workshop.)

The Roaring Fork Valley is nestled in the Colorado Rocky Mountains, from Glenwood Springs to Aspen. It has a population of between 25,000 and 35,000 in a 9000-degree-day climate with plenty of high, intense sun and solar architecture is growing as fast as the environmental awareness of the residents. Through educational programs, like the Aspen Energy Forum, the people are able to make the choice between a home that uses excessive amounts of fossil fuels and one that is more responsive to the environment, making maximum use of the sun's energy.

In a survey of the Valley's solar architecture, conducted in May of 1977, the Roaring Fork Resource Center found 40 individual solar projects completed and 38 that were either under construction or proposed for construction in the summer of 1977. This survey considered all buildings using the sun's energy, either actively, passively or any combination, to provide space-heating and/or domestic hot water. Active solar heated residences led the collection of solar projects, followed by passively heated residences, as well as greenhouses, bus stops, workshops, swimming pools, an airport terminal and an apartment complex.

A SURVEY

The following is a sampling of some of the solar buildings that are completed and performing, as well as some that are in or are ready for construction during the 1977 building season.

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Craven Residence

The Craven residence (Figure 6.1-1) is a contemporary residence designed to utilize solar heating (construction: 1976-77). An estimated 80 per cent of the heating requirements for the Craven residence will be provided by the active solar air-heating system.

A separate thermosyphon solar hot-water system provides the domestic hot water for the residence. A food- and heat-producing solar greenhouse is attached to the 2800-square foot residence.

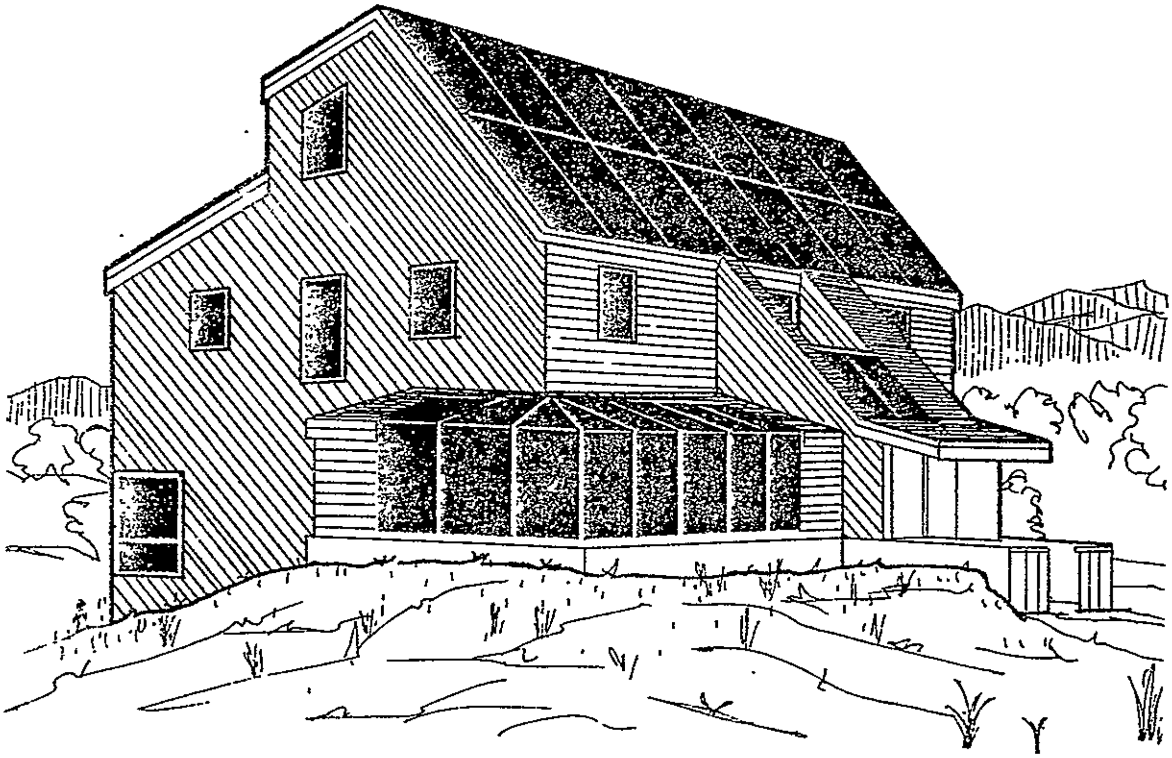

Figure 6.1-1 Exterior view of Craven residence (designed by Sundesigns Architects)

Meadowwood Apartments

Energy conservation was one of the major design parameters in this 36-unit apartment complex (Figure 6.1-2). The structure (construction:

1976-77) is well insulated and each unit has an air-lock entry. The north, east and west walls only have an approximate 5 per cent penetration of glazing, while the south wall has over 50 per cent penetration in glazing, for direct solar gain. The living, dining and kitchen area for each unit has a south-facing deck. Fortunately, the best view is also to the south. The total construction cost was approximately $20 per square foot.

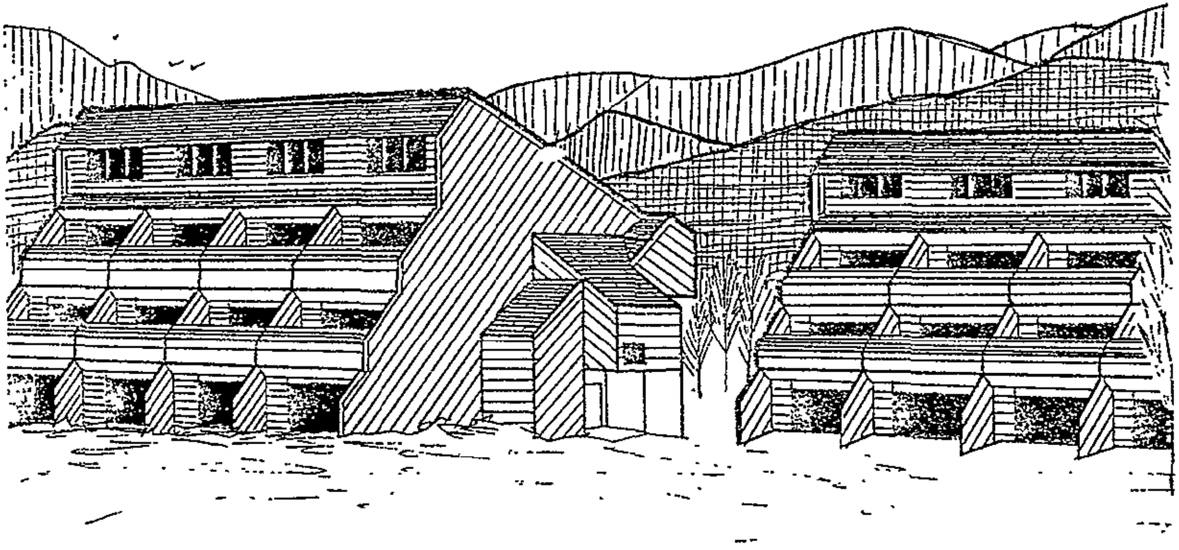

Figure 6.1-2 Southeast view of Meadowood Apartments (designed by Sundesigns Architects)

St. Benedict's Monastary

St. Benedict's Monastery (Figure 6.1-3) is a 20-year old structure that is very energy-inefficient and consequently has very expensive fuel bills.

Presently in design stages is a solar-assisted methane digester to provide space heating for the monastery in order to reduce the dependance on fuel oil. The plant has an estimated capacity of 2,000,000 cubic feet of gas per year with 90 to 95°F heat provided by flat-plate solar collectors. The methane is to be produced from the manure of 10,000 chickens at the Monastery eggery.

In addition, architectural modifications should reduce the heating requirements by 20 percent to 25 percent. A solar system is also planned to provide the domestic hot water.

Figure 6.1-3 Exterior view of St. Benedicts Monastery (Energy consulting by Sundesigns Architects)

Shore Residence

- The shore residence (Figure 6.1-4) is located in Snowmass, Colorado (construction: 1974). It is a very well insulated 1,500-square foot house tucked into a south-facing hillside. There is 564 square feet of double-glazed water collectors with 5,300 gallons of storage in a concrete tank. Distribution is radiant heating from 3/4-inch high-temperature polyethylene tube in a concrete floor.

This house also utilizes passive gain through south glazing insulated with beadwall and controlled gain above collectors with insulating covers, reflective on underside for increased gain.

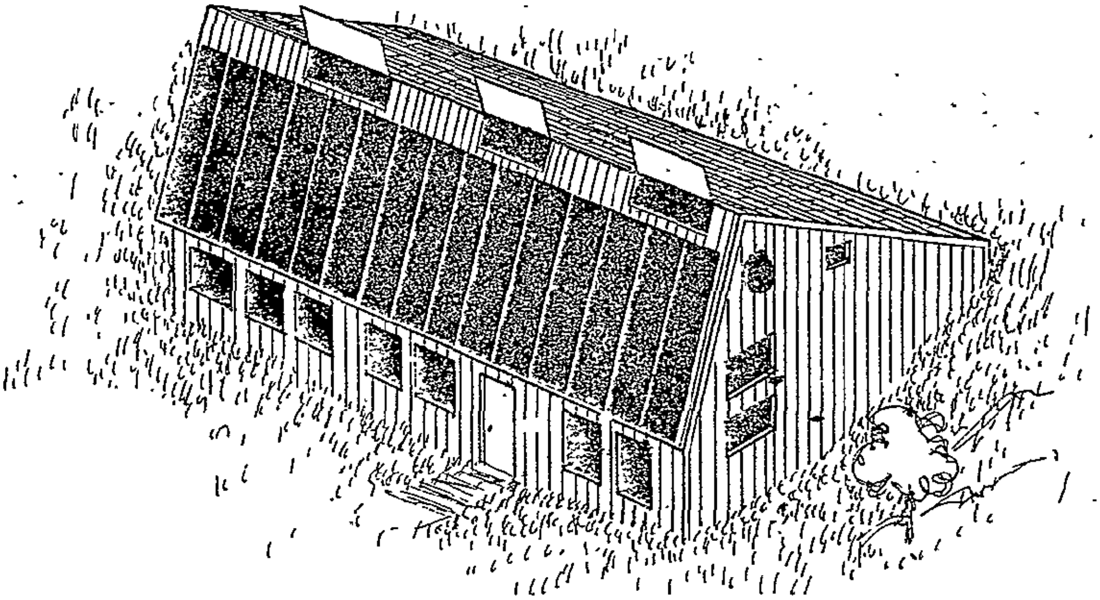

Figure 6.1-4 Exterior view of Shore Residence from southeast (designed by Ron Shore)

Pitkin County Air Terminal

The Pitkin County Air Terminal (Figure 6.1-5) is one of the nation's largest passively solar-heated structures (construction: 1975). The terminal is designed to accommodate a comprehensive transportation center for air, auto and ground mass transportation systems serving Aspen and its contiguous population centers.

In addition to the accommodation of specific terminal functions, an overall design objective was resource conservation. The architects designed the building to utilize materials, components and construction techniques that placed a low demand on natural and labor resources for its completion.

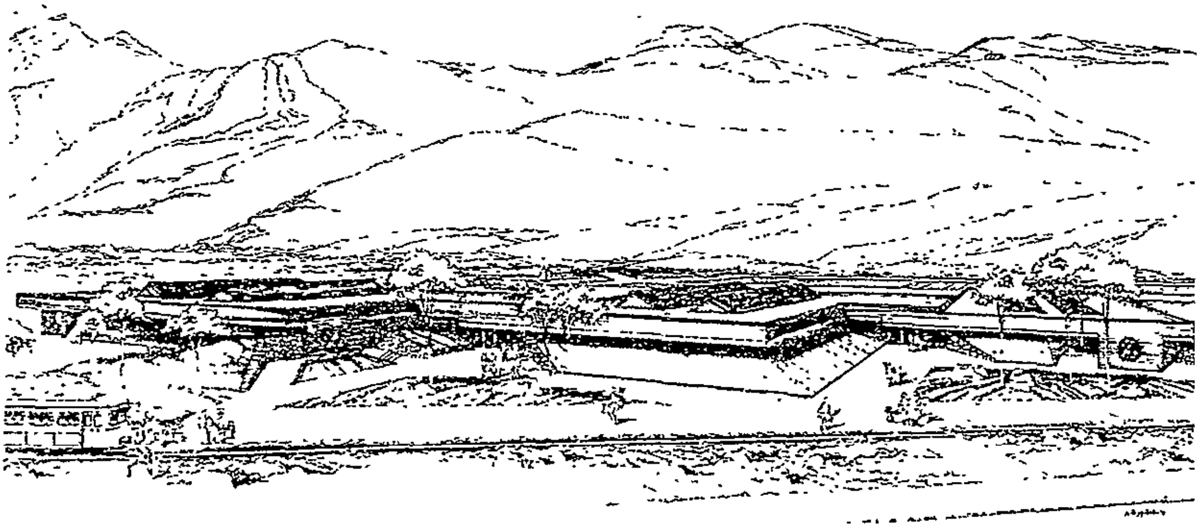

Figure 6.1-5 Pitkin County Air Terminal
(designed by Copland, Finholm, Hagman and Yaw)

The understated architectural character attempts to harmonize with the natural earth forms surrounding the building. To further lower the building profile, as well as to reduce the building heat loss, earth berms are used against all north perimeter walls. Simple and warm interior elements relate the environmental experience of the Terminal to the Aspen character.

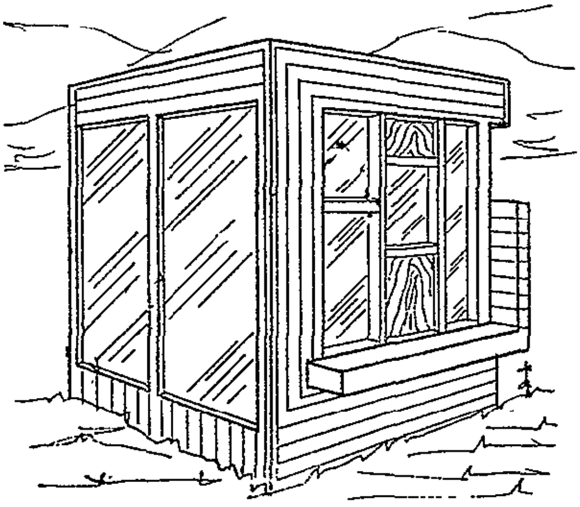

Figure 6.1-6 SE view of bus stop
(P. Dobrovolny design)

Pitkin County Bus Stops

Two bus stops (Figure 6.1-6) built by the Pitkin County government contain passive solar heating systems (construction: 1976). The system uses a "Trombe wall" concept with a black thermal mass wall and a glass glazing. Natural convection introduces the heat into the space during the day while the concrete mass stores heat to be radiated into the space at night. This system has provided a comfortable waiting space for the Valley's bus riders.

Mollica Residence

The Mollica residence (Figures 6.1-7 and 6.1-8) is located near Aspen,

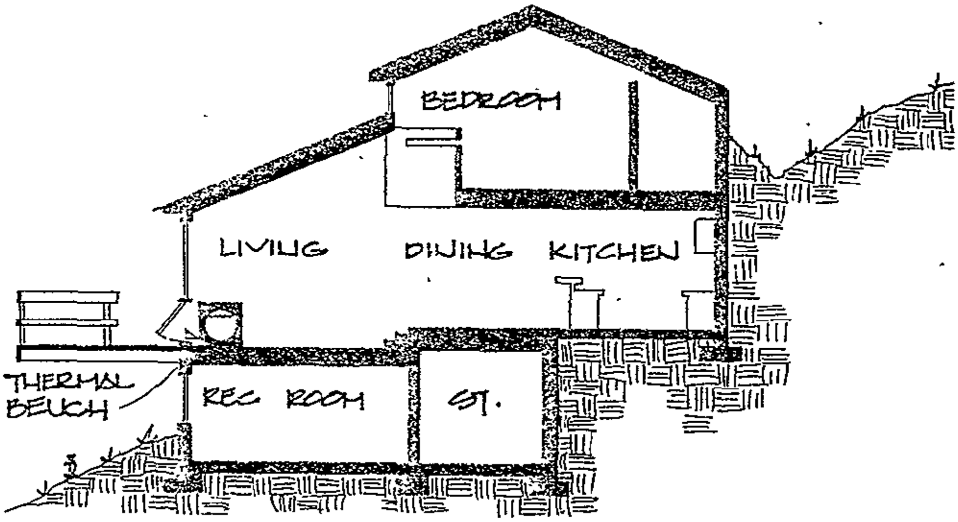

Figure 6.1-7 East-west section of Mollica residence (designed by Sundesigns Architects)

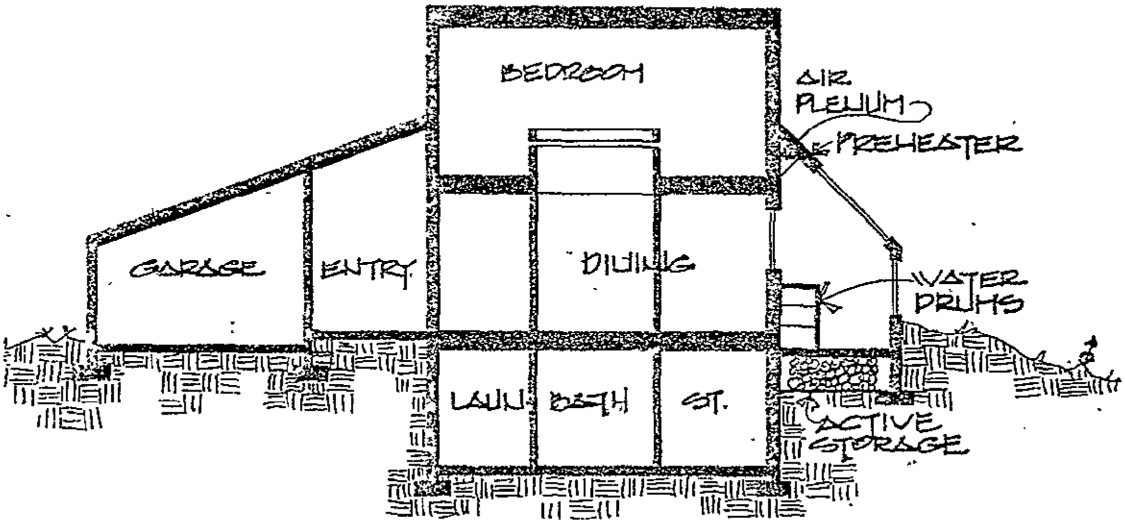

Figure 6.1-8 North-south section of Mollica residence

Colorado at an elevation of 9,500 feet (construction: 1977-78). It is a 1,400-square foot house utilizing a passive-active greenhouse as its collector with thermal mass built into the house's shell. The house is well insulated, has air-lock entries and is set into the side of a very steep site.

The domestic hot water collectors are integrated into the greenhouse as are two panels of air collectors to boost the air temperature before going to the rock storage. Composting toilets are used in order to conserve water.

Smith-Hite Studio

This building (Figure 6.1-9) is an 800-foot weavers studio with an attached garage and is designed to be 100 per cent independent of fossil fuels for heating and cooling (construction: 1977). Its collection system is an attached greenhouse with transparent solar air collectors and rock storage. There are also five skylights and thermal mass in the floor and north wall to passively provide as much heat as possible. A

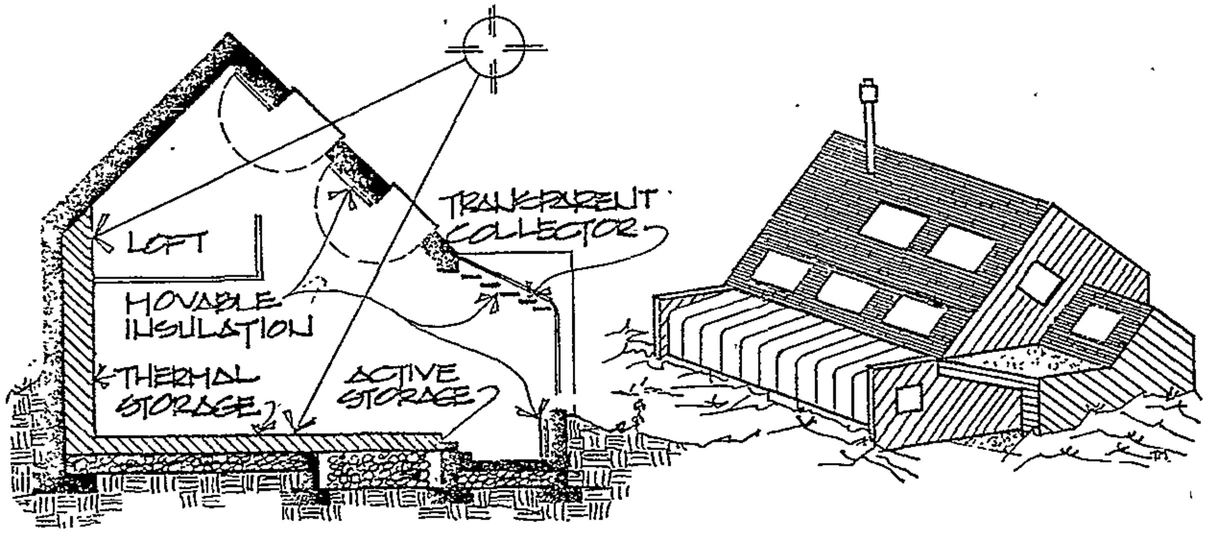

Figure 6.1-9 Section and exterior view of Smith-Hite Studio (designed by Sundesigns Architects)

wood-burning stove is used as an auxiliary heat source and for dyes used in weaving.

The domestic hot-water collectors are integrated into the garage along with three more skylights to heat the garage. A composting toilet is also being used to conserve water.

Franta Solar Residence

This future residence (Figure 6.1-10) for the aspen area contains 1,000 square feet of living space. It uses passive and active solar systems. The transparent 640-square foot solar air collector, sun-louvers, is connected to a 50-cubic yard storage bin below the first floor. In addition to the active heat collection, the sun-louvers control the amount of direct solar gain into the heat and food producing greenhouse. It also insulates the greenhouse glazing during the winter nights.

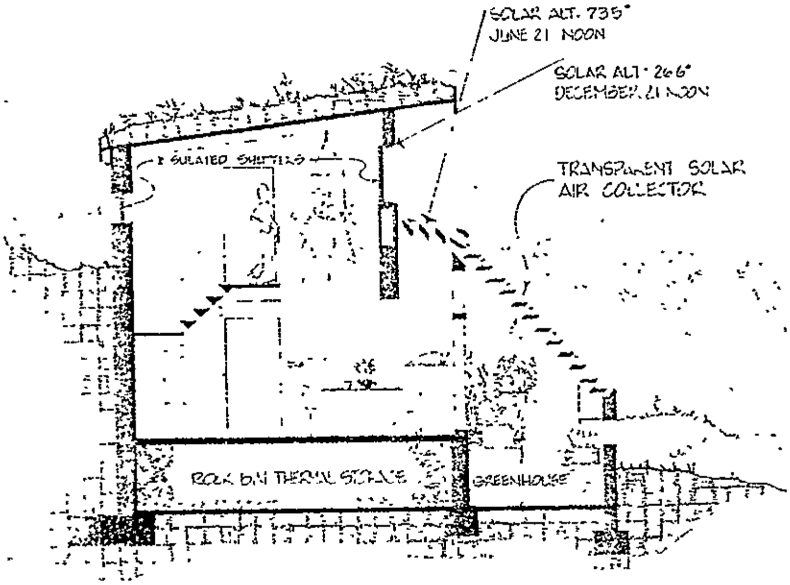

Figure 6.1-10 Franta residence (designed by Gregory Franta)

The residence is designed to utilize energy-conserving hardware and appliances. The "Clivus Multram" organic waste treatment system is utilized to conserve water. Two wood-burning stoves provide the auxiliary heating.

CONCLUSION

The Roaring Fork Valley is becoming increasingly aware of the need for alternatives in architecture at all levels from the owner-builder to the government. Approximately 80 buildings will be purposefully using the sun for heat this winter with more being designed and built every day. It is a natural evolutionary step in the integration of people and environment. It is architecture that is the interface between people and nature.

6.2 ENERGY STORAGE - THOMAS R. SCHNEIDER

Program Manager, Energy Storage, EPRI

(Note: the text presented here is an excerpt from a paper entitled, "Energy Storage," by Thomas R. Schneider and Fritz R. Kalhammer, also of EPRI, published in the Annual Review of Energy, Vol. 1, 1976. Dr. Schneider has submitted this material for presentation in the workshop proceedings to document his informal comments at the workshop.)

INTRODUCTION

In modern societies, energy is extracted, supplied and consumed (converted into heat and useful work) at different times, in different locations and in different ways. To reconcile these differences, energy must be stored in large amounts. Despite today's complexity of energy supply and use, energy storage remains largely limited to the familiar forms of fossil fuel storage: in the oil tanks, gas reservoirs and coal piles of utilities; in the fuel oil tanks of industrial, commercial and residential consumers; and in the gasoline tanks of transportation modes.

Only a few new forms of energy storage have been introduced during the past 50 years. Among these, electrically heated water tanks and hydroelectric pumped storage have resulted in significant economic and operational benefits to consumers and utilities alike. At a time when society has become acutely aware of the problems and constraints surrounding the key issue of adequate energy supply, the national expectation is that energy storage will eventually provide major conservation, environmental and economic benefits.

Most importantly, large-scale conservation of irreplaceable petroleum and natural gas resources would become possible if advanced energy storage devices and systems were to power electric vehicles, replace (in conjunction with additional coal or nuclear baseload plants) the combustion turbines used by electric utilities, allow space heating and cooling to be done with off-peak electric power, and permit a more effective utilization of solar energy.

Major environmental benefits can be expected from future, large-scale use of energy storage: Electric vehicles would result in greatly reduced urban air and noise pollution and traffic congestion, and dispersed energy storage in utility systems would defer or eliminate the need for unsightly electric transmission lines. Finally, significantly lower costs of energy -- for transportation, electric power and heating/cooling -- should be achievable if cost-competitive energy storage methods could be introduced into the transportation, power generation and residential/commercial sectors. How, and to what extent, energy storage is likely to be used will depend critically on the success of current efforts to develop advanced energy storage devices and systems.

This article begins with a review of those energy storage applications that have potential for major social benefits. Subsequently, status and prospects of the major energy storage technologies are examined, with a view toward identifying the more promising approaches. This information is followed by a summary and some comments on the outlook for energy storage.

APPLICATIONS OF ENERGY STORAGE

Opportunities for significant new applications of advanced energy storage methods in modern industrial societies are readily identified by considering the flow of energy, from its extraction to its ultimate use. Figure 6.2-1 shows this flow, including the locations and forms of energy storage as currently used. As noted before, existing energy storage is limited almost entirely to chemical energy (fossil fuels). Other noteworthy points are that (a) with the exception of hydroelectric pumped storage, the lack of storage methods for electric energy reduces the opportunities to use this versatile energy form; (b) with the exception of hot water and brick storage, only fuel energy is presently stored sufficiently close to the major end uses to be fully effective in reconciling supply and demand; and (c) the biomass (vegetation) is the only -- and rather inefficient -- medium for conversion and storage of solar energy.

Together with the potential benefits previously presented, the foregoing points indicate that the major opportunities for new applications of energy storage are in electric utility systems, the residential/commercial sector and the utilization of solar energy.

Electric Utility Systems

Much of the current interest in energy storage -- and many of the ongoing efforts to develop advanced storage technologies -- originated from the realization that energy storage can improve the operation and economics of electric power systems.

The role of utility energy storage becomes apparent by considering the daily and weekly variations in electricity demand, as expressed by the typical weekly load curve shown in Figure 6.2-2 (top). The steady demand base throughout the day is met by baseload plants, the units with the highest efficiency and lowest operating costs -- typically, modern fossil and nuclear steam-generating units. The broad daily peak is served by intermediate generating equipment, which comprises a system's less modern fossil steam units and, where necessary, combustion turbines and diesels. Although this "generation mix" approach has worked quite well in the past, it is becoming increasingly costly and restrictive. Sharply increased fuel prices create a heavy cost penalty for older, less efficient equipment and the limited supplies and high costs of natural gas and distillate fuels make the use of low-capital-cost combustion turbines less attractive than in the past. Thus, there is a clear conservation and economic incentive to use baseload plants as a source of the power now generated by peaking and intermediate equipment. In a simplified way, this use is shown in Figure 6.2-2 (bottom): The more efficient and economical baseload capacity of a system is increased, and the excess capacity during night and weekend periods is used to charge the energy storage system.

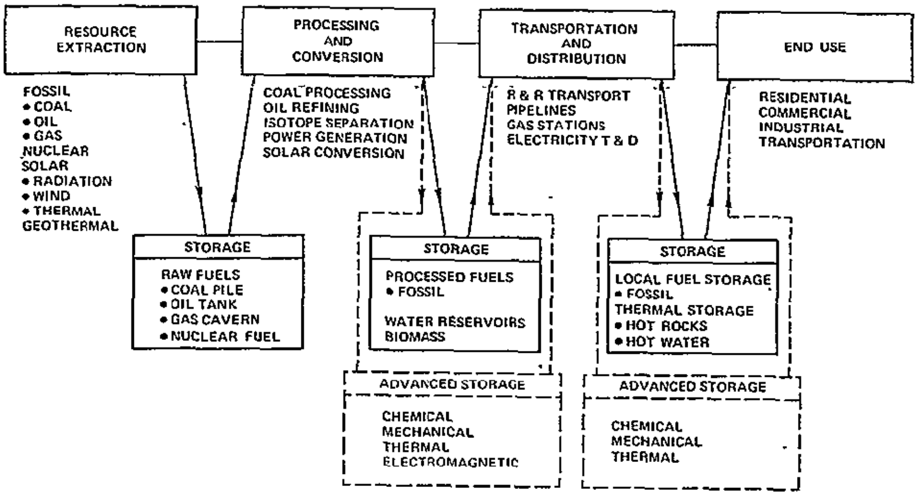

Figure 6.2-1 Energy flow and storage.

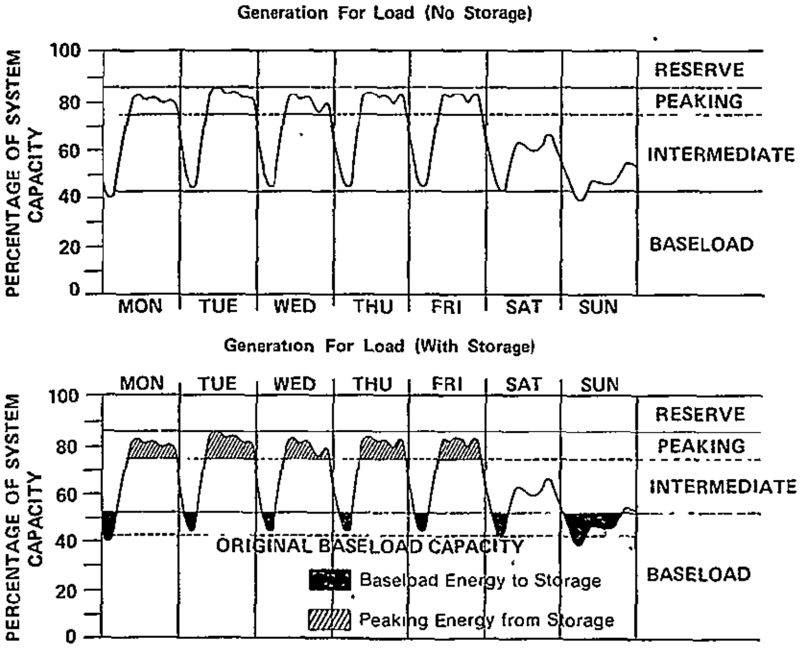

Figure 6.2-2 Typical weekly load curve of an electric utility.

Discharge of that system provides for the daily peak demands, thus replacing oil- and gas-burning generating capacity. From published projections it is readily estimated that replacement of peaking combustion turbines would result in the conservation of nearly 100 million barrels of petroleum per year by 1985.

The favorable experience with hydroelectric pumped storage -- which in the United States goes back to a 1929 installation at the Connecticut Light Company -- has already shown that energy storage on electric power systems can yield substantial operating and economic benefits. Significant expansion of pumped hydro storage from 8,100 MW in May, 1974, to about 40,000 MW in 1993 can be expected. However, this capacity represents less than 4 per cent of the generating capacity projected for that year. Geographic, geologic and environmental constraints are likely to limit pumped hydro storage to a steadily decreasing percentage role thereafter. This potential must be compared with recent estimates, which could be installed in the form of energy storage. This represents a very large ultimate market for competitive new energy storage methods.

Simple sensitivity analyses can be used to approximate the influence of key parameters on the economic competitiveness of energy storage methods for utilities. For example, as shown in Figure 6.2-3, the economic break-even cost of energy storage systems may be expressed as a function of peaking equipment cost, with parametric dependence on the costs of combustion turbine fuel and of charging energy for the storage device.

Certain advanced storage devices, such as batteries and flywheels, appear capable of being sited closer to the load than conventional generating equipment for peaking and intermediate cycling power. Dispersed siting of energy storage could result in significant savings or deferments of capital costs for new transmission and distribution facilities; dispersed storage could also increase system reliability. Preliminary analyses of

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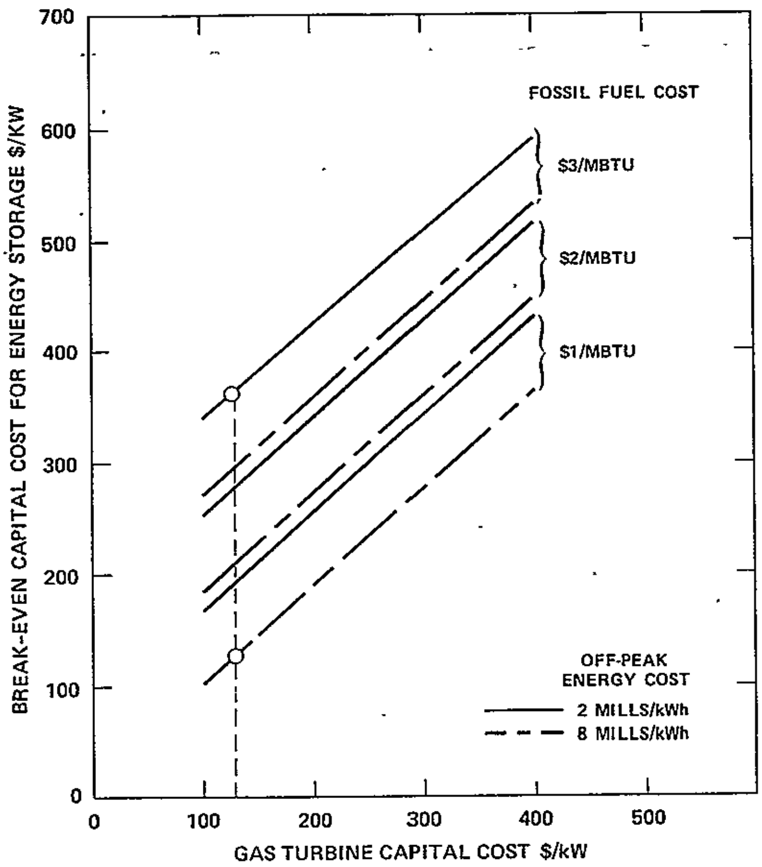

Figure 6.2-3 Break-even capital costs for energy storage vs gas turbine capital costs for intermediate load operation

these benefits have been made. Realistic analyses must include comparison with generation equipment such as fuel cells (possibly also combustion turbines), which also could be sited close to load centers. Another factor to be considered is that installation costs per unit of storage system capacity tend to be higher for smaller installations, even for basically modular devices, such as batteries.

Energy storage is almost invariably associated with inefficiencies that increase storage system operating costs to the off-peak power costs.

In practice, efficiency is not considered a problem area, because most of the proposed advanced energy storage methods appear capable of efficiencies above 70 per cent.

Lifetime of a storage system is a more critical factor. The annual carrying charges can become economically prohibitive for devices with a short life, for example less than 10 to 15 years. To achieve utility-type service life, some energy storage systems may require upgrading or replacement of life-limiting components or subsystems as part of their scheduled maintenance.

Overall, the anticipated conservation and operational benefits constitute a large incentive toward development and introduction of new methods for utility energy storage. Current uncertainties regarding applicable technical and economic feasibility criteria -- and the prospects for advanced technology to meet these -- will receive clarification in the future.

UTILIZATION OF SOLAR ENERGY

Solar energy has potential for becoming a major new source of energy. An NSF/NASA Panel Report projected that, by the year 2000, 10 per cent of the heating and cooling demand and 10 per cent of the demand for electric energy in the United States could be met by utilizing solar energy. Although appreciably lower utilization percentages have been estimated more recently, there remains a substantial incentive to develop the solar energy resource.

The main problems associated with efficient and cost-effective utilization of solar energy derive from the diffuse and intermittent nature of the resource. Use of energy storage in solar energy systems can solve or mitigate these problems. Most importantly, energy storage bridges the gap between solar energy input during sunny days and energy demands at night or during cloudy daytime periods. The general approach in designing solar energy utilization systems is therefore to provide for substantial storage capacity.

If little or no storage is provided, solar energy utilization systems can only "displace energy," that is, replace some of the energy supplied by conventional sources. On the other hand, if the system includes sufficient storage, it can "displace capacity," that is, reduce the demand for generating capacity placed on the conventional sources. The important consequences of this factor for the cost-effectiveness of solar energy utilizations have been emphasized.

Energy storage is also a practical necessity for solar-thermal generation of electric power. Depending on the type of solar-thermal system and the location of storage within the system, various kinds of thermal storage will be more appropriate than batteries, which tend to result in higher costs of electricity. On the other hand, batteries are the logical complement of photovoltaic solar conversion systems, unless these systems, which are currently prohibitively expensive, are aimed almost exclusively at energy displacement.

In general, energy storage appears to offer considerable potential for more flexible and efficient utilization, reduced environmental impacts and improved economics of future energy resources.

METHODS AND TECHNOLOGIES OF ENERGY STORAGE

On the basis of the stored energy form, these technologies fall under four broad groups: mechanical, thermal, chemical and electromagnetic energy storage. These are discussed briefly; a comparison table is included with the Summary section.

Mechanical Energy Storage

Hydroelectric Pumped Storage ("Pumped Hydro") This method is based on pumping water from a lower to a higher level with expenditure of pumping energy. Much of this energy is recovered by allowing the water to return to the lower level through a turbine driving an electric generator. The water may be pumped between two dedicated reservoirs, or the lower (upper) reservoir may be a naturally occurring body of water, such as a lake, river or ocean.

Hydro pumped storage is a technology already in a mature state of development and an extensive body of knowledge exists. Properly designed plants operate efficiently and with low maintenance costs. Research and development problems relate mainly to the proposed underground siting of lower reservoirs and to overcoming environmental objections to siting.

In underground pumped storage, the lower reservoir and power plant are located in deep underground caverns and the upper reservoir is at the surface. By being free of surface topographical restrictions, the siting of these underground plants should be considerably easier than the siting of conventional pumped storage facilities.

The largest uncertainty is the underground reservoir: its cost, durability with pressure cycling and the rate of water leakage into the lower reservoir. Costs are heavily dependent upon suitability of the site and local labor conditions. Given a specific site and knowledge of the geological locations, good accuracy in the cost estimates is expected. Since the economics of scale in pumped hydro dictates sizes in the range of 200 to 2,000 MW, these units require substantial transmission facilities unless sites can be developed within or near large urban load centers.

Compressed Air-Gas Turbine Systems Compressed air storage, as currently conceived, uses a modified combustion turbine (split Brayton cycle), uncoupling the compressor and turbine so that they can operate at different times and incorporating the intermediate storage of compressed air. During off-peak load periods, the turbine is disengaged and the compressor is driven by the generator, which is now used as a motor and takes its power from other generating units, through the system's interconnections. The stored compressed air is subsequently used during peak load periods when it is mixed with fuel in the combustion chamber, burned and expanded through the turbine. During that period, the compressor clutch is disengaged and the entire output of the turbine is used to drive the generator, which feeds power to the electrical system.

Since, in normal operation, the compressor consumes about two-thirds of the power output of the turbine, the rating of the gas turbine operating from the stored compressed air is increased roughly by a factor of three. Current estimates for the heat rate of the combustion turbine operating from stored compressed air are in the range of 4,000 BTU/kW-hr. to 5,400 BTU/kW-hr. The variable maintenance cost should not be any greater than that for a conventional combustion turbine.

The compressed air may be stored in naturally-occurring reservoirs (caverns, porous ground reservoirs and depleted gas or oil fields) or man-made caverns (dissolved-out salt caverns, abandoned mines or mined hard-rock caverns). Each approach has its advantages and all are applicable to different underground reservoirs.

Flywheels Energy storage in form of the kinetic energy of a rotating mass has been used almost since the beginning of the industrial age. The technological advances in rotating machinery and high-strength lightweight materials achieved since then -- especially in the past few decades -- hold out promise for longer periods and greater specific capacity of energy storage, which raises the possibility of new applications.

Most of the proposed advanced applications of flywheel systems have been directed at either vehicular propulsion or electric utility energy storage. For vehicles, several modern applications are reported, while utility system applications have been restricted to special-purpose uses for smoothing pulsed power.

Innovative designs will be necessary to achieve high working stress levels in advanced composites and must take into account realistic stress levels in fabricated wheels, practical methods and acceptable costs of fabrication and quality assurance and the fracture tolerance of the wheel material. Wheel configurations of high energy density and potentially low cost will not by themselves insure feasibility of compact economical flywheel systems inasmuch as auxiliary and safety subsystems will contribute materially to the size and cost of a flywheel system.

Thermal Energy Storage

Thermal energy storage may be defined as storage of energy in the form of: a) sensible heat and b) the latent heat associated with phase changes. The major technical parameters for thermal energy storage include the storage medium, the operating temperature range and the mode of heat exchange between the storage subsystem and the heat source/sink. Any practical system must include, not only the thermal energy storage and transfer subsystems, but also provisions for control and insulation.

Thermal energy storage can be useful in a wide spectrum of applications, including: a) hot-water heating, b) heating and air-conditioning of buildings with off-peak (or solar) energy, c) low-temperature process steam storage, d) central - station thermal storage (for conventional or solar-thermal power plants) and e) industrial process heat storage. Depending largely on the temperature of the storage medium, these uses may be grouped into applications of low-grade (relatively low-temperature) and high-grade (high-temperature) heat.

Storage of Low-Grade Heat Storage of sensible heat in hot water reservoirs is established commercial practice and is not reviewed here. Heat storage in the ceramic bricks of storage heaters has gained commercial acceptance in Europe. Among the key tasks in making storage heaters practical, were the design and refinement of control methods.

The operation of air-conditioning systems with off-peak power requires coolness storage. Although coolness storage has not yet found significant applications, it would be a useful option in the service areas of summer-peaking electric utilities and commercial applications appear to be economically attractive.

Storage of relatively low-temperature heat will be a key requirement for the residential and commercial utilization of solar energy and appropriate approaches have been explored experimentally.

Storage of waste heat from power plants or industrial processes for later use is another possible application of low-grade heat storage. For example, municipal heating systems can be integrated with power plants via hot water storage and transport. This energy system approach could improve the economics of generating equipment such as fuel cells that permit ready recovery of their waste heat.

Storage of High-Grade Heat The advantage of storing high-temperature heat is twofold: a) the specific storage capacity of a high-grade heat storage system tends to be high and b) high-temperature heat can be converted with good efficiency into other forms of energy, especially work. Storage of high-temperature high-pressure steam-water mixtures is the prime example in this category. The basic technology of steam storage is well understood and thermal storage has been in service since 1929. To be economical, innovative engineering designs must be applied toward reduction of the costs of pressure vessels.

In power plant applications of high-grade heat storage, steam storage would probably be used together with a separte peaking turbine. In another approach, hot feedwater storage would be integrated into the design of the station; this would require a rather sopisticated main turbine. Although a thorough analysis of probable capital costs has not been made, preliminary information suggests that such systems could be economically attractive if costs of storage tanks can be reduced. Similar storage schemes can be developed around working fluids other than water; sodium would be particularly appropriate in conjunction with sodium-cooled nuclear reactors. However, safety and regulatory considerations could impede the acceptance of central thermal energy storage and the entire range of possibilities under consideration for central power plant thermal storage can be considered for this application of the future.

Chemical Energy Storage

In the broadest sense, chemical energy storage is the storage of energy as the chemical potential of metastable reactants that can be made to react with a net release of energy. Storage of energy in chemical form has two inherant advantages. The high energy density of a chemical system results in compact, generally low-cost storage and ready transportability of energy, and chemical energy is readily converted into other useful energy forms by a variety of methods and devices. These advantages are responsible for the almost exclusive use of conventional chemical fuels as today's energy storage media.

The chemical energy storage methods and systems in this article meet a second criterion that excludes conventional fuel storage: the reactant systems containing the stored energy must be reformed readily from their reacted (the discharged) state upon addition of energy in a suitable form. All chemical energy storage systems may be described functionally by the general scheme shown in Figure 6.2-4, but widely differing subsystem configurations and conversion techniques are used in the specific storage devices and systems reviewed in the following.

Batteries In secondary or "storage" batteries, the conversion from electrical to chemical energy (charging) and the reverse process (discharging) is performed by way of electrochemical reactions. The electric form of

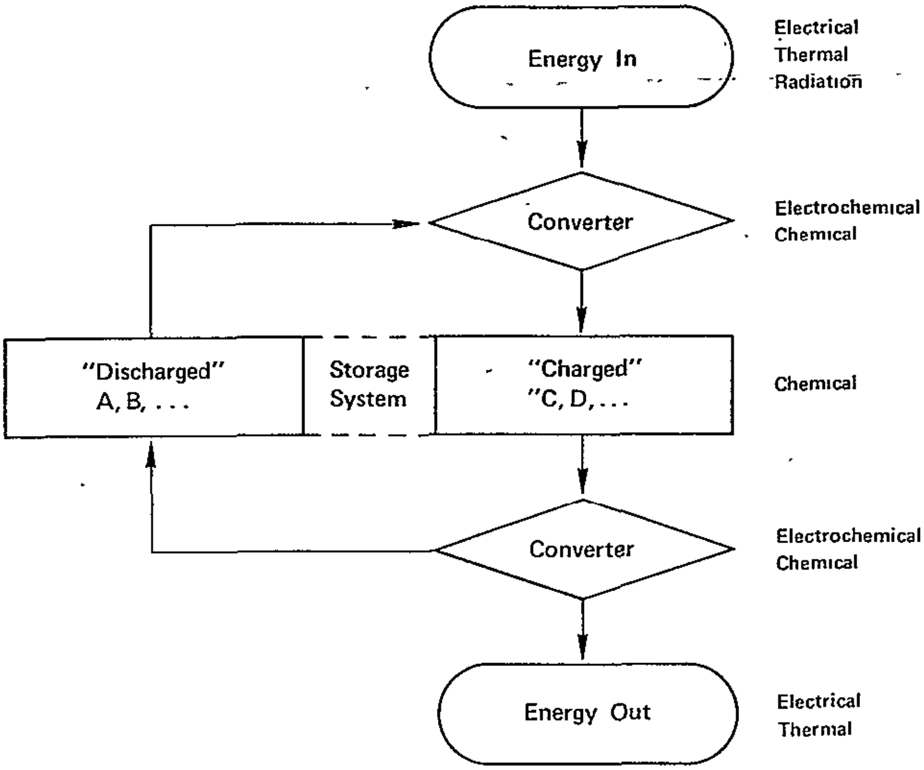

Figure 6.2-4 Principle of chemical energy storage systems

input and output energy, compactness and the modular characteristics common to electrochemical devices, make batteries potentially the most useful among advanced energy storage methods. A number of different electrochemical systems have been developed, or offer prospects for development, into practical storage batteries. We review the more promising of these briefly.

The lead-acid battery is the only chemical energy storage system with near-term prospects for application in vehicular propulsion and possibly also for utility energy storage.

If the technical goals for mobile and stationary applications can be met, inexpensive mass-production techniques remain to be developed before lead-acid batteries can capture extensive new markets over the next five or ten years.

Metal-gas batteries are functional hybrids between conventional batteries and fuel cells. Beacuse of their potential for good energy density and reasonably low cost, the zinc-air, iron-air and zinc-chlorine systems are the most interesting representatives of this group. For various reasons, application of metal-air batteries to utility energy storage does not appear attractive. The outlook for vehicular applications is still uncertain.

The zinc-chlorine battery is attracting considerable interest, primarily because an apparantly practical solution to the problem of chlorine storage has been developed at EDA (Energy Development Associates, Madison Heights, Michigan). Potential for high efficiency, good cycle life and low cost are claimed for this battery and a vehicle test (using a mechanically charged battery) was successful. A commercial zinc-chlorine battery could become available within another five years.

Redox batteries -- in which the positive and/or negative active materials are dissolved in the electolyte -- have been proposed for large-scale energy storage. The potential advantage of this approach (compared with more conventional battery designs) is that external reactant storage in tanks tends to result in relatively low capital costs for the storage-related part of capital costs. This characteristic might qualify redox batteries for accumulating and storing energy over longer periods -- for example, weekends -- than can be handled economically by conventional batteries.

Lithium/iron sulfide batteries are being developed at Atomics International (AI) and the Argonne National Laboratory (ANL). Both programs emphasize utility energy storage, but design of a vehicle battery is also

C-3

addressed at ANL. For either approach, the capability for long cycle life and potential for low cost are yet to be established. Even if current approaches prove to be basically successful, the establishment of a commercial technology is likely to require at least another four to six years.

Hydrogen Storage Systems Hydrogen energy storage represents the best-known example of advanced chemical storage. Several approaches have been proposed and explored for each of the required subsystems -- hydrogen generation, storage and reconversion -- which can be combined in various ways into overall energy conversion and storage systems.

For hydrogen generation from water and energy, electrolysis is the only established industrial process. Current electrolysis technology is handicapped by modest efficiency and high capital costs, but considerable potential appears to exist for development of more efficient lower-cost electrolyzers. Realistic targets for advanced technology might include efficiencies up to 100 per cent and electolysis equipment costs between $100/kW and $150/kW.

Closed-cycle thermochemical processes are being proposed for hydrogen production via water splitting, but current work is still in the conceptual and early laboratory stages. The incentive to develop such processes derives from the potential for efficiencies and economics that might be superior to those offered by electrolysis, particularly if sources of fairly high=temperature heat -- such as high-temperature gas-cooled reactors or perhaps focused solar heat -- become available.

Hydrogen storage, the second major subsystem of hydrogen energy storage systems, can take several different forms. Storing hydrogen in concentrated forms -- as a cryogenic liquid or chemically bound in metal hydrides -- is technically feasible and logistically attractive. However, cryogenic storage of hydrogen carries a significant efficiency penalty that is unacceptable for large-scale energy storage on utility systems. The outlook is better for metal hydride storage.

Reconversion of hydrogen to electric energy can be done in fuel cells or in combustion-based devices (gas-fired boilers or gas turbines). The fuel cell approach offers potential for high efficiency, with 60 per cent as a realistic target for pure hydrogen fuel. Probable technical and economic characteristics and the first generation of a commercial fuel cell technology are expected to be established within the next three to four years.

Advanced combustion technology, such as "hotshot" hydrogen-oxygen gas turbines also appear to offer potential for high energy conversion efficiencies -- on the order of 50 per cent and higher for a combined combustion turbine-steam cycle.

The overall efficiencies of hydrogen energy storage systems are likely to be lower and the capital costs higher, compared with several other energy storage methods. Accordingly, it is imperative that the unique advantages of hydrogen energy systems be adequately identified and, if possible, quantified to guide development and application of hydrogen energy storage technology.

Closed-Loop Chemical Systems Other recently proposed concepts for chemical conversion and storage of energy are based on closed-loop chemical reaction systems. Such systems would be thermally coupled to nuclear (or solar) heat sources to achieve an energy-absorbing chemical change. The absorbed energy, now in chemical form, would be storable and transportable, possibly over significant distances. At the point of consumption, the reaction would be allowed to proceed in the reverse direction, with evolution of heat at a somewhat lower temperature. To be suitable, the forward and reverse reactions must be readily reversible and must occur at useful temperatures. One may include under chemical energy storage those reactions (or reaction systems) that can be used to directly convert solar or nuclear radiation into the chemical energy of metastable reaction products. Chemical energy conversion and storage might eventually offer more efficent and less costly routes for the utilization of solar and fusion energy -- the energy sources of the future.

Superconducting Magnetic Energy Storage (SMES)

The application of superconductivity to power systems is a technology in a very early stage of development. The proposed use of a superconducting inductor for energy storage takes advantage of the principle that energy can be stored in an inductor of zero resistance for, theoretically, an infinite amount of time. The superconducting magnet is charged, using off-peak energy, and, during peak periods, energy is fed back into the system through an inverter, which is used as a rectifier during charging. Work on superconducting systems for energy storage is being carried out at the Los Alamos Scientific Laboratory and the University of Wisconsin.

So far, all data indicate that this will be a rather expensive method for energy storage. Further development of superconducting materials with high critical currents and high fields at reasonable cryogenic temperatures could reduce projected system costs. Since total stored energy increases with the surface area, the relative costs of storage should decrease as the magnet size increases.

Many detailed technical problems remain to be solved before SMES can be considered feasible and substantial reductions in costs will be necessary before it can be applied to bulk energy storage in utility systems.

SUMMARY

Storage of energy is basic to the functioning of all societies, even simple ones. Modern industrial societies depend vitally on storage of very large amounts of energy, Primarily in the form of fossil fuels. The multiplicity of energy-dependent functions and services in a modern society open up broad opportunities and potential benefits from storage of energy in new forms.

In electric utility systems, pumped hydroelectric storage has already demonstrated significant benefits. The full potential of utility energy storage can be achieved only through development of advanced, more broadly applicable, storage methods and systems of competitive technical and economic characteristics. Development of such systems could result in reduced costs and higher reliability of electric service. The conservation goals suggested by President Ford for the electric utilities could eventually be met by a shift -- with the aid of energy storage -- from petroleum to a mix of coal and nuclear fuel for generation of peaking and a part of the intermediate cycling power.

Use of thermal energy storage will be a key to the more efficient and economical utilization of solar energy for residential and commercial heating and cooling and for electric power generation. Energy storage and transport via advanced chemical reaction systems appear to have potential for efficient and economical utilization of nuclear or solar high-temperature heat.

The broad range of possible uses of advanced energy sotrage methods gives rise to an equally broad range of desirable storage device and system characteristics. In response to the opportunities for large-scale applications, a variety of energy storage technologies are currently under study and development. These efforts are funded by industry, the electric utilities (primarily through the Electric Power Research Institute) and the federal government.

Information on characteristics and status of candidate energy storage methods is summarized in Table 6.2-1.

Table 6.2-1

Projected characteristics and status of some energy storage systems

Type	Round Trip Efficiency (%)	Capital Costs[b]		Energy Density (kW-hr/ft^3)	Development Stage	Potential Application
		C_p($/kW)	C_s($/kW-hr)			
Mechanical						
Pumped hydro	67–75	100–140	2[c]–15	0.04[d]	Existing application; engineering studies for underground	Central energy storage for peak shaving and load leveling
Compressed air–gas turbine system	65–75[e]	120–150	3–10	0.1–0.5	First commercial demonstration 1977	Central energy storage for peak shaving and load leveling; reserve generating capacity
Flywheels	70–85	80–120	50–100[f]	0.5–2	Initial development	Distributed energy storage; power factor correction; emergency generating capacity
Thermal						
Steam (pressure vessel)	70–80	150–250	15–25	up to 1	Historical installations; engineering studies of modern systems	Central energy storage, integrated with baseload steam generation
Hot oil	65–80	150–250	10–50			
Batteries						
Lead-acid	60–75	60–100	25–50[g]	1–2	State-of-the-art	Distributed energy storage for daily peak shaving; stand-by and emergency generating capacity, vehicle propulsion; energy storage in solar energy systems
Advanced aqueous	60–75	60–100	15–50[g]	1–3	Small prototypes	
High-temperature	70–80	60–100	15–35[g]	2–5	Laboratory cells	
Redox	60–70	100–200	5–15[g]	0.5–2	Conceptual and laboratory studies	
Chemical						
Hydrogen (electrolysis plus fuel cell)	35–55	300–400	5–30	N.A.[h]	Advanced development of subsystems	Central energy storage with distributed generation; combined gas/electric energy systems
Reaction systems (closed loop) $CH_4 + H_2O \rightleftharpoons CO + 3H_2$	?	?	?	N.A.	Conceptual studies and initial development	Conversion, storage, and transport of nuclear and solar energy
Electromagnetic						
Superconducting magnets	80–90	40–50	35–200	0.5–1	Concept; key components under development	Central energy storage and system stabilization (large-scale only)

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[b] Total storage system capital cost is given by $C_t = C_p + t_{max} \times C_s$, where t_{max} is the maximum period for which the storage system can be discharged at its rated power.

[c] Assuming one existing reservoir (lake)

[d] Assuming 3000-ft head

[e] Efficiency with respect to recovery of stored energy.

[f] Not including subsurface vault (estimated at $20–50/kW-hr)

[g] Not including installation (estimated at $3-10/kW-hr)

[h] Not applicable

OUTLOOK

It is reasonable to expect introduction of the first compressed-air and underground pumped-hydro storage installations into service in U. S. utilities by 1990. During the same period, advanced lead-acid batteries should find increasing use in electric vehicles, with some possibility that their usefulness can be demonstrated also for utility energy storage. Storage of low-temperature heat will also increase as residential and commercial utilization of off-peak power and solar energy increase. All of these uses require only evolutionary changes and adaptation of existing technology.

The realization of large-scale applications of new energy storage methods will depend not only on the success of research and engineering development, but also on a number of institutional factors. These include the large costs of commercializing new technologies, future costs and availability of energy sources and conversion equipment and regulatory strategies affecting competitive situations in the energy sector.

Some of the more important strategy options are in a) pricing and tax policies with respect to oil and natural gas -- the major fuels used for transportation, home heating and electric peak power generation; b) restrictions and priorities in fuel allocations; c) electric power pricing policies to achieve better electic load management; d) tax and other financial incentives to promote the use of energy storage devices; and e) the extent of national commitments to the nuclear option and the utilization of solar energy.

Despite the considerable uncertainty, the potential benefits and technological possibilities of energy storage appear sufficiently large to insure for it an important role in the energy systems of the future.

Closing Summary 7.0

At the conclusion of the workshop, a wrap-up presentation and discussion was performed to form a consensus on the major conclusions of the participants. The discussion was oriented topically to each of the major areas comprising Section 5.0 of these Proceedings.

The following is a summarized record of the major conclusions concurred upon by the workshop participants. This information is repeated, in part, from Section 2.0 and the topical summaries in Section 5.0 of these Proceedings.

INSTITUTIONAL ISSUES

- A need exists for clarification of the public image (or opinion) and expectations regarding solar energy utilization. This issue requires widespread information dissemination to the public regarding the real potential of solar power and the timing of its introduction to commercial use.

- Significant involvement in solar thermal power development requires a long term commitment, which conflicts with the near term planning horizons of most utility companies.

- Integration of solar electric generating technology into existing systems is difficult, not only technically, but also politically and legally. The specific barriers in these areas should be identified.

ENVIRONMENTAL AND SITING ISSUES

- New siting and licensing regulations and techniques must be created to deal with the safety and environmental considerations specific to focusing solar collector systems.

- The siting of solar plants is dependent upon the regional climate and local microclimate conditions and requirements. Careful study of each specific prospective site must be performed to avoid unwise site selections based on over-generalized regional characteristics.

- Safety, aesthetics and the availability of adequate space pose significant problems for plant siting in urban areas.

- Small distributed collector systems are best located at or near the primary load point.

- Solar plants do not appear to have significant problems with respect to pollutant emissions; however, conventional fossil-fuel back-up systems may cause some difficulty in obtaining a suitable site.

FINANCIAL ISSUES

- Solar thermal power technology must be economically feasible in order to penetrate the utility industry in any degree.

- Solar can expect no special consideration from financing entities regarding the acceptance of higher levels of investment risk.

- Lines of financial responsibility in the development of solar power must be more clearly defined, between the Federal Government, R&D organizations, utility companies and equipment manufacturers.

EXPERIMENTAL SOLAR THERMAL SYSTEM SITING ISSUES

- The siting problem for the first SPS experimental plant will require careful study, prior to issuance of the site request for proposal (RFP), if some segments of the electric utility industry are not to be effectively excluded from the site competition.

- Before the RFP, a qualifications statement should be widely distributed clearly defining the responsibilities of the host utility. This procedure will permit utilities to evaluate effectively their levels of interest in responding to a comprehensive RFP.

- The final RFP should describe:
  Type of solar thermal system

Host utility role and requirements
JPL/DOE role
Method of evaluation and host selection

- Experimental solar installations must be built and operated in a fashion that is attractive and inexpensive to the host utility/community.

SOLAR COMMERCIALIZATION ISSUES

- Commercialization of solar thermal power systems may require special participation on the part of the government in providing incentives to industry.

- Utility adoption of solar technology will depend on the existance of a strong industrial system that can support the construction, operation and maintenance requirements of the utilities.

- Successful commercialization will depend in part on the demonstration of economic feasibility and a market potential to reduce adequately the degree of risk to stimulate private investment decisions.

GENERAL CONCLUSIONS

The participants agreed that there are numerous institutional, economic and technical barriers to the adoption of such a new high-risk technology into a stable and conservative utility industry. Nevertheless, these barriers were seen as being surmountable, and virtually all of the participants voiced their desire to continue whatever involvement necessary to benefit solar thermal power development. Implementation of this technology may require 15 years, but the need for alternative power sources is clear and, hence, the support for its development is well established.

The near term generation interests of small utilities are generally best served by strong generation pooling agreements so that they may take advantage of the economics of scale inherent in large power plants using coal, oil, and nuclear fuels. When small solar thermal power plants have become economically competitive, the utilities can then consider them in their planning. It is clear that utilities cannot be expected to absorb significant cost or risk in the application of solar power plants. This is especially true for the small utilities.

Appendices 8.0

8.1 UTILITY PLANNING AND THE COMMERCIALIZATION OF SOLAR THERMAL ELECTRIC TECHNOLOGY - THOMAS J. KUEHN

Task Manager, Commercialization Analysis SPSA Project, JPL

INTRODUCTION

The commercialization of advanced energy technology is a long and complicated process that involves both the private sector and federal research and development efforts. The DOE sponsors the development efforts. The DOE sponsors the development of alternative energy technology that will help provide solutions to national energy problems and accelerate the development of new technology. However, the private sector must be intimately involved in the adoption and transfer of federal research and development.

Electric utilities and vendors must assess independently the economic, environmental and institutional viability of new energy hardware in the market place in order to make rational choices to add or replace power generation plant capacity. Both the Federal Government and the private sector must be concerned with reducing the risks and uncertainties associated with the commercialization of advanced energy technology. In order to understand their viewpoints and requirements better, a questionnaire soliciting the opinions of utility managers and expert consultants was prepared for the SPSA workshop held at Aspen, Colorado on October 10-12, 1977. This appendix reports some of the results and preliminary findings of this questionnaire.

The questionnaire results provided insights into three subjects of interest including: a) the utility planning process and leadtimes, b) barriers and incentives to the innovation of small solar thermal electric power systems, and c) the role of demonstration projects in the commercialization of advanced technology. Many of the questions specifically concern smaller utilities in order to improve our understanding of some of the differences between small and large utility planning processes. The tabulated results were reported at the last workshop session and provided substantial information used in planning activities in the SPSA project.

The questionnaire has served as an important means to initiate two-way communications of opinions and ideas between the SPSA project and private sector as potential adoptors of small power systems. In order to develop the most appropriate technology and maximize the benefits to potential users and adopters it is vital to understand fully their problems and requirements. Since utilities and most other users must plan years ahead for the adoption of advanced energy technology, the process of research, development and demonstration (R, D & D) must be carefully planned to maximize the potential for successful transfer and commercialization.

UTILITY PLANNING AND THE COMMERCIALIZATION OF ENERGY TECHNOLOGY

Electric Utilities must plan years ahead to select, license and construct new power plants. The commercialization of a new energy technology, therefore, must take into account the lag-time required for the utility planning process and recognize that information transfers from federal R&D projects must be available years ahead of the technology itself. Commercialization primarily depends on financial and implementation decisions in the private sector that are based on institutional and economic viability of innovative ventures. The risks and uncertainties of such ventures must be reduced to an acceptable level before a utility will choose to adopt a new system over some conventional power plant. Risks and uncertainties may include questions about the "readiness" of the technology, the cost, demand, institutional feasibility and environmental impacts.

Private investment decisions become more critical and perhaps, conservative as the cost of technology innovation increases through the stages of research, development and demonstration and moves toward the final stages of commercialization. Federal support of R & D may be necessary when the costs, risks and uncertainties are too great to attract private investment, though national goals and public benefits may be achieved by bringing the technology to a higher level of development. Indeed, only a small fraction of technology innovations ever reach the final stages of development or commercial production because of the thorough process of screening for economic and institutional feasibility. Many federal R,D & D programs have failed to provide for technology transfer or to result in successful commercialization in the private sector. This may be partly due to the fact that the effects of federal tools and options for accelerating the process of innovation are poorly understood. The federal R,D & D process has only recently become a subject for researchers seeking to provide guidelines for the management of successful projects. At the very least, it is necessary for federal R,D & D projects to be fully aware of private sector problems and requirements and to plan for successful transfer and commercialization of the technology that is developed.

UTILITY PLANNING, LEAD TIMES AND INFORMATION REQUIREMENTS

The average leadtimes required for the planning, licensing, and construction of new non-nuclear power plants varies between different utility systems. The questionnaire respondents, a total sample of 30 representatives of utilities and utility consulting firms, estimated that small utilities plan ahead approximately 10 years while large utilities plan ahead about 13 years. It may be that large utilities have more planning resources, drawing from a larger revenue base, and/or need more time to plan larger generation plants. It was also found that initial planning and analysis of a new power plant requires about three years. The power plant approvals or licensing process requires about 3.5 years and construction requires about 4 years to complete.

(Additional statistical information regarding the questionaire results are given later in this appendix.)

All of the phases of the utility planning process mentioned above require different types of analysis and information during each phase. These requirements present lag-times in the process of commercialization that must allow for the leadtimes required in utility planning. The respondents were asked what and when analysis and information was required to be of most use in the utility planning process. If small solar thermal electric power systems could be demonstrated and commercially available by 1995, the three most important categories of information are ranked in the following order:

a) Market and financial analysis needed by 1983
b) Technology Assessments required by 1983
c) Systems Analysis required by 1982
d) Environmental Impact Assessments needed by 1985
e) Technology Forecasts needed by 1981

Taken as a whole the importance of information and analysis of this kind was rated as very important by the respondents.

One of the clearest findings of the questionnaire is that information transfers are regarded as very important and that these transfers represent one of the most effective federal incentives for accelerating the commercialization of energy technology. Many of the strongest co-relations in the questionnaire data indicate that the greater the anticipated barriers, the greater the importance of planning and analysis. The results of a Spearman Correlation analysis of the questionnaire data are given in Table 8.1-1. Of particular interest is the correlation between the number of years large utilities plan ahead and the importance of federal incentives offered by technology and environmental assessments. Figure 8.1-1 shows a direct relationship between large utility planning leadtime and the importance of technology and environmental assessment. The greater the leadtime required for utility planning, the more effective technology and environmental assessments become as

Table 8.1-1. Spearman Correlation Analysis Results

Name Variable	No.	Correlation Coefficients (Significance 0.05 Level or Better)																				
		2	5	6	11	16	21	28	38	40	48	54	78	80	86	113	114	120	124	136	143	148
Initial Planning and Analysis Requires-- Years	2	1																				
Small Utilities Plan Ahead-- Years	5		1																			
Large Utilities Plan Ahead-- Years	6		65	1																		
Difficulty to Acquire Additional Power Supplies-Year 2000	11				1																	
Difficulty to Finance Power Plants--Year 2000	16					1																
Difficulty to Obtain Fossil Fuel--Year 2000	21				50	41	1															
Importance of Technology Assessment	28					35		1														
Demonstrations Required to Reduce Uncertainty	38								1													
Importance of Cost of Ownership Barriers	40		-53	-53						1												
Importance of Cost of Alternatives Barriers	48			-38							1											
Importance of Capital Requirement Barrier	54										36	1										
Timing of RD&D Barriers	78											56	1									
Development of Competitive Solar Industry Barriers	80			-43				41			41			1								
Integrating Solar into Electric Grid Barriers	86											-38			1							
Technology and Envir Assessment Incentive	113			44		-45			-34							1						
Federal R&D Incentive	114					-61										54	1					
Environmental Pollution Benefits	120						33	35			-53				36			1				
Fuel Savings Benefits	124	-35	-38					45					36					46	1			
Technology Well in Hand	136												45		45					1		
Market Pull Rather than Tech Push	143																-41				1	
Small Scale Projects with Low Visability	148				-33			-41	-34												49	1

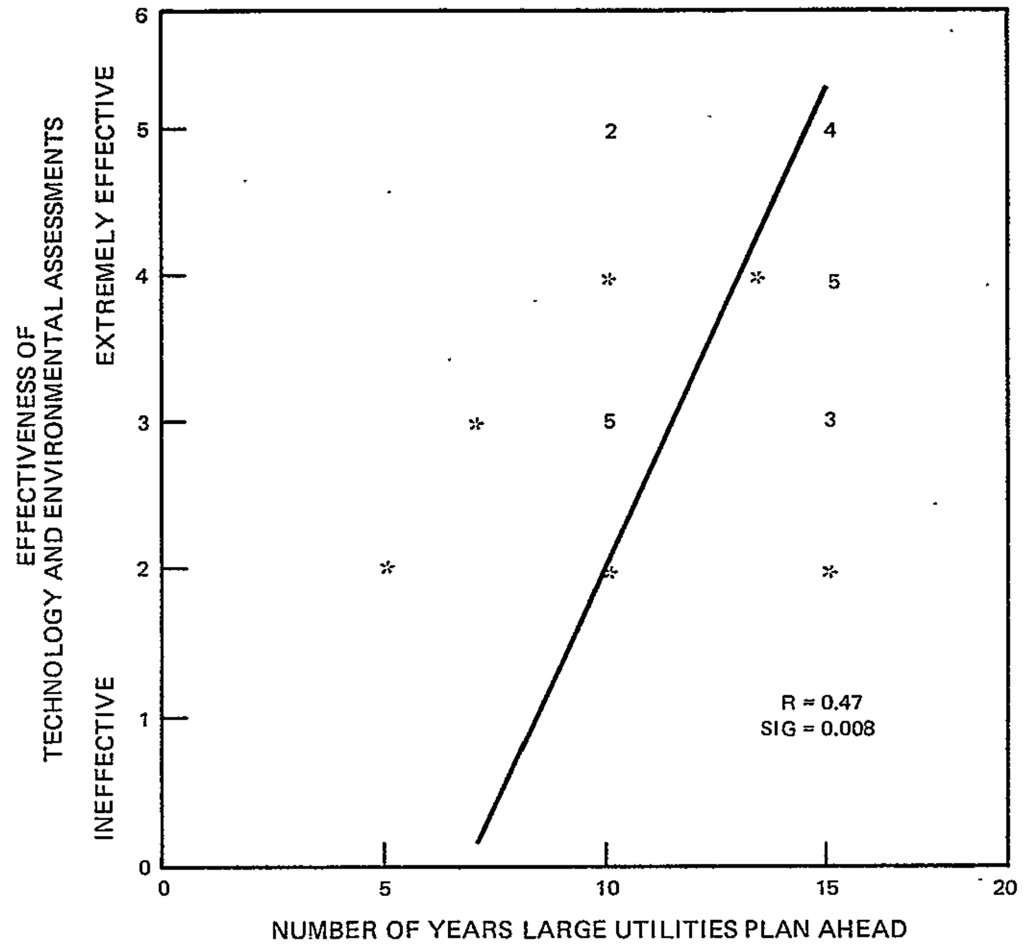

Figure 8.1-1. Planning Lead-Times and the Effectiveness of Federal Technology and Environmental Assessments

federal incentives to promote the industrialization and commercialization of advanced SPS technology.

However, it is difficult to explain satisfactorily this relationship. Large utilities may require longer leadtimes that allow more time for technology and environmental assessments, or they may have more resources for such analysis, and/or may be involved in larger and more complex projects as alternative explanation for this correlation. Further analysis is required to determine the causes and the direct effects of information transfers in the utility planning process.

FUTURE RISKS AND UNCERTAINTIES IN UTILITY PLANNING

The level of risk and uncertainty regarding future fossil fuel prices and availability, electric power plant capacity and capital costs of new power plants was also highly correlated with the perceived importance of planning, analysis and information transfer. Figure 8.1-2 shows the degree of difficulty that small utilities may encounter in acquiring additional power supplies from large utilities or from electric power grids anticipated by the respondents. Between 1980 and 2000 the degree of difficulty increases moderately as shown in Figure 8.1-2. Using the standard deviation as a measure of uncertainty and divergence of opinion on this question, it is interesting to note that the standard deviation increases slightly in the latter years between 1990 and 2000. It is also noteworthy that the degree of difficulty increases at the fastest rate between 1980 and 1990 at which time the curve levels off. It may be inferred that the respondents are relatively optimistic that some solutions to energy supply problems may begin to take effect by 1990 as indicated by the decreased rate of change in the degree of difficulty in acquiring added power supplies. However, the respondents do not perceive any major relief to the problem of acquiring power supplies between 1980 and 2000.

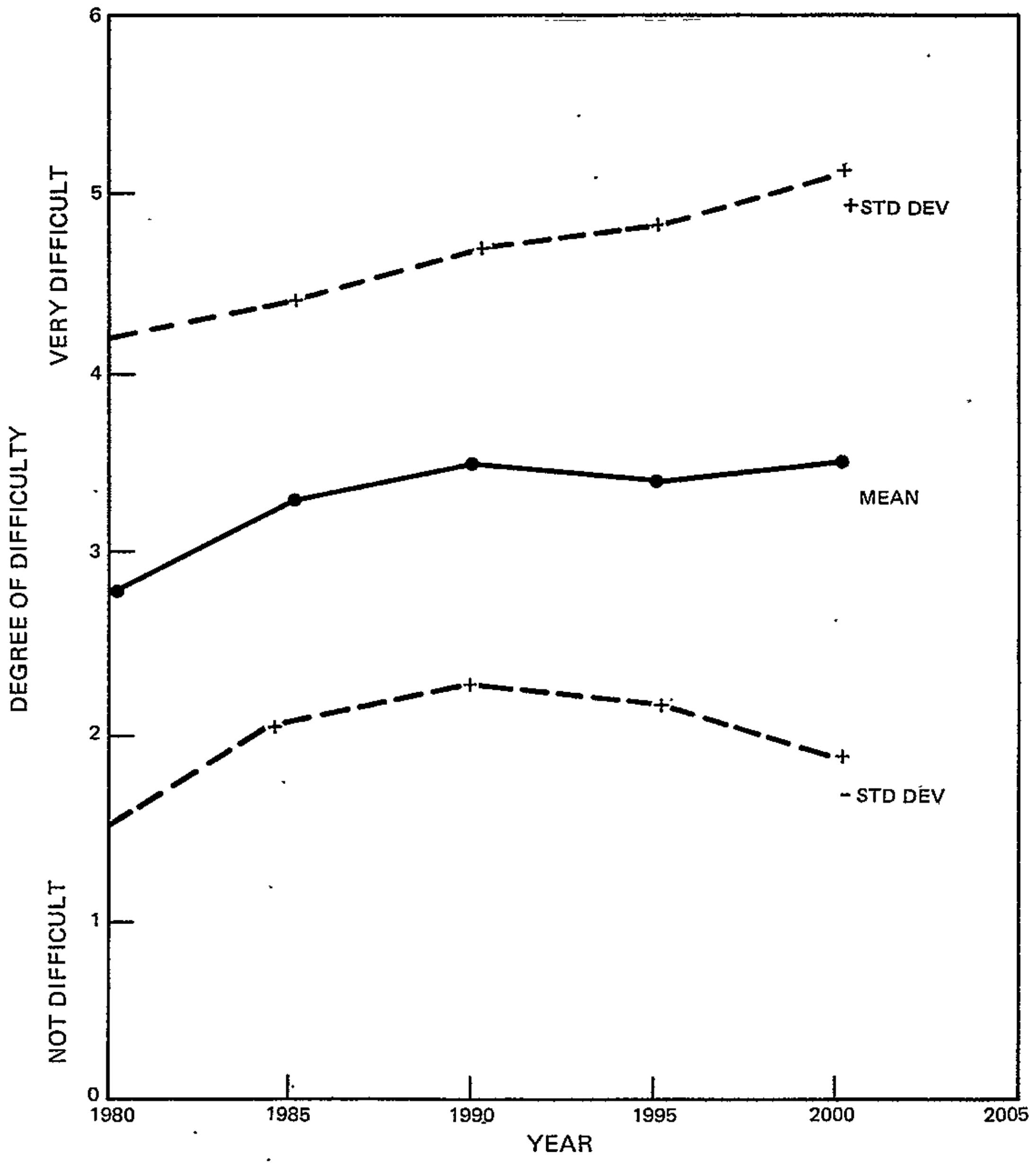

Figure 8.1-2. Difficulty for Small Utilities to Acquire Additional Power Supplies from Large Utilities or Electric Power Grids

Coupled with the problem small utilities may have in acquiring power supplies is the problem of financing large capital investments for developing their own power generation capacity. Figure 8.1-3 shows the perceived difficulty that small utilities will encounter in financing large capital investments. Financing new power plants is seen as slightly more difficult than buying power from the electric grid (see Figure 8.1-2) and this difficulty increases at a slight higher rate as well.

The most obvious question than can be asked is: Why is it becoming more difficult to both buy additional power supplies and finance capital investments to add generating capacity? Perhaps the heart of the issue is represented in Figure 8.1-4 showing the perceived difficulty in obtaining reliable supplies of fossil fuel at a reasonable price. There is a relatively clear consensus that the difficulty will increase dramatically between 1980 and 2000. Comparing Figures 8.1-2 through -4, it is interesting to note that capital availability, fossil fuel availability and power supplies are seen as moderately difficult as early as 1980. A future research question would be to examine the historical trend beginning in 1950 to provide a better perspective on the rate of change over the years.

INFORMATION TRANSFER AND THE FEDERAL R, D & D PROCESS

There is a clear indication that it will become more difficult for small utilities to finance large capital investments in the future. It was also found that technology and environmental assessments were rated as one of the most effective federal incentives for promoting the industrialization and commercialization of advanced SPS technology for utility applications. Indeed, there is a relatively strong correlation in the data between these two findings. Figure 8.1-5 shows the relationship between the effectiveness of technology and environmental assessment versus the perceived difficulty of financing electric power plants

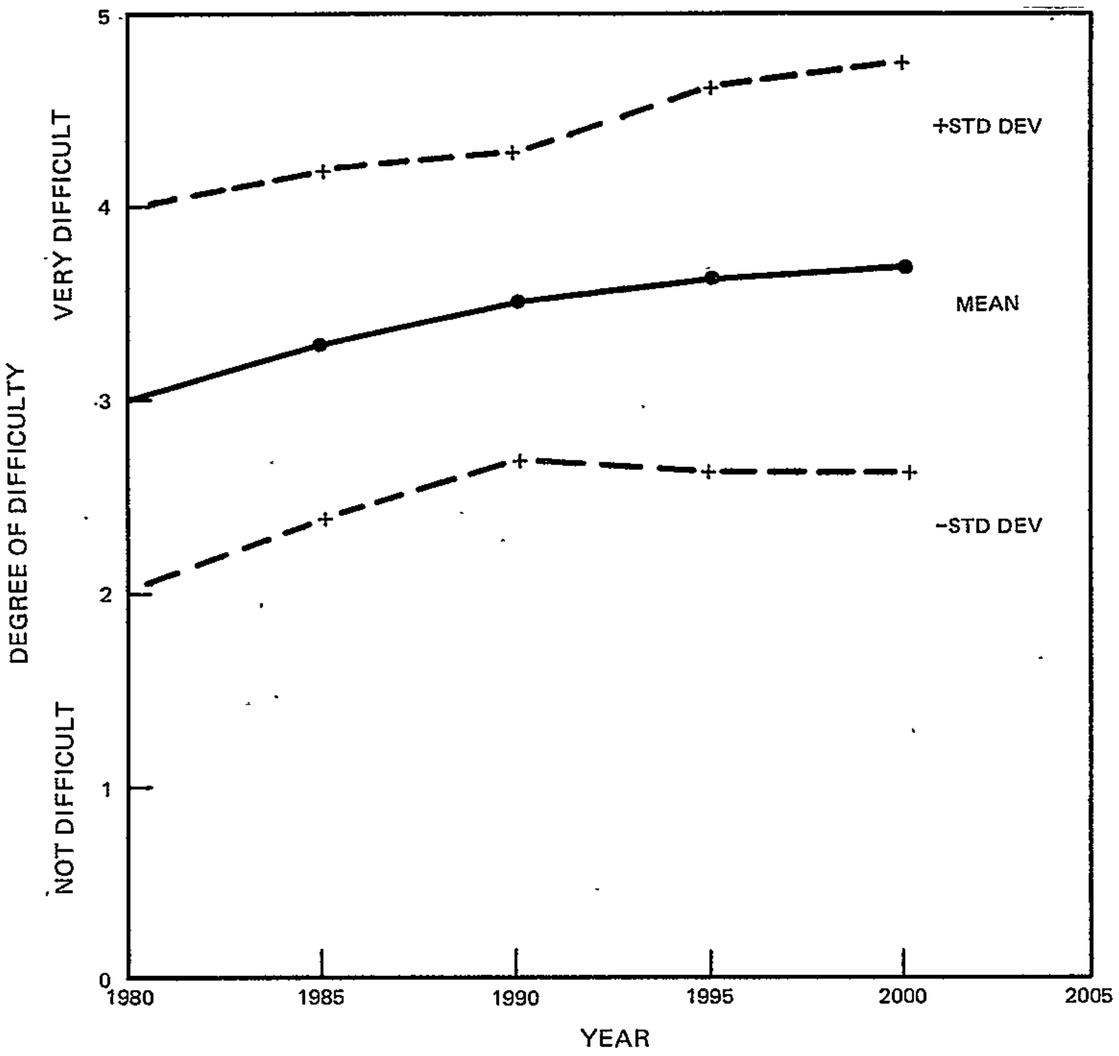

Figure 8.1-3. Difficulty Small Utilities will Encounter in Financing Large Capital Investments for Power Plants

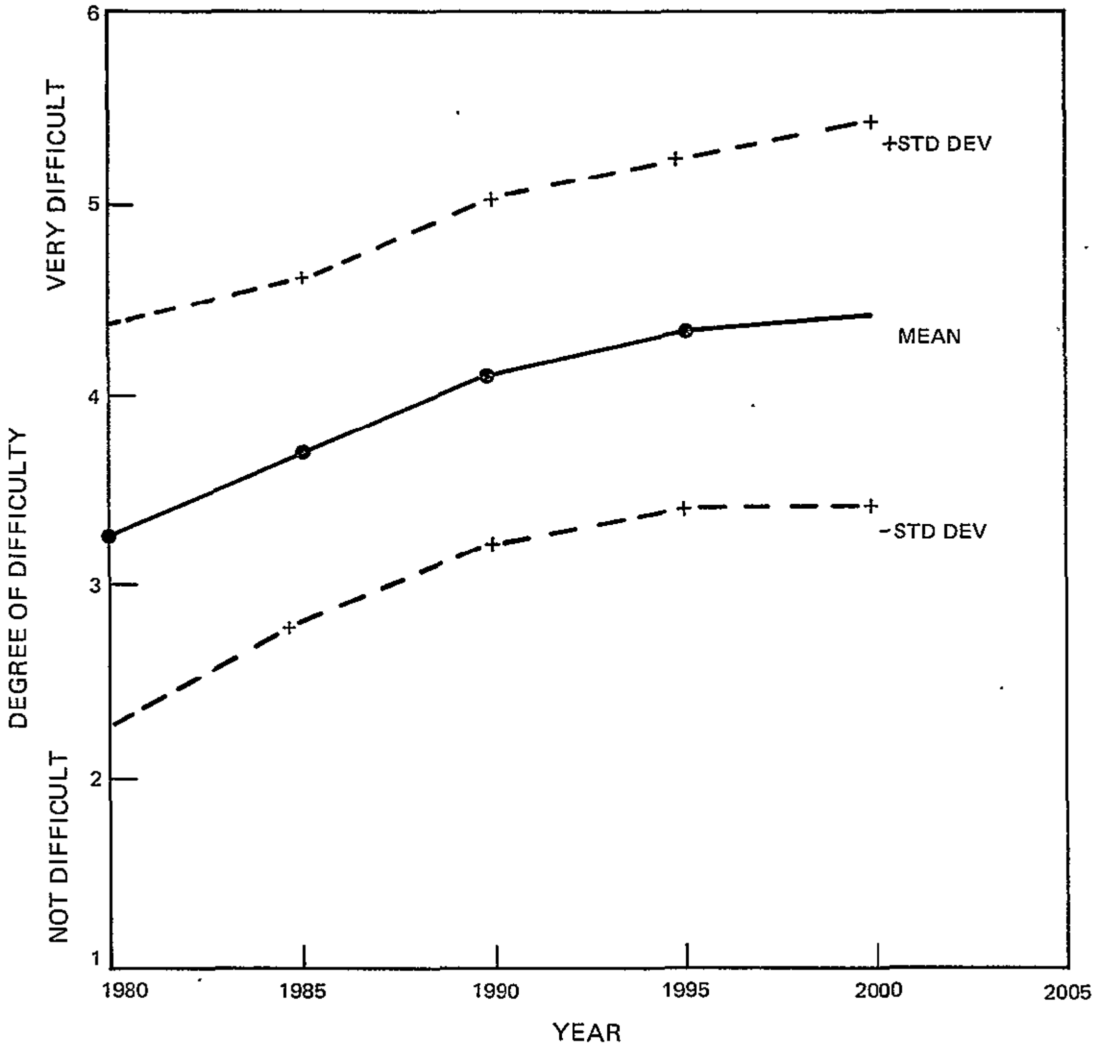

Figure 8.1-4. Difficulty to Obtain Reliable Supplies of Fossil Fuels at a Reasonable Price in the Future

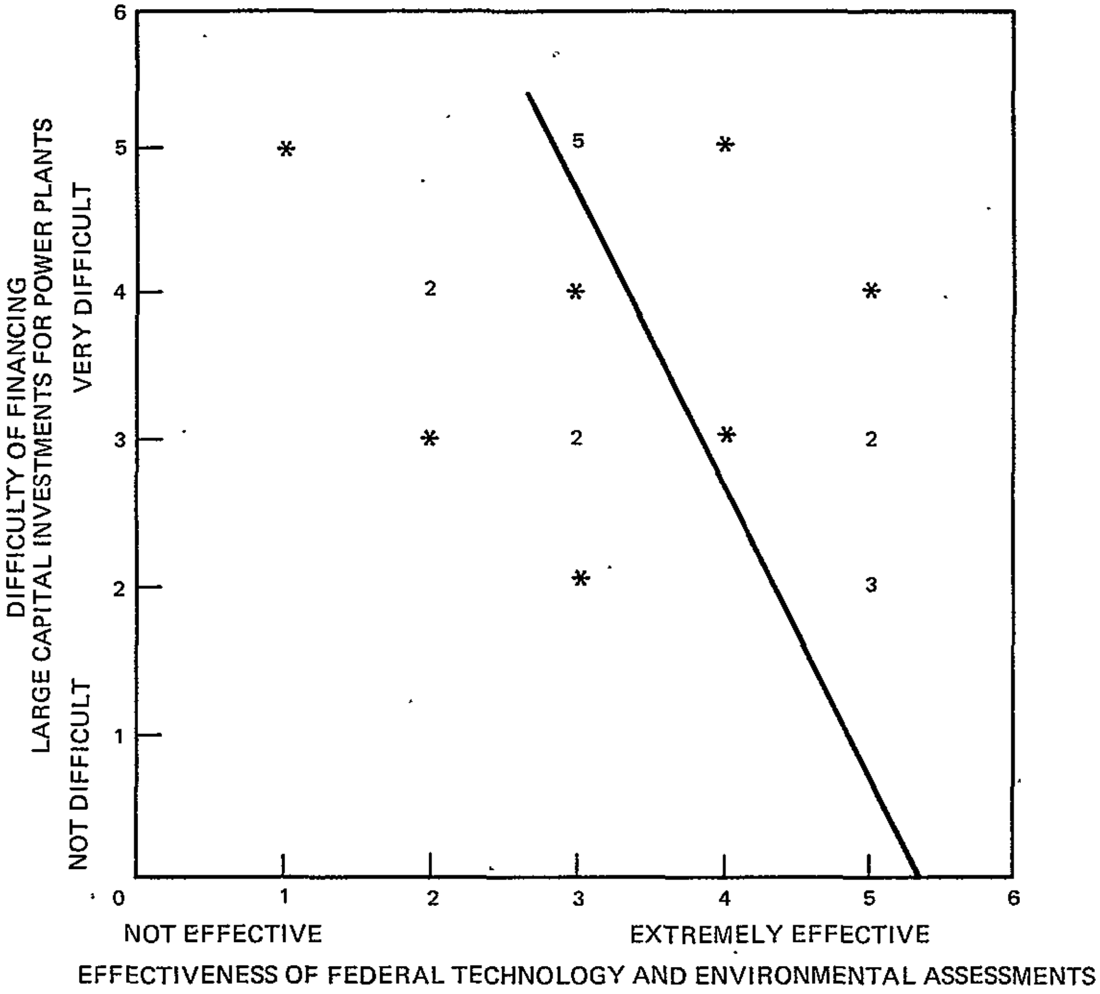

Figure 8.1-5. Effectiveness of Federal Technology and Environmental Assessments and the Difficulty of Financing Large Capital Investments

in the year 2000. The inference is that the greater the effectiveness of federal incentives for technology and environmental assessment, the less difficult it will be to finance large capital investments for replacing and adding electric generating capacity by the year 2000.

This same relationship was found to be even stronger for research and development as the most effective federal incentive in the face of high uncertainties about future capital investments as shown in Figure 8.1-5. The greater the level of perceived effectiveness of federal R & D, the less the perceived difficulty for financing large capital investments in the year 2000. Evidently, the respondents who found federal R & D and technology assessments to be very effective incentives for the industrialization and commercialization of new energy technology have a more optimistic view of solving the problems of fossil fuel shortages, capital availability and power supplies in small utilities.

In sum, the questionnaire results show a relatively high correlation between technology and information transfers with the anticipated solution of energy supply problems in both large and small utilities in the future. The availability of analysis and information such as technology and environmental impact assessments within the right time frame for utility planning will play a vital part in the successful industrialization and commercialization of advanced SPSA technology.

RESEARCH PROPOSITIONS

Many other interesting corelations were found regarding the interfaces between research and development and the utility planning process that cannot be reported in this preliminary analysis. Only a few of these correlations are shown in Table 8.1-1. A follow-on questionnaire and analysis of present data are needed to confirm the axiomatic propositions or relationships discussed above. However, some additional hypotheses for future analysis include the following:

1) The greater the difficulty to acquire fossil fuel supplies, the greater the difficulty to acquire additional power supplies and the more difficult it will become to finance large capital investments in power plants (See V21, V16, and V11).

2) The greater the difficulty to acquire additional power supplies, the more important technology assessment (V11 and V28).

3) The greater the difficulty to acquire additional power supplies, the less appropriate it would be to conduct demonstration projects on a small scale and with little initial visibility (V11 and V148).

4) The more effective federal technology and environmental assessments are, in promoting industrialization and commercialization of small power systems, the less the difficulty to obtain fossil fuel supplies at a reasonable price in the future (V113 and V16).

5) The more effective federal research and development is, in promoting the industrialization and commercialization of small power systems, the less the difficulty in obtaining fossil fuel supplies and at reasonable price in the future (V114 and V16).

6) The longer utilities plan ahead, the less important the cost of ownership, operations and maintenance are as barriers to successful commercialization of SPS technology (V6, V5 and V40).

7) The longer small utilities plan ahead, the less important the issue of fuel savings and conservation is in determining public acceptance of solar thermal power systems in small communities (V6 and V124).

8) The longer large utilities plan ahead, the less important the cost of competing technologies are as barriers to the adoption of solar thermal power systems (V6 and V48).

9) The longer large utilities plan ahead, the greater the tech-

nology and environmental assessments are as an incentive to promote the industrialization and commercialization of SPS technology (V6 and V113).

10) The longer large utilities plan ahead, the less important the development of competitive solar industry that can manufacture and maintain equipment will be as a barrier to successful commercialization of SPS technology (V6 and V80).

11) The greater the barriers created by capital requirements, the more important the timing of research and development to the successful commercialization SPS technology (V54 and V78).
12) The greater the environmental benefits, the less the importance of the cost of competing alternatives as a barrier to the successful commercialization of SPS technology (V120 and V48).
13) The greater the barriers to the proper timing of research, development and demonstration of SPS technology, the more important it is to have the technology well in hand before commercial demonstration (V78 and V136).
14) The more difficult it is to integrate solar thermal power systems into the electric grid, the more important it is to have the technology well in hand before commercial demonstration (V56 and V136).

SUMMARY

These are only a few of the hypotheses that are suggested by the analysis of the questionnaire data. The results and findings provide a fruitful source of information about the utility planning process and requirements.

Additional descriptive statistics are provided in the Appendix summarizing the results of the entire questionnaire. These data are

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presently being analyzed and the results will be made available as a separate document in the near future. Only a few highlights have been presented in this discussion though the results to date have been very informative.

The relationship between R & D and the utility planning process is clearly important to the successful application and commercialization of SPSA technology. Analysis and planning for technology and information transfers to potential users and adoptors of small power systems must be an integral part of the SPSA project to maximize the potential for successful industrialization and commercialization.

PRELIMINARY QUESTIONNAIRE RESULTS

PART I. UTILITY PLANNING PROCESS AND LEAD-TIMES

1. What is the average lead time required for the planning, licensing, and construction of new non-nuclear electric power generation systems in utilities? (Circle one)

		Number of Years					Variable Number	Mean	Standard Deviation	Skew	Number of Cases
a	Initial planning and analysis requires	3▼	5	7	10	15	2	3.33	1.49	3.57	27
b.	Plant approvals or licensing requires:	3 ▼	5	7	10	15	3	3.66	1.73	2.15	27
c.	Construction requires:	3 ▼	5	7	10	15	4	4 26	1.29	0.28	27
d.	Small utilities plan ahead	3	5	7	▼10	15	5	9.8	3.67	-0.45	25
e.	Large utilities plan ahead	3	5	7	10 ▼	15	6	12 7	3 34	-0.30	26

2. How difficult will it become in the years ahead for small utilities and cooperatives to acquire additional power supplies from large utilities and power grids at a reasonable cost?

		Not Difficult				Very Difficult	Variable Number	Mean	Standard Deviation	Skew	Number of Cases
a	1980	1	2	▼3	4	5	7	2.82	1.28	-0.32	28
b.	1985	1	2	3▼	4	5	8	3.29	1.18	-0.17	28
c	1990	1	2	3	▼ 4	5	9	3.46	1.17	-0 42	28
d.	1995	1	2	3	▼ 4	5	10	3 41	1.42	-0.52	27
e	2000	1	2	3	▼ 4	5	11	3.52	1.65	-0.58	27

3 How much difficulty will small utilities encounter in the years ahead in financing large capital investments for replacing or adding electrical generating capacity?

		Not Difficult				Very Difficult	Variable Number	Mean	Standard Deviation	Skew	Number of Cases
a	1980	1	2	▼3	4	5	12	2 96	1.04	0.74	28
b	1985	1	2	3 ▼	4	5	13	3 35	0 89	0 31	26
c	1990	1	2	3	▼ 4	5	14	3.54	0 81	0 11	26
d.	1995	1	2	3	▼ 4	5	15	3 64	1.04	-0.16	25
e	2000	1	2	3	▼4	5	16	3 72	1 06	-0 28	25

4. How difficult will it be in the years ahead to obtain reliable supplies of fossil fuels at a reasonable price?

		Not Difficult				Very Difficult	Variable Number	Mean	Standard Deviation	Skew	Number of Cases
a.	1980	1	2	3 ▼	4	5	17	3.25	1 11	-0.18	28
b	1985	1	2	3	▼ 4	5	18	3 7	0.87	-0.37	28
c.	1990	1	2	3	4▼	5	19	4 11	0.92	-0 52	28
d	1995	1	2	3	4 ▼	5	20	4 33	0 92	-1 36	27
e.	2000	1	2	3	4 ▼	5	21	4.41	0.97	-1 46	27

5. If small solar thermal electric power systems are to be demonstrated and commercially available by 1995, what analysis and information is required in the utility planning process that should be provided by the small power systems application project? When must this information be provided to be of most use in the utility planning process?

		Importance	When Needed	Importance					When Needed	
		Not Important — Extremely Important	1980 — 1990	Variable Number	Mean	Standard Deviation	Skew	Number of Cases	Variable Number	Mean Year
a	Technology Forecasts	1 2 3 ▼4 5	80 ▼82 84 86 88 90	22	3 79	0 92	-0.77	28	23	81.8
b	Systems Analysis	1 2 3 ▼4 5	80 82▼ 84 86 88 90	24	4 00	0 82	0 00	28	25	82 5
c.	Market and Financial Analysis	1 2 3 4▼ 5	80 82 ▼84 86 88 90	26	4 21	0 16	-1 33	28	27	83 2
d	Technology Assessment	1 2 3 ▼4 5	80 82 ▼84 86 88 90	28	4 04	0 77	-0 66	26	29	83 2
e	Environmental Impact Assessment	1 2 3 ▼4 5	80 82 84 ▼86 88 90	30	3 85	0 95	0 23	27	31	84 8
f	Utility Dispatch Models	1 2 3 ▼4 5	80 82 84 ▼86 88 90	32	3 85	0 95	-0 55	27	33	85 4
g	Other (Specify)	1 2 3 4 ▼5	80 82 84 ▼86 88 90	34	5 00	0 00	0 00	4	35	85 6
	____________	1 2 3 4 ▼5	80 82 84 ▼86 88 90	36	4 66	0 57	-1 06	3	37	86 0
	____________	1 2 3 4 5	80 82 84 86 88 90							

PART II. BARRIERS AND INCENTIVES TO INNOVATION OF SMALL POWER SYSTEMS

	Variable Number	Mean	Standard Deviation	Skew	Number of Cases
1. What level of technology demonstration is required to reduce the risks and uncertainties to an acceptable level for utility adoption of new small power systems technology? (Circle one)	38	3.48	1 18	-0 77	29

a. Prototype must be successfully tested and documented (1)

b Successful pilot testing (2)

c. Full scale demonstration (3)

d. Full scale demonstration with government guarantees or subsidies (4)

e. Several years of industrial or large utility operating experience (5)

f. Other (Specify) ____________

2 In your opinion, what are the most serious economic and financial barriers to the successful commercialization and application of SPS technology? (Rank order and evaluate importance)

		Rank Order	Importance	Rank Order		Importance				
		(Top Five Only)	Not Important Extremely Important	Variable Number	Mean Rank	Variable Number	Mean	Standard Deviation	Skew	Number of Cases
a	The cost of ownership, operations, and maintenance	1	1 2 3 4▼ 5	39	3 21	40	4 30	0 91	-1 28	27
b	General business climate and considerations	——	1 2 ▼3 4 5	41	5 42	42	2 81	0 85	-0 86	26
c	Marginal cost/effectiveness considerations (Cost of next increment of added generation capacity)	4	1 2 3 ▼4 5	43	4 04	44	3 81	0 88	0 19	27
d	Interest cost and availability of capital	5	1 2 3 ▼4 5	45	4 29	46	3 76	0 88	-0 28	25
e	Cost and availability of alternative power systems technology	2	1 2 3 4▼ 5	47	3 66	48	4 31	0 62	-0 28	26
f	Central power plant vs dispersed siting considerations as they relate to allocation of scarce resources and the economics of scale.	——	1 2 3 ▼4 5	49	5 66	50	3 30	0 82	0 42	23
g	Future fossil fuel availability and prices	——	1 2 3 4▼ 5	51	4 38	52	4 19	1 00	-1 61	27
h	Capital requirements for solar thermal vs alternative power systems	3	1 2 3 4 ▼5	53	4 00	54	4 48	0 64	-0 85	27
i	Life cycle cost considerations	——	1 2 3 4▼ 5	55	4 42	56	4 29	1 02	-4 79	24
j	Other (Specify)	——	1 2 3 4 5	57	5.76	58	5 00	0 00	0 00	1

3 In your opinion, what are the most serious institutional and environmental barriers to successful application and commercialization of SPS technology? (Rank order and evaluate)

		Rank Order	Importance	Rank Order		Importance				
		(Top Five Only)	Not Important Extremely Important	Variable Number	Mean Rank	Variable Number	Mean	Standard Deviation	Skew	Number of Cases
a	The impact of restrictive contracts or agreements between utilities	——	1 2 3▼ 4 5	59	5 12	60	3 28	1.17	-0 42	25
b	Utility regulatory considerations	——	1 2 3▼ 4 5	61	4 96	62	3 24	0 93	-1 18	24
c	Power plant siting considerations and requirements	——	1 2 3 ▼4 5	63	4 79	64	3 75	0 74	0 43	24
d	Land requirements and land use considerations	5	1 2 3 ▼4 5	65	4 75	66	3 74	0 81	0 52	23
e.	Potential risk of unanticipated time delays in licensing and construction of new power plants	4	1 2 3 ▼4 5	67	4 66	68	3 92	0 81	-0 35	25
f	Availability of reliable environmental, economic and social impact analysis	——	1 2 3 ▼ 4 5	69	5 16	70	3 40	1.19	-0 22	25
g	Availability of impartial comparative assessments of the advantages and disadvantages of alternative power systems	3	1 2 3 4 ▼5	71	4 42	72	3 38	0 93	-0 85	25

h (Continued on next page)

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3 (Continued) In your opinion, what are the most serious institutional and environmental barriers to successful application and commercialization of SPS technology?
(Rank order and evaluate)

		Rank Order	Importance	Rank Order		Importance				
		(Top Five Only)	Not Important Extremely Important	Variable Number	Mean Rank	Variable Number	Mean	Standard Deviation	Skew	Number of Cases
h	Availability of skilled technicians to operate and maintain solar thermal equipment	——	1 2 3 ▼ 4 5	73	5 50	74	3 26	1.01	-0.28	23
i	Problems of introducing new generation capacity into a utility system with only transmission and distribution capabilities.	——	1 2 3 ▼ 4 5	75	5 00	76	3 58	1 18	-0 64	24
j	Timing of research, development, and demonstration as they relate to introducing new equipment into the utility market place	2	1 2 3 ▼4 5	77	3 75	78	4.04	0 77	-0 66	26
k	Development of a competitive solar industry that can manufacture and maintain equipment	1	1 2 3 4 ▼ 5	79	3 71	80	4 44	0 65	-0.73	25
l	Existing electric utility company barriers for the use of solar thermal generating equipment in dispersed siting applications	——	1 2 3 ▼ 4 5	81	5 54	82	3 24	1 13	-0 32	25
m	Potential for public utility commission to create barriers for the use of solar thermal generating equipment in dispersed siting applications.	——	1 2 3 ▼ 4 5	83	5.70	84	3 22	1.17	0 99	23

4 In your opinion, what are the most serious technical and engineering barriers to successful application and commercialization of power systems technology?
(Rank order and evaluate importance).

		Rank Order	Importance	Rank Order		Importance				
		(Top Five Only)	Not Important Extremely Important	Variable Number	Mean Rank	Variable Number	Mean	Standard Deviation	Skew	Number of Cases
a.	Appropriate matching and integration of solar equipment and generating systems	2	1 2 3 ▼4 5	85	3 80	86	4 04	0 87	-0 46	26
b	Equipment operating duty cycles and maintenance requirements	——	1 2 3 ▼4 5	87	5 16	88	3 83	0 82	-0 70	25
c.	Utilities load and peaking requirements	——	1 2 3 4 ▼ 5	89	4 60	90	3 88	1 63	-0 95	25
d	Uncertainties regarding equipment forced and planned outage rates (Reliability).	4	1 2 3 ▼4 5	91	4 28	92	3 96	0 90	0 75	27
e	Availability of alternative generating equipment	——	1 2 3 ▼ 4 5	93	4 60	94	3 48	1.16	-0 55	25
f	Opportunities and technologies for storing electric energy	1	1 2 3 4 ▼ 5	95	3 68	96	4 33	0 88	-1 09	27
g	Solar thermal electric system reliability as it relates to isolation	5	1 2 3 4 ▼ 5	97	4 44	98	4 15	0 92	-0 64	26
h	Generation system optimization as it relates to insolation and storage strategies	——	1 2 3 4 ▼ 5	99	4 52	100	4 16	0 82	-0 83	24
i	Applicability of solar thermal equipment to various duty cycles including peaking, intermediate, and base load integration	3	1 2 3 ▼4 5	101	3 96	102	3 85	0 82	-0 16	27

5 What are the most effective federal incentives to promote the industrialization and commercialization of advanced SPS technology for utility applications?

		Ineffective Incentive			Extremely Effective Incentive		Variable Number	Mean	Standard Deviation	Skew	Number of Cases
a	Tax deduction and credits	1	2	3▼	4	5	103	3.14	1.09	-0.46	29
b	Federal loan guarantees	1	2	3	▼4	5	104	3.48	1.05	-0.47	27
c.	Federal interest subsidy	1	2	3	▼4	5	105	3.44	0.97	-0.23	27
d	Federal power plant purchase and lease back	1	2	3▼	4	5	106	3.18	1.22	-0.23	28
e.	Federal guarantee of private power plant leasing	1	2	▼3	4	5	107	2.81	1.02	-0.31	26
f	Direct subsidies to utilities	1	2	3	▼4	5	108	3.41	1.19	-0.13	27
g	Fossil fuel price control	1	2▼	3	4	5	109	2.43	1.32	0.57	28
h	Regulation and controls	1	2▼	3	4	5	110	2.54	1.20	0.45	28
i	Technology demonstrations	1	2	3	4▼	5	111	4.03	0.86	-0.42	29
j	Information transfer and dissemination	1	2	3	▼4	5	112	3.72	0.99	-0.32	29
k	Technology and environmental assessment	1	2	3	▼4	5	113	3.62	1.12	-0.32	29
l	Research and development	1	2	3	4▼	5	114	4.25	0.70	-0.38	28
m.	Other ________	1	2	3	4	▼5	115	5.00	0.00	0.00	2
n	Other ________	1	2	3	4	▼5	116	5.00	0.00	0.00	1

6. In your opinion, what will be the most important issues or factors in determining public perception and acceptance of solar power systems in small communities?

		Not Important			Extremely Important		Variable Number	Mean	Standard Deviation	Skew	Number of Cases
a.	Land use requirements	1	2	3	▼4	5	117	3.43	1.10	0.10	28
b.	Aesthetic values or site pollution issues	1	2	3	▼4	5	118	3.62	1.12	-0.48	29
c.	High capital cost	1	2	3	4▼	5	119	4.32	0.90	-1.02	28
d	Environmental pollution benefits	1	2	3	▼4	5	120	3.96	0.88	-0.61	28
e.	Decentrialized control or ownership of power generation	1	2	▼3	4	5	121	2.93	0.92	-0.70	27
f	Unfamiliarity with new technology	1	2	▼3	4	5	122	2.97	1.08	0.24	29
g	Resistance to change	1	2	▼3	4	5	123	3.03	1.12	0.91	29
h.	Fuel savings and conservation	1	2	3	▼4	5	124	4.17	0.86	-1.09	28
i.	Willingness to innovate	1	2	3▼	4	5	125	3.32	1.05	0.30	28
j.	Willingness to accept costs and risks of new technology	1	2	3	▼4	5	126	3.86	1.19	-0.80	29

7. What public and private organizations will have the most influence on the successful commercialization and application of small power systems technology?

	Least Influence				Most Influence	Variable Number	Mean	Standard Deviation	Skew	Number of Cases
a. Small utilities	.1	2	3	▼ 4	5	127	3.79	1.11	-0.71	29
b. Large utilities	1	2	3 ▼	4	5	128	3.48	0.99	-0 89	29
c. Public utility commissions and regulatory organizations	1	2	3 ▼	4	5	129	3.41	1.02	-0.29	29
d. Manufacturers	1	2	3 ▼	4	5	130	3.59	0.98	-0.49	29
e. U.S Department of Energy	1	2	3	▼ 4	5	131	3 82	0 97	-0.39	29
f. State and local governments	1	2	3 ▼	4	5	132	3 48	1.12	-0.91	29
g. Oil companies	1	2 ▼	3	4	5	133	2.68	1.06	0.98	28
h. Public interest groups	1	2	.3 ▼	4	5	134	3.41	1.05	-0.73	29
i. Other ________	1	2	3	4	▼ 5	135	5 00	0.00	0.00	1

PART III DEMONSTRATION AND COMMERCIALIZATION OF ADVANCED TECHNOLOGY

1. Demonstrated innovations that are adopted for electric utility use are, of course, those that show relative economic advantage. A primary goal of commercialization analysis is to determine the major factors that help or hinder a technology demonstration's ability to show whether such economic advantage exists Do you agree or disagree whether the following factors are important to successful application of new electric power systems technology? (Circle one)

		Strongly Disagree	Disagree	Do Not Know	Agree	Strongly Agree	Variable Number	Mean	Standard Deviation	Skew	Number of Cases
a	A technology well in hand Projects showing significant diffusion success are those in which the principal technological problems had been worked out beforehand	1	2	3	4 ▼	5	136	4 25	0 70	-1 07	28
b	Cost and risk sharing with local participants. Technology showing significant diffusion success involve nonfederal cost sharing, while those funded entirely by the federal government result in little or no diffusion	1	2	▼ 3	4	5	137	3 00	1 10	0 00	29
c.	Project initiative from nonfederal sources. Demonstration projects originating from private firms or local public agencies enjoy greater diffusion success than those directly pushed by the federal government.	1	2	3 ▼	4	5	138	3 31	1 17	0 08	29
d	The existence of a strong industrial system for commercialization Diffusion proceeds more rapidly when there are obvious manufacturers and purchasers of the new technology, and when markets for similar products exist	1	2	3	4 ▼	5	139	4 34	0 72	-1 23	29
e	Inclusion of all elements needed for commercialization Demonstrations that show significant diffusion success include in their project planning and operations potential manufacturers, potential purchasers, regulators, and other target audiences	1	2	3	▼ 4	5	140	4 03	0 91	-0 68	29
f	Absence of tight time constraints Demonstrations facing externally imposed time constraints fare less well than those developed at an accelerated rate	1	2	3 ▼	4	5	141	3 24	0 99	-0 52	29

2 Demonstration projects may also be an important means of generating information for utility planning and for regulatory decision-making such as licensing and environmental impact processes Do you agree or disagree with the following general statements about the appropriateness of demonstration projects and about their characteristics that contribute to commercialization? (Circle one)

		Strongly Disagree	Disagree	Do Not Know	Agree	Strongly Agree	Variable Number	Mean	Standard Deviation	Skew	Number of Cases
a	Demonstration projects have a narrow scope for effective use. They are most effective when diffusion is hampered by lack of knowledge in the hands of potential adopters about the use of the technology under commercial operating conditions But demonstrations are appropriate only when these uncertainties are not large and when there is strong rationale for federal involvement.	1	2	3▼	4	5	142	3.04	0.96	-0.74	28
b	Diffusion depends on "market pull" rather than "technology push" In the absence of a well articulated market demand, the pursuit of demonstration projects is an especially risky activity, whatever successes are achieved are accompanied by many failures	1	2	3 ▼	4	5	143	3.41	1.15	-0.45	29
c.	Demonstration projects appear to be weak tools for tackling institutional and organizational barriers to diffusion Other government interventions, such as changes in regulations or subsidies, may be more effective than demonstrations in stimulating diffusion in such situations	1	2	▼3	4	5	144	2.97	0.94	0.71	29
d	Large demonstration projects with heavy federal funding are particularly prone to difficulty Heavy federal investment tends to make projects highly visible and vulnerable to political pressures detrimental to success	1	2	3 ▼	4	5	145	3.31	1.00	-0.67	29
e	On site project management is generally effective Whatever management problems arise are overshadowed by other more serious problems noted above	1	2	3	▼4	5	146	3.66	0.86	-0.69	29
f.	Dissemination of information from demonstration projects is generally not a serious problem When projects fail to achieve diffusion success, they generally do so not because of weaknesses in the information network, but for other reasons noted above.	1	2	3 ▼	4	5	147	3.32	1.12	-0.35	28

3 There are at least two different strategies for managing federal demonstration projects The first approach involves pushing the technology state of-the art at the fastest possible rate leaving the economic and institutional problems of commercialization to private industry and market places to solve The second approach requires that the technology is already well in hand before a demonstration is conducted

Keeping these different approaches in mind, do you agree or disagree with the following guidelines for federal demonstration projects? (Circle one)

		Strongly Disagree	Disagree	Do Not Know	Agree	Strongly Agree	Variable Number	Mean	Standard Deviation	Skew	Number of Cases
a	Conduct the demonstration on as small a scale and with as little initial visibility as possible	1	2	▼ 3	4	5	148	2.57	1.03	0.31	28
b	Do no emphasize large projects at the expense of small ones involving incremental improvements to existing products or processes	1	2	3	▼4	5	149	3.89	0.74	-1.59	28
c.	Resist political pressure to demonstrate before a technology is well in hand	1	2	3	▼4	5	150	3.86	0.89	-1.37	28
d	Allow enough time in the project's schedule for slippage, especially when undertaking large projects with significant technological uncertainty	1	2	3	▼4	5	151	3.75	0.84	-1.05	28
e	Potential adopters and other target audiences, including regulatory agencies where relevant, should help plan the demonstration	1	2	3	▼ 4	5	152	3.57	0.92	-0.52	28
f	Concrete planning should be done at the local operating level with federal review, and not by the federal agency	1	2	3	▼4	5	153	3.75	0.80	-0.89	28
g	Demonstrations should include cost sharing by private sector firms with incentives to diffuse the technology	1	2	3	4	5	154	3.79	0.88	-1.65	28

3. (Continued)

		Strongly Disagree	Disagree	Do Not Know	Agree	Strongly Agree	Variable Number	Mean	Standard Deviation	Skew	Number of Cases
h	When demonstrations involve continuing experimentation, the distinction between these activities should be made clear to potential adopters.	1	2	3	4 ▼	5	155	4.21	0.57	0.26	28
i	Because demonstrations involve tradeoffs among costs, performance, and time, the time element – rather than cost and/or performance – should be relaxed.	1	2	3	▼ 4	5	156	3.46	0.84	-1.08	28
j	The federal agency should avoid day to-day supervision and control of operations It should monitor at a distance with targeted evaluations to make needed corrections.	1	2	3	▼ 4	5	157	3.96	0.74	-1.08	28
k	Whenever possible, the federal government should not be a party to contracts between the demonstration operator and vendors or other subcontractors	1	2	3	▼ 4	5	158	3.57	0.84	-0.64	28
l.	Federal agencies should disseminate the information generated by the project, whether or not it shows relative economic advantage	1	2	3	4	▼ 5	159	4.78	0.61	-1.12	28
m	A dissemination strategy should be chosen as part of the basic planning. This choice depends on the industrial links for subsequent commercialization and on the agency's own resources.	1	2	3	▼ 4	5	160	3.68	0.77	-1.40	28
n	Agencies should emphasize dissemination devices that are specific to particular target audiences.	1	2	3	▼ 4	5	161	3.43	0.79	-1.42	28

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